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Sciences of the Interface

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Sciences of the Interface

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Preface

Interface is one of these hermeneutically grown concepts that refuses to be exactly defined. In computer sciences and robotics it is in vogue to speak of interfaces, especially of *man–machine–interfaces*. Everybody has a clear intuition what is meant by interface in this context. The keyboard or the monitor of a computer, for example, are interfaces which transform between different states or representations. However, also parts of software can be called interface. Consider, for example, an interface that allows for a communication between two or more programs written in different languages. In contrast to the hardware case, the latter interface cannot be localized anywhere. It rather is the functionality behind it that allows to speak of an interface.

In a first approach we can say that the concept of an interface has to do with transformations of states or representations and/or a communication between parts of a compound system. This in turn highly depends on the scale at which the system is viewed. As a simple example consider a computer monitor. This is a cascade of interfaces that transforms internal electro-magnetic states via data buses, oscilloscope, fluorescent material etc., to electro- magnetic states in the visuell range of wavelenghtes. A purist may write down a (partial) differential equation of the whole thing on a microscopic level where the notion of an interface seem to become rather arbitrary.

It seems, that the intuitive notion of an interface is resided on the (human) scale of cognition. In a sense, it is a relativistic concept. In the natural sciences, so far, the notion of an interface with respect to human cognition has been widly ignored or avoided. A *Laplacian demon*, the metaphor for determinism in form of a non-relational super- or exo-observer may not need the interface-concept. However, the humans as intrinsic observers ask themselves ever since the ancient greeks whether there is a difference of *the world in our head* – the shadows on the cave's wall – and the *objective outer world*. A question which is allowed to inquire in arts and humanities ...

The symposium *Sciences of the Interface* and the proceedings in hand are to honor Otto E. Rössler on the occasion of his 60^{th} birthday. He focused on the *interface* in his work and stimulated and provoked a lot of scientists to re-think the *interface*. The syposium has been held to throw a further glimpse on the interface concept. We also hope to contribute to "close the ranks" between artists and natural scientists.

We express our deep gratitutes to all authors for taking a large amount of effort and time to prepare their contributions. Parts of these proceedings will we reprinted in a book on *interface* intended for a broader audience.

Karlsruhe
December 2000

Hans H. Diebner
Timothy Druckrey
Peter Weibel

Obituary Notice

Our dear friend Michael Conrad passed away a few month after the meeting "Sciences of the Interface". During the meeting he was present with is giant screen-video where his penetrating, winning type of thinking swaped all minds in a moving manner. We are happy and deeply touched that he finished the manuscript during the last weeks of his life while already in hospital. We learned that he was granted the previledge to be at home with his family in his last hours. We say thank you to Michael. Thank you also Debbie and Emily.
The editors

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The Gulliver Effect

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Abstract

Captain Lemuel Gulliver visited islanders who were many times taller or shorter. Yet the secret lever which caused the size change was not revealed to him. Such a lever appears to be implicit in the "Aarau vision"of the young Einstein. The algorithm of the corresponding computer game reads:

$$x' = \gamma(x - vt), \qquad y' = y/1, \qquad z' = z/1, \qquad t' = \gamma(t - vx/c^2)\ .$$

This algorithm, the so-called "Lorentz transformation", acquires intuitive features if the speed of light (c) is reduced to the speed of a cyclist. This was shown by George Gamow in his classic "Mr. Tomkins in Wonderland" comic book. Alice would love the game. Buildings and cyclists wear clock faces on their fronts and backs. Departing cyclists are slowed in their clock rate, voice and color, by a certain factor, the Doppler factor:

$$D = \sqrt{(1 + v/c)/(1 - v/c)} = \gamma(1 + v/c).$$

The Doppler factor depends on the relative speed (v) of the cyclists. Surprisingly, they are at the same time linearly enlarged (or diminished, respectively) by the same factor. This is the Gulliver effect. The new effect can be spotted in a simple subgame already, that of the two lizards who suffer from different clock rates. As it turns out, the game algorithm produces anisotropic distortions, unless the unit constant in the second and third equation is replaced by the factor D. The resulting new game algorithm has educational value if car makers decide to incorporate it into their Global Positioning System software. Is reality an interface that can be manipulated?

1 The Aarau Vision

At age 16, Einstein had the "Aarau vision" [1]. Like Achilles stalking the tortoise, he imagined trying to overtake a light wave. It did not work, neither. Why? Because the light wave kept fleeing him. No matter what his own speed, he remained at the center of a concentric light bubble of the standard speed.

This was the beginning of the greatest revolution in physics — the interface revolution. Einstein thought like a computer kid, a game boy. A personalized Virtual Reality [2], a William Gibson-like total immersion [3], apparently seemed appealing to him: a democracy of interfaces. The "substance", the stuff that matter is made of, and space and time themselves, was thereby reduced to a phantom. Manipulability of the most basic reality (space, time and matter) was implicit.

It is hard to reconstruct how this revolution could happen. The youthful assertiveness was guided by a sense of "musicality" (a word used later by Einstein himself to characterize the thinking of his friend Bohr). But this still is not the right word. A "feel" for the design of computer games would be a more fitting expression today. An appreciation for the precariousness of the human condition was the third ingredient. The vision reminds one of a recent Walt Disney-like panorama display (depicted in Time magazine): the user stands or walks inside a ball made of opaque glass onto the outside of which an immersive computer-generated Virtual Reality is projected. Other players can be met (and touched) in the Virtual Reality of the first, while each remains enclosed in his or her own glass house: The Cartesian prison.

The prison, however, contains a new lever inside that can be used for escape. The "destruction of simultaneity" (of the synchronicity, equal rate, and space-independence of clocks) is the most important implication of Einsteins finding according to Gödel [4], who tried to base the blueprint of an escape machine (a time machine) on it. The second major implication is the loss of objectivity of the mass of a stone. The third is a contraction of all non-comoving objects in the forward direction if their length is measured by spatial coincidence, as formerly proposed by FitzGerald and Lorentz.

Science is like washing sand in search for gold, Maxwell said. If someone by chance or gift, which is the same thing, finds a nugget or whole gold vein, one should always go back to the very first beginning and dig close-by: Invariably, a second vein would be waiting [5]. The interface revolution no doubt is a big golden vein. The message was later taken up by Everett [6] who made it include the quantum world. Again, manipulability of everything (the world) is implicit. This major gold vein is, however, not to be pursued here. Only a little nugget lying right beside the three picked up by the young Einstein will be held up for closer examination: the Gulliver effect.

2 Gulliver

Jonathan Swift as an old man wrote "Gulliver's Travels" [7], a typical tale for a deep-immersion computer game, as it were. The number of details is mind-boggling. A humanist's soul at its best can be felt. Size change was his big thing. Can Achilles also change size?

Amazingly, this too is an implication of the Aarau vision. Whenever a watched object is slowed in terms of its clocks (Doppler-redshifted), its size is proportionally enlarged. The opposite outcome (shrinking) occurs when there is a blueshift. This is very surprising. There is no contradiction between the new size change and the old FitzGerald-Lorentz contraction, since at the moment of coincidence in space (the condition under which that contraction occurs as mentioned), there is no Doppler effect present — the zero net Doppler shift lets the FitzGerald-Lorentz factor remain in charge.

Maybe the Gulliver effect is not real. We are in fairy-tale land, after all, and the reader has to make sure that the text is not all virtual. Fortunately, the game of the two lizards, implicit in the Aarau vision, can be presented at this point to show that the Gulliver effect is indeed as real as anything else inside the light bubble.

3 The Two Lizards

The one lizard is morning-cold and slow, so that the world appears dizzyingly fast (say, twice as fast) to him. The other lizard has already basked on a sun-warmed stone and sees everything in normal motion. (For if one is fast, everything looks normal, if one is slow, everything looks fast.) Now, they are about to communicate. Are there any problems to be expected? Obviously not.

To the one lizard (the slow one), the time between giving off a signal and getting a response is half as long as for the other. That is all.

Enter the constancy of the speed of light. If the lizards communicate by light (as they may), and if the lower one is slowed, not by the coldness of his body as assumed so far, but by a gravitational gradient (as is also allowed [8]), the Aarau assumption of the constant light speed has a further consequence. Since a roundtrip of light between the two lizards, measured with the slower clock downstairs (that is, by the slower lizard), takes only half as much time as in the other case, the distance (height difference) is only half as large for the lower lizard [9]. Hence the lower lizard is twice as large.

This is the Gulliver effect. Since everything is locally unchanged downstairs, one awakens like Gulliver who has been fastened by 1000 tiny needles to the ground by the Lilliputans: no escape possible.

4 A First Amendment

Gulliver closes his eyes for a moment and realizes that something must have happened to the Lorentz transformation, the algorithm that underlies the Aarau computer game which governs his world. Lateral distances, according to that rule, are inviolable. But here he lies, magnified in *all* directions.

The alarm bells ring. Suppose the Lorentz transformation were to be modified laterally by the redshift (or blueshift) factor. Would this minor amendment of the laws of physics not make the whole temple come tumbling down like in the case of Samson?

Gulliver accepts the change as we saw. To the user of the real universe, the question of whether this amendment is acceptable is more difficult to answer. Should the present tale rather be kept from the reach of computer-game kids? For they might feel tempted to incorporate the amended algorithm into their own Mr. Tomkins' game, crafted after Gamow's synonymous novel [10] in which the velocity of light is only $15km$ per hour (not 300000 per second), the normal speed of a cyclist. While nothing can prevent anyone from doing such a thing (after all, the first computer-implemented V.R. drew its inspiration from Einstein's algorithm, cf. [2]), they should not be misled into believing that this is reality.

Or is it reality?

5 Games in the Real World

Empirical tests are waiting. The Global Positioning System, the satellite-based navigation system that is the current favorite toy of car makers in the real world, should work even better if the new algorithm of the game world were implemented in it. Second, a new lateral Doppler effect in the presence of gravity, implicit in the game world, can be tested in reality. The technology of the Mössbauer effect [11] can be used unchanged (only a tilt is needed). Will it confirm or will it falsify the game?

Chances are that the lateral directions will vote against the new algorithm (less redshift for the distant overtaker — confirmation of the standard Lorentz transformation). The two lizards may have misunderstood something. In this case, however, a new catastrophe lingers. The people downstairs get a bonus in return. They can "misuse" the upper floor to, by means of mirrors, send superluminal messages to the side, a feat at variance with the Aarau principle. This third prediction — violation of the Einstein speed limit by the standard Lorentz transformation in the presence of acceleration — can, in the absence of a black hole candidate in our immediate neighborhood, unfortunately only be tested in the computer world at the time being.

6 Return to the SutherLand

Thus we are allowed to return to Mr. Tomkins' wonderland. Cyclists become dwarfs when they approach and giants when they have passed. A landscape that is cycled into becomes "Lilliput" while the portion behind your back becomes "Grobdingnag". People downstairs become giants, too (if gravity is assumed to be normal). This effect presupposes that the whole landscape is put into a giant accelerating rocket whose jets downstairs generate the standard gravitational acceleration familiar from the surface of the earth. "Adjusting gravity" therefore becomes a desirable game option — to keep the distortions of the buildings moderate (and to keep light rays from being bent too much).

What makes the game so attractive, even before a multi-player option will be incorporated, is that it is very hard to predict how the new environment will "feel" once one is inside. New surprises are in store. Achilles at least reckons with anything.

We have herewith arrived at the end of our fairy tale: Einstein a computer kid, the world an interface that can be manipulated. A fourth implication of the game of relativity (after clock change, mass change, and contraction) can be hoped for: Becoming a giant or dwarf. The whole world turns into a roller-coaster landscape with all kind of new effects. Is the world fundamentally different than anticipated? The interfacialization of the world lets the problem of the "kiss" (a synonym to interface) rise to unprecedented prominence. Dolphins smile across the Internet. An artificial hometown appears on the horizon. Is the interface revolution the door to a new future? Computer games at least, far from seducing the youth, could be the arena in which new Gullivers find their vocation.

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Platonic Quantum Mechanics: Taking the Theory Literally

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Abstract

An account is given of the history and implications of Everett's "many worlds" interpretation of quantum mechanics, in which the formalism of quantum mechanics is regarded as providing a representation of "reality" in exactly the same sense as the formalism of classical mechanics was once thought to do. Everett's original view is brought up to date by descriptions of the following developments that have occurred within the last decade:
1. A proof that the standard probablility interpretation emerges from the quantum formalism itself and does not need to be imposed from outside.
2. Explanations of how the classical world emerges from the quantum world without having to be separately posited.
3. An understanding of the role of the "other worlds" in biology, the theory of quantum computers, and the theory of knowledge.

To take quanutm mechanics literally is to view the theory as being the true reality — as belonging to Plato's realm of ideal essences.

I enjoy talking with mathematicians. Most of them, especially the ones of world-class stature, treat physics and physicists with the greatest respect, even though we physicists are usually bumbling amateurs when it comes to mathematics. And a few of us (fewer as the years go by) still view mathematicians with amused tolerance.

When talking with mathematicans I sometimes pose the following question:

> Is mathematics *there*, to be discovered, or is it a free construct of the human mind?

Second-rate mathematicians often give the second answer. But, almost without exception, those of world-class stature say that mathematics is *there*, to be discovered. In other words, the mathematics produced by a civilization in a distant galaxy would be essentially the same as ours, differing only in historical development and emphasis. This is, of course, Plato's view, that ideas are more real than things.

Is Plato right? Consider the following. Mathematics cannot be produced without the physical universe, but the universe cannot exist without the mathematical laws that govern it. One cannot say, however, that Plato is right simply (and trivially) because the universe is mathematical. The mathematics produced by intelligent beings seems to be broader than the mathematics needed to describe the physical world.

This brings me to the first of three "hobby horses" that I like to ride around in the corridors during physics conferences and that I should like briefly to share with you. What part of mathematics plays *no* role in the description of Nature?

A number of years ago Stephen Hawking and George Ellis wrote a book called "The Large-Scale Structure of Spacetime." In it they claimed to prove that from any given set of Cauchy data for Einstein's equations of general relativity there is a "maximal" solution, i.e., a solution up to points where singularities occur. In their "proof" they used Zorn's Lemma, which is equivalent to the Axiom of Choice. The axiom of choice is a marvelous axiom, which leads to many amazingly beautiful and often counter-intuitive theorems in mathematics. But I have always insisted that it has no place in theoretical physics. Until Hawking and Ellis are able to *display* an appropriate *choice function* their work is unfinished, and their "theorem" is empty of real physical content. In view of the astonishing work of the so-called "constructivists," I am even ready to assert that the Axiom of Infinity has no place in physics, but I regard this axiom as relatively harmless, and certainly useful.

My second "hobby horse" concerns the topology of the universe. Many cosmologists, to this day, distinguish between "closed" universes, by which they mean compact universes of positive average curvature, and "open" universes, by which they mean infinite universes of negative curvature. It has always been a mystery to me why they seem totally unaware of the work of the mathematician *Bill Thurston*, who showed thirty years ago that there exists an infinity of compact (i.e., "closed") 3-spaces of constant negative curvature, each having the familiar open hyperboloid as its universal covering space and each being associated with a knot in Euclidean 3-space. Over 99% of all known knots have such associated 3-spaces. Our universe could be any one of them. None would be incompatible with either inflation or the isotropy of the cosmic microwave background.

My third "hobby horse" concerns the interpretation of quantum mechanics, and that will be the main focus of my talk to you today. In 1956 my wife organized a conference in North Carolina on "The Role of Gravitation in Physics." The conference was by invitation only. The discussion flowed freely and no formal papers were presented. But a number of the participants agreed to assemble their ideas into articles that were published in the July issue of *Reviews of Modern Physics*, 1957. John Wheeler, one of the participants, asked if he could include a paper by a student of his, Hugh Everett, who had not attended the conference. As editor for this issue, I agreed to this provided I could look the paper over first.

I don't know how many of you are old enough to remember how extremely boring most of the papers on the interpretation of quantum mechanics were in the days before 1957. There were a few exceptions, such as Heisenberg's earliest papers, but these exceptions did *not* include papers by Bohr, or the sometimes vitriolic utterances of his collaborator, Leon Rosenfeld. When I received Everett's paper, I immediately realized that here was something new and fresh. I was simultaneously delighted and shocked. I was shocked because Everett was asking me to believe that the formalism of quantum mechanics provides a representation of "reality" in exactly the same sense as the formalism of classical mechanics was once thought to do. This meant that I had to view the state vector of a system-apparatus combination as representing reality. But this state vector — after the apparatus has reacted to the system, via an appropriate coupling, by measuring a system observable — consists of a superposition of state vectors, in each of which the observable has assumed one of its eigenvalues and the apparatus has observed that value. Everett was asking me to believe that the reality described by the state vector consists of simultaneous worlds each representing a different outcome.

The idea that the world may "split," as a result of couplings, into many worlds, is hard to reconcile with the testimony of our senses, namely, that we simply do not split. So I wrote Everett an eleven page letter alternately praising and damning him. But I accepted his paper. He merely added a footnote in which he wrote that those who object to the many-worlds view because it conflicts with the testimony of their senses are like the anti-Copernicans in the time of Galileo, who did not feel the earth move.

To which I could only reply "Touché," for it is not hard to show that to the extent to which we may be regarded as automata, and hence on a par with ordinary measuring apparatus, *the laws of quantum mechanics do not allow us to feel ourselves split.* Just introduce a second apparatus which not only "looks at" what the first apparatus records, but also carries out an independent direct check on the value of the system observable. If the splitting into many worlds is to be unobservable then the results had better agree.

The appropriate couplings for accomplishing this are easily set up. The total state vector, after the observations have taken place, is again revealed as a superposition of vectors, each of which represents the system observable as having assumed one of its possible values. Although the value varies from one element of the superposition to another, not only do both apparatus within a given element observe the value appropriate to that element, but also the second apparatus "sees" that both have observed that value.

It is not difficult to devise increasingly complicated situations in which, for example, each apparatus can make decisions by switching on various couplings, depending on the outcome of other observations. No inconsistencies will ever arise, however, that will permit a given apparatus to be aware of more than one world at a time. Not only is its own memory content self-consistent (think of the two apparatus considered previously as a single apparatus that can communicate with itself) but consistency is always maintained as well in rational discourse with other automata.

After Everett's paper appeared life in the physics community went on as usual. Everett was ignored. This was at least in part due to the subdued tone of Everett's paper, which as we now know was imposed by John Wheeler who sat down with him and told him precisely what to write. My own view is that Wheeler did not wish to offend his old hero, Bohr. For Everett had written an Urwerk[4] that was much bolder and more direct, which did not come to light until many years later. He didn't tell me about it even when I met him, for the only time, in the early seventies. I remember, on that occasion, that as he approached me he was brandishing in his hand my old eleven-page letter.

I had, of course, somewhat redeemed myself by then. In the late sixties I had received a visit from Max Jammer who was planning to write a book on the history of the interpretation of quantum mechanics. I was astonished to learn that Jammer had never heard of Everett, and resolved to rectify this neglect. I wrote a popular account of Everett's ideas, which appeared in *Physics Today*.[3] After that Everett could no longer be ignored.

Some physicists, while admitting the self-consistency of Everett's view of reality, regard it as preposterous to assert the "reality" of worlds of which one cannot be aware. A consistent application of this logic requires one to deny the existence of planets in distent galaxies.

Other physicists object to the superfluousness of the "other worlds" and to the prodigality of a universe that includes them all, forgetting the prodigal scale of the universe we actually see. These physicists are comfortable with little huge numbers, but not with big ones.

Objections have often been raised also against the language used in explaining Everett's views, in particular against words such as "worlds" (in "many worlds") or "splitting." The only possible answer to these objections is: if the words offend then choose others. Better still, let the formalism speak for itself.

The question is sometimes asked: when do the splits occur? It should be obvious that the splits do not occur instantaneously. The branching into alternative worlds takes place smoothly, during the interval of coupling that engenders the measurement, assuming it is not interrupted.

This leads to another question that is asked: what happens when the measurement is imperfect? For many reasons, including imperfect preparation of the initial apparatus state, one may arrive at decompositions of the state vector into eigenvectors of the system observable, for which the associated apparatus vectors are not orthogonal. A true split into many worlds has not occured. A split can, however, be forced, either by bringing in a second apparatus to look very accurately at the first apparatus or by simply letting the first apparatus interact with its environment. Through either mechanism it is possible to give a meaning and an answer to the question: in what sort of state does an imperfect measurement leave the system? Not surprisingly, this state is found to be a superposition of observable eigenstates with a spread determined by the lack of perfection in the preparation of the apparatus, or by disturbances that degrade its quality.

The edifice that Everett constructed was incomplete. It has taken several decades for others to finish the construction. The simple statement that we should take the formalism of quantum mechanics literally is by itself unable to tell us how to apply this formalism to practical problems. The symbols that describe a given system, namely the state vector and the operator dynamical variables, describe not only the system as it is observed in one of the many worlds comprising reality, but also the system as it is seen in all the other worlds. We, who inhabit only one of these worlds, have no symbols to describe our world alone. Because we ordinarily have no access to the other worlds we are unable to make rigorous predictions about reality as we observe it. Although reality as a whole is completely deterministic, our own little corner of it suffers from indeterminism. The interpretation of the quantum formalism is complete only when we show that this indeterminism is nevertheless governed by rigorous statistical laws. Moreover, our interpretation must emerge from the formalism itself; it must not be imposed from outside.

The earliest attempts to derive the standard probability interpretation from the formalism itself, by Everett, by myself, and by others, failed, because our arguments, upon close examination, proved to be circular. David Deutsch was the first to give a proper derivation[1]. He begins by considering a finite subset of eigenvectors of the system observable, and introducing an apparatus that can perform all possible permutations of this subset. He then shows that if and only if the components of the system state vector, relative to the permutable eigenvectors, all have the same absolute value, then it is impossible for any second apparatus, under any coupling to the system whatever, to detect any change in the system state under any of the permutations. This implies that none of the eigenvalues associated with the permutable subset has a preferred status in the state in question and that all are equally likely to turn up if an attempt is made to measure the system observable. The phrase "equally likely" can be converted into a standard probability statement by normalizing the state vector.

I have not time here to describe Deutsch's analysis of the case in which the probabilities are not all equal. Essentially what he does is to introduce two auxiliary systems, prepared in equal-probability states, and then invoke the calculus of joint probabilities to the system obtained by adjoining the auxiliary systems to the original system. Through purely factual (i.e., physically verifiable) statements about the state of the system he is then able to assign an unimpeachable probability to the outcome of any single observation. It is then straightforward to show that this assignment is consistent with histograms obtained experimentally by making observations on ensembles of identical systems in identical states.

Another gap in Everett's edifice was his failure to explain how to prepare apparatus so that they would be capable of making good measurements. Typically the variance in the position of the "pointer" that records the outcome of an observation must be small. Why did neither von Neumann, nor Everett, nor the rest of us worry in the beginning about our ability to secure the necessary variances? Because in practice they fall into our laps. We do not have to "sweat" to get them. Why is this so? It is because *the classical world emerges from the quantum world. There is no interface* as Bohr would have us believe.

How does classical behavior emerge spontaneously from the total state vector — from the state vector of the universe, or from a suitable isolated part of the universe? The germ of the answer was first given by Nevill Mott in 1929, in a beautiful paper entitled "The Wave Mechanics of α-Ray Tracks." When an *apparatus* observes a quantum system it causes a *decoherence* of the states of the observable being measured. But there are also inverse processes, involving the decoherence of the states of high-inertia or "classical" systems (in Mott's case an α-particle) by coupling to low-inertia systems (in Mott's case, the electrons in the ambient gas). This process, which stems from remarkable properties of wave functions in high-dimensional configuration spaces (as opposed to the wave function in three dimensions beloved of Schrödinger), is far more common than the quantum measurement process, which requires careful apparatus design. It can be illustrated by a model that is much simpler than Mott's.

Consider a massive body moving in one dimension in an arbitrary potential V and colliding with a light body moving freely in the same one-dimensional space, the collision being mediated by a relatively weak potential v. The Hamiltonian operator of the combined system is

$$H = -\frac{1}{2M}\frac{\partial^2}{\partial X^2} + V(X) - \frac{1}{2m}\frac{\partial^2}{\partial x^2} + v(x-X)\,, \quad \hbar = 1\,,$$

where M and m are the masses of the two bodies and X and x are their positions. We seek a solution of the Schrödinger equation for this Hamiltonian operator, with the light body in an "incoming" momentum state at momentum p.

The collision with the light body will leave the motion of the massive body virtually undisturbed, provided $m << M$. The state of the massive body can be quite arbitrary. We shall assume only that the velocity states into which it can be decomposed correspond to velocities that are small compared to the velocity of the light body. If $p > 0$ the time-dependent wave function of the combined system is then given very accurately by

$$\begin{aligned}\langle X\,, x\,, t|\Psi\rangle = L^{-\frac{1}{2}}\left\{\theta\,(X-x)\left[e^{ipx} + R(p)e^{ip(2X-x)}\right]\right.\\ \left.+\theta(x-X)T(p)e^{ipx}\right\} e^{-i\left(p^2/2m\right)t}\langle X\,, t|\psi\rangle\,,\end{aligned}$$

where θ is the step function, L is the length of an effective "box" controlling the normalization of the momentum wave functions, T(p) and R(p) are the transmission and reflection coefficients for the collision, and $\langle X\,, t|\psi\rangle$ is the wave function of the massive body in the absence of the light body:

$$\left[-i\frac{\partial}{\partial t} - \frac{1}{2M}\frac{\partial^2}{\partial X^2} + V(X)\right]\langle X\,, t|\psi\rangle = 0\,.$$

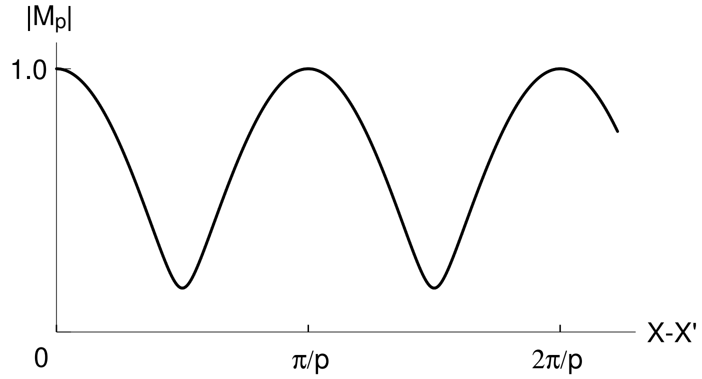
The factorization of the combined wave function into a part referring to the light body and a part satisfying the Schrödinger equation of the massive body alone is entirely due to the condition $m << M$. Note, however, that the first factor does not refer *solely* to the light body. The term involving the reflection coefficient contains a phase factor e^{2ipX} representing the effect of the momentum transfer to the massive body. Although this momentum transfer has no practical effect on the motion of the massive body, which continues to be described by the wave function $\langle X\,, t|\psi\rangle$, its role in decoherence is crucial. In order to see this, construct the density operator $\boldsymbol{\rho}$ of the massive body by tracing out the light body:

$$\langle X\,, t|\boldsymbol{\rho}|X'\,, t\rangle = \int_{-L/2}^{L/2}\langle X\,, x\,, t|\Psi\rangle\langle\Psi|X'\,, x\,, t\rangle dx$$

By considering specific interaction potentials v (for example a δ-function) it is not difficult to show that, in the limit $L \to \infty$, the above expression takes the form

$$\langle X\,, t|\psi\rangle\langle\psi|X'\,, t\rangle M_p(X-X')$$

Figure 1:



where M_p is a *modulation function* whose absolute value has the general appearance shown in figure 1.

The above density matrix does not describe the massive body as being in a localized state. However, suppose the massive body is allowed to collide with N identical light bodies, all in the same momentum state and having identical interactions with the massive body. Then in the wave function for the combined system there will be a factor for each light body, and when all these are traced out the density matrix of the massive body will take the form

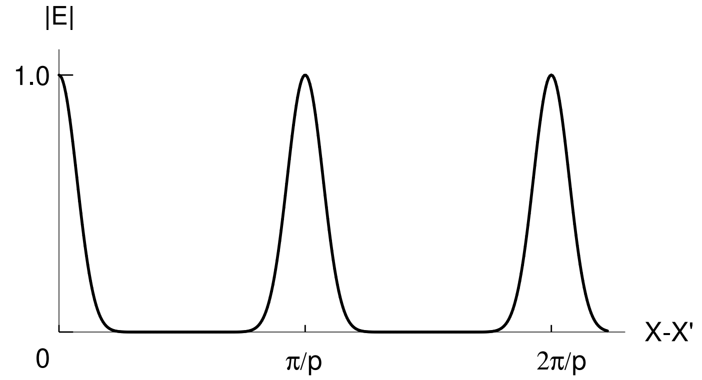
$$\langle X\,, t|\rho|X'\,, t\rangle \underset{L\to\infty}{\longrightarrow} \langle X\,, t|\psi\rangle\langle\psi|X'\,, t\rangle E\,(X-X')$$

where

$$E(X-X') = [M_p(X-X')]^N \ .$$

The function E may be called an *environmental modulation function.* For N = 20 its absolute values based on the previous figure, takes the form shown in figure 2.

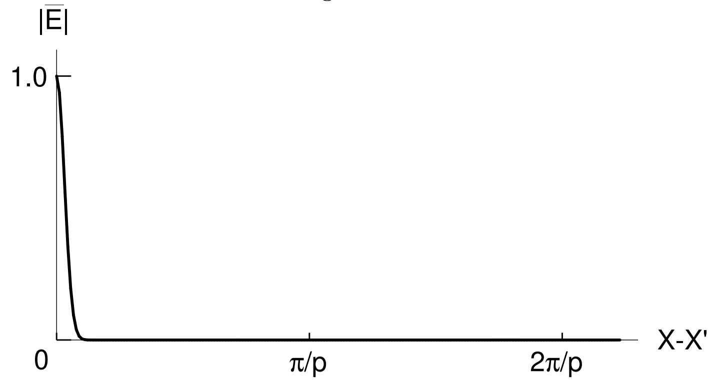
Figure 2:



Here localization is beginning to show itself. But it is a localization modulo π/p. To get true localization it is clear what one must do. One must let the massive body collide with N_1 light bodies having momentum p_1, N_2 having momentum p_2, and so on, and choose the p's to be incommensurable. The environmental modulation function is then given by

$$E\,(X-X') = [M_{p_1}(X-X')]^{N_1}\,[M_{p_2}(X-X')]^{N_2}\cdots$$

Figure 3:



and its absolute value has the appearance shown in figure 3.
As the N's become large (but not so large as to affect the motion of the massive body significantly) E becomes a very narrow function. The standard interpretation of the resulting density matrix is that the massive body has become localized at a point, the probability that the point is in a neighborhood of width dX containing X being

$$|\langle X\,, t|\psi\rangle|^2 dX$$

Note that only the squares of the absolute values of the probability amplitudes now appear. The phases of the amplitudes have become irrelevant through decoherence. Note also that the light bodies do not need to be in a thermal bath to produce this decoherence.

There is a more general and, at the same time, more precise approach to decoherence, which accounts not only for localization but also for the emergence of classicality. The formalism used in this approach has been developed largely by Griffiths, Omnès, Gell-Mann and Hartle,[6] and is easily applied to the present model. One first introduces a set of projection operators that defines a *coarse graining* of the possible dynamical histories of the massive body. For example

$$\mathbf{P}_\epsilon\left(\bar{X}\,, t\right) = \int_{\bar{X}-\epsilon/2}^{\bar{X}+\epsilon/2} |X\,, t\rangle\langle X\,, t| dX\,,$$

where ϵ determines the coarseness of the graining. If $\bar{X}$ is chosen from a discrete set of points, separated by intervals ϵ from one another, then these projection operators, at a fixed instant of time, are mutually orthogonal. More generally, one introduces projection operators at successive instants of time, and the finest useful graining is controlled by the phenomenon of wave-packet spreading. If the spreading were entirely due to the quantum behavior of the massive body one would choose

$$\epsilon >> \sqrt{\frac{\hbar \Delta t_{max}}{M}}$$

where Δt_{max} is the largest of the successive time intervals. In fact the environment (i.e., the light bodies) causes additional spreading. But in any case the larger M is the finer the graining can be.

Using the projection operators one defines the so-called *decoherence function*;

$$D\left(\bar{X}_n\,, \ldots\,, \bar{X}_2\,, \bar{X}_1 | \bar{X}'_1\,, \bar{X}'_2\,, \ldots \bar{X}'_n\right)$$
$$= \mathrm{tr}\left[\mathbf{P}_\epsilon\left(\bar{X}_n\,, t_n\right) \cdots \mathbf{P}_\epsilon\left(\bar{X}_1\,, t_1\right) \boldsymbol{\rho} \mathbf{P}_\epsilon\left(\bar{X}'_1\,, t_1\right) \cdots \mathbf{P}_\epsilon\left(\bar{X}'_n\,, t_n\right)\right]\,,$$

the selected instants of time, $t_1, \dots, t_n$, being assumed to be in chronological order. It is then not difficult to show that if the width of the environmental modulation function is small compared to ϵ, so that the density operator $\boldsymbol{\rho}$ represents the massive body as localized within a range equally small, then the decoherence function will be *diagonal.* Now each diagonal element

$$D\left(\bar{X}_n, \dots, \bar{X}_1 | \bar{X}_1, \dots \bar{X}_n\right) ,$$

is easily shown to be equal to the joint probability that the massive body will be observed to pass within intervals of width ϵ about the points $\bar{X}_1, \dots, \bar{X}_n$ at the times $t_1, \dots, t_n$. It is found that all diagonal elements vanish except those for which the intervals straddle a *classical trajectory.*

The most sophisticated modern investigations are those that turn the problem around and try to discover, in more realistic contexts, the kinds of coarse graining that lead to decoherence functions having similar properties. The coarse graining may involve projection operators of a more general kind than the $\mathbf{P}_\epsilon$'s, in which observables other than position are bracketed within certain limits. Or it may involve projection operators that place limits on observables that are themselves averages over regions of space*time.* In quantum cosmology, where one is dealing with the wave function of a whole universe and where it may be meaningless to introduce a space of possible state vectors for this universe, one may attempt to define the decoherence function (and its associated coarse graining) as a double functional integral (one for the rows and one for the columns) over sets of histories that are restricted in even more general ways.

Quite generally decoherence may be said to occur whenever the decoherence function, regarded as a matrix, is diagonal. The nonvanishing diagonal elements represent alternative "realities" or alternative histories. These histories, being mutually decoherent, do not normally interfere with each other. They constitute a new class of *many worlds*, in addition to those of which Everett made us aware. In Mott's example the α-particle does not ooze out from the nucleus in a spherical blob, as Schrödinger's wave function would have us believe. There are many worlds, in each of which the α-particle makes an ionization track in a particular direction during a particular interval of time. These worlds, like those induced by measurements, are unaware of one another, but they arise from processes, such as scatterings, that are much more common than those found in a laboratory setting. They will therefore be ubiquitous in the states of any sufficiently complicated system, regardless of initial conditions. Note that the decoherent histories of a high-inertia system need not always be "classical." Indeed they will not be if the system is a measuring apparatus capable of amplifying and recording the strictly quantum features of a low-inertia system to which it is coupled. Of course, important classical features are present in this case that are fundamental to the success of the measurement, in particular, the narrow variances that arise spontaneously from the action of the environment.

David Deutsch has made even broader use of the many-worlds picture of reality. In his book "The Fabric of Reality"[2] he invokes the many-worlds picture to give a novel and stimulating cross-universe analysis of the stability and robustness of genes in living organisms. This analysis permits an abstract distinction between true genetic material and junk DNA. True genetic material displays a stability under displacements to nearby worlds. A similar analysis can be applied to *knowledge*, showing that knowledge, as distinct from mere information, should be regarded as a fundamental physical quantity.

Deutsch also uses the many-worlds view as the setting for the infant science of quantum computers. According to him "quantum computation is a dinstinctively new way of harnessing nature. It will be the first technology that allows useful tasks to be performed in collaboration between parallel universes." It will do this by holding at bay the decoherence caused by the environment and hence allowing interferences to occur on at least a mesoscopic scale, which is equivalent to allowing some of the alternative worlds to become aware of one another. If programmed according to an algorithm discovered in 1994 by Peter Shor of Bell Laboratories, quantum computers could in principle carry out the rapid factorization of numbers having as many as 250 digits. It is possible to estimate the number of interfering universes that would become involved in such a factorization. It is a staggering 10^{500}, which gives some idea of the really huge numbers to which Everett's view of nature leads.

Deutsch asks how we can persuade our counterparts in 10^{500}-odd universes to start working on the factorization task. "Will they not have their own agendas for the use of their computers? No — and no persuasion is necessary. Shor's algorithm operates initially only on a set of universes that are *identical* to one another, and it causes them to become differentiated only within the confines of the factorization engine. So we, who specified the number to be factorized, and who wait while the answer is computed, are identical in all the interfering universes. There are, no doubt, many other universes in which we programmed different numbers or never built the factorization engine at all." But of these we are unaware. They do not interfere with our world. At the present time we cannot say whether the technology of quantum computation will ever reach maturity. But if and when it does the "other worlds" will unquestionably be as real as atoms to computer technicians. It would be nice if someday we could make planets in distant galaxies seem equally real.

To me, the host of universes parallel to our own consitutes at least a part of Plato's realm of ideal essences. Are they really there? Quantum theory, taken literally, says that they are. As to whether we should take the theory literally I can do no better than to say that it is always rewarding to push our theories to their ultimate logical conclusions. As David Deutsch says, "Our best theories are not only truer than common sense, they make more sense than common sense." The chief objection voiced by those who would *like* to share Everett's view is a simple question: "*Why* do I find myself in this particular world rather than in one of the others." The only possible answer is: "That's the way the dice tumble."

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For more details on the material covered in this talk see Bryce DeWitt, The Quantum Mechanics of Isolated Systems, *Int. Jour. Mod. Phys.*, A13:1881, 1998.

Quantum Gravity and the Persistence of Interface

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Abstract

The fluctuon model of force identifies the virtual particles that mediate the fundamental interactions with chains of transient pair creation-annihilation processes that propagate in the vacuum sea. The density of curvature of the supersea of all vacuum particles corresponds to the space-curvature of general relativity. The picture of the universe that emerges is that of a giant homeostat that is continually chasing consistent relations between the distribution of manifest mass and the density structure of the surrounding unmanifest plenum. The model suggests that the evolution and persistence of complex structures, in particular the structures connected with biological life, are abetted by these self-consistency dynamics

1 Interfacing with the Vacuum Sea

I want to consider the possibility that biological organisms are twinned to complementary images, anti-organisms of sorts, that reside in the unmanifest vacuum sea. The image can be thought of as a dynamic mold or cast that supports the manifest dynamic form of the organism, and conversely. It is as if a man and his vacuum twin are two wobbly individuals continually pulling each other back to the straight and narrow as they meander along a precipitous mountain path.

I will go even further and consider the possibility that the organism and its twin support each other by interacting indirectly through gravitational rays that emanate from throughout the universe and that this is the case for all bodies, even those that we perhaps inappropriately refer to as inanimate. Every time a body changes its state of motion it creates disequilibrium in the vacuum sea, hence a flux of gravitational rays that opposes this motion. The common form of the opposition is inertia. But what mediates the interplay between organism and anti-organism is not the ordinary resistive effect of inertia nor the ordinary gravitational attraction between bodies. The disequilibrium engendered by the change in motional state, or acceleration, suppresses graviton exchanges between particles that would otherwise interact with each other. A deviation from the ordinary law of gravity occurs; but this is immediately followed by induced graviton bombardments that rectify this deviation. The true underlying physics of the universe is an error feedback dynamic, very like the cybernetic concept of biological self-regulation. Each change in state of motion is a mutation of sorts, for all practical purposes a random jump to a new organization of the universe. The consequent corrective gravitational bombardments move each body and its anti-body back towards a self-consistent relationship, a harmony that the universe and all its parts ever chase but never catch. For the most part the error is sufficiently small and the correction sufficiently rapid for the time development to appear continuous. Under appropriate conditions the mutations make themselves known;

superpositions mutate to distinctly different superpositions. The collapse phenomena characteristic of measurement then enter into the time development. But the term superpositional mutation is more accurately descriptive. Measurement, which can be viewed as acceleration under special record keeping conditions, does not reduce superpositions but rather squeezes them into different forms consistent with the uncertainty principle. Every possible form of the universe has some probability of coming into existence whenever a change in state of motion occurs; but only those that lead the chase to self-consistency have any chance of surviving.

Black holes are giant creatures, each twinned in self-regulatory interplay with an indent in the vacuum sea. Gravitational collapse is the equivalent of superpositional collapse in the high mass, high velocity domain. Ultimate gravitational collapse never occurs. Collapse turns off the gravitational forces that initiate it, leading to interactions that reverse the collapse. The black hole breathes in a rhythm whose degree of regularity depends on the structure, both manifest and unmanifest, of the entire universe. The universe itself undergoes a kaleidoscopic sequence of expansions and contractions; there is no ultimate crunch; and very likely no primordial bang.

Ordinary objects, for example teacups and spoons, support and are supported by vacuum twins, but so well that it is possible to give a good account of their properties without reference to anti-teacups and anti-spoons. The situation is quite other with biological organisms. The combinatorics of biomolecular sequences allows for material organizations with fantastically improbable nonlinearities. The thesis that I wish to forward is that the evolution and maintenance of such forms depend critically on the underlying self-regulatory dynamics of the universe. It would not, on this view, be possible to account for the capabilities of manifest organisms without paying attention to their images in the vacuum sea.

But the picture has to be qualified. All material systems swim in the same vacuum sea. My vacuum image in some degree must reflect your vacuum image. My twin is a little bit your twin and a little bit the twin of every star and planet in the universe. It is Mach's principle, that inertia is due to the distribution of all the matter in the universe, expanded to a cosmic homeostatic form. Black holes, because of their vast mass, exert a slight influence on distant regions of the vacuum sea. The fate of the hole depends not just on this influence, its image proper, but on the influences exerted by all other masses. Biological organisms exert hardly any influence on the distant vacuum sea. The influence of an object corresponds to the space curvature it induces, which in our picture translates to the density curvature induced in the vacuum sea. The curvature effects fall off extraordinarily rapidly with distance, so fast that practically speaking my image belongs to me, your image belongs to you, and so on for each system in the hierarchy of biological systems: molecules, cells, organisms, even ecosystems.

This paper is written in honor of Professor Otto Rössler's sixtieth birthday fest. Some discussion we had nearly thirty years ago is pertinent, but best placed in the concluding section.

2 Physical Model

Hopefully the above remarks, however hyperbolic, will serve to convey the conception I have in mind. The picture is suggested by the fluctuon model of force [1, 2], in particular as it applies to gravity. An informal outline of the main features is pertinent at this point; for details see [2, 3, 4, 5, 6].

The Dirac vacuum sea is the motivating picture, but with the provision that in the fluctuon model negative energies are formal assignments inherited from interactions engaged in as positive energy modes. It is sufficient to think of the negative energy particles as pair production potentialities. The existence of a vacuum sea is implicit in models that combine special relativity and quantum mechanics; quadratic forms appear that admit negative as well as positive energy solutions [7].

The vacuum sea as whole, to be referred to as the supersea, comprises three subseas. The electron subsea, or more accurately, the potentialities associated with the electron family of particles, mediates the electroweak force. The quark subsea mediates the strong force. The third sea, consisting of postulated particles referred to as massons, is the primary mediator of the gravitational interaction. The masson subsea is vastly more dense than the electron subsea, which in turn is more dense than the quark subsea. The density structure of the supersea is thus almost exclusively determined by the density structure of the masson subsea. The space curvature of general relativity is interpreted as masson sea curvature in the fluctuon model.

Forces are mediated by virtual particles in the fluctuon model, as they are in conventional quantum field theories. The new feature is that the force carriers are identified with chains of transient fermion-antifermion pairs. Photons are interpreted as chains of transient electron-positron pairs; gluons as chains of quark-antiquark pairs; mesons are one step chains of quark-antiquark pairs. Gravitons are similarly interpreted as chains of masson-antimasson pairs (with the provision that vacuum electrons and quarks of sufficiently high energy can be recruited into these chains).

Chains of vacuum excitations will be referred to as fluctuons. Two general types are possible: propagating and trapped. A propagating fluctuon can only be initiated when a fermion-antifermion pair materializes as a result of an uncertainty fluctuation in the neighborhood of a positive energy particle. Once initiated it perpetuates itself as a frustrated mode due to the fact that it cannot simultaneously satisfy all the requisite conservation laws and uncertainty principles until it interacts with a second positive energy particle. In order for chain propagation to occur the fluctuation energy and momentum of the pair must match the vacuum density, i.e., it must be commensurate with the space and time intervals that separate the particles of the surrounding vacuum sea. Propagating fluctuons are the momentum carriers that mediate the fundamental forces.

Trapped fluctuons arise when a fermion-antifermion pair spontaneously appears as a result of an uncertainty fluctuation, but does so in so-called free space (i.e., not immediately adjacent to a manifest particle). Such fluctuations ordinarily disappear without initiating a chain, since in the absence of a manifest particle it is impossible to conserve momentum in all coordinate systems. However, the spontaneous pair can interact with a propagating fluctuation, either to terminate or initiate it. The pair could then itself become a propagating fluctuation, but this is only possible if the fluctuation energy of the pair matches the vacuum density. If it does not satisfy the match (or resonance) condition the pair cannot propagate, but nor can it decay without leaving a momentum conservation violation. The fluctuon can be thought of as a chain of vacuum excitations that would be at rest in an appropriately chosen coordinate system unless accelerated by interaction with a propagating fluctuon, or annihilated in a process that is the reverse of the process that created it. Trapped fluctuons allow the distribution of particles in the vacuum sea to be altered by interactions with manifest mass and charge (since in their unmanifest state vacuum particles only mediate forces). Vacuum particles are thus in a superposition of unmanifest and manifest (trapped) states. The mass and charge formally assigned to vacuum particles is inherited from interactions in which they engage in their trapped mode of existence.

Direct interactions in the fluctuon model are repulsive (apart from those mediated by mesons). This is consistent with the spin 1 character of photons and gluons (and with the fact of spin 0 mesons). The direct gravitational interaction is also repulsive, mediated by spin 1 gravitons built from spin 1/2 mesons. This conflicts with the spin 2 character generally attributed to gravitons (and seemingly required by the tensor character of general relativity). Spin 1 is consistent with the general relativistic model, however, since gravitational attraction in the fluctuon model is an indirect interaction that arises through the depressing effect of positive energy particles on surrounding vacuum density. Positive energy masses are pushed together by graviton chains emanating from vacuum particles (in trapped fluctuon modes) in comparatively high density regions of distant space. The net attractive effect is due to mutual screening of graviton fluxes. As noted above the space curvature of general relativity is identified with the density structure of the vacuum sea. The graviton fluxes follow this density structure, hence are compatible with the field equations of general relativity.

When an aggregate of positive energy particles becomes sufficiently dense to prevent photons escaping it also prevents gravitons from escaping. Collapse to a black hole ensues. The particles constituting the collapsing aggregate no longer initiate graviton chains and therefore cease to repel each other or to depress surrounding vacuum density. Initially the aggregate continues to collapse due to continued compressing interactions from gravitons in distant space, but as the vacuum density in distant space declines the direct repulsive effect comes to dominate. The black hole breaks up.

The connection to superpositional collapse is this: when positive energy particles accelerate they enter more dense regions of the vacuum sea. Inertia is identified with the increase in opposing graviton flux. The altered relation between masson rest mass and vacuum density interferes with graviton initiation, however. The density structure of the vacuum sea becomes inconsistent with the distribution of positive energy mass (as it does in the black hole situation). Graviton interactions spring into action that move the system back in the direction of self-consistency (a state that is never in fact reached in the fluctuon model). The breakdown of consistency is associated with superpositional collapse (through randomizing effects on quantum mechanical phase). The return to self-consistency is associated with reversal of collapse (i.e., restoration of phase relations that satisfy self-consistency dynamics). Superpositions are continually mutating to new superpositions, but as indicated above the requirement for self-consistency acts as a restorative force that can preserve the appearance of a continuous, unitary time development.

3 Fluctuon Principle

It is a relatively simple matter to explicate the linchpin concept, that of the fluctuon, in a more precise fashion.

Particles that can initiate or terminate fluctuons will be referred to as absorbers. Manifest particles (i.e., particles with real positive energy) are absorbers. This includes propagating fluctuons that carry real energy (e.g., real photons). Propagating fluctuons that approach virtuality (in an appropriate coordinate system) also act as absorbers, as do trapped fluctuons. Particles in unmanifest vacuum states are not absorbers.

Consider an absorber residing in a sea of unmanifest vacuum particles that are separated on the average by a distance r_K (where the subscript will later be used to specify the subsea in question). Particle-antiparticle pairs, say electron-positron pairs, should arise for time periods compatible with the uncertainty principle, $\Delta t \approx \hbar/\Delta E$. Such pairs decay without effect in the absence of a neighboring absorber since conservation of momentum would otherwise be violated in all but the specially chosen coordinate system in which the electron and positron have equal and opposite momenta.

The presence of an immediately neighboring absorber removes this restriction. Still, purely virtual pairs would have to decay within limits set by the time-energy uncertainty principle and would have to do so without initiating any chain propagation process. Consider, however, the case in which the fluctuation energy has the specific value, $\Delta E_K \approx \hbar c/r_K$, where $\tau_K = r_K/c$

is the lifetime of the pair (and for now we ignore the effect of gravity on c). As a temporary simplification consider a one dimensional universe. The momentum uncertainty of the pair the time interval τ_K should be $\Delta p_x \approx \hbar/x_K$, where in accordance with our assumption we have set $r_K = x_K$. A transient fermion-antifermion pair that satisfies the $\Delta E \approx \Delta E_K$ condition will have some chance of transferring its fluctuation momentum to an immediately neighboring absorbing particle and recoiling with equal and opposite momentum. So far no violation of conservation of momentum has occurred. Whether or not this scattering event occurs, the pair must decay within a time interval compatible with $\hbar/\Delta E_K$, otherwise an unacceptable violation of energy conservation will occur. But if the momentum transfer has occurred the decay process will create a momentum conservation violation, due to the fact that disappearance of the pair (and its momentum) leaves an unbalanced alteration in the momentum of the initiating absorber or other absorbers with which it has in the meantime interacted, in effect formally moving the energy conservation violation to the universe external to the chain. The momentum violation is not allowable over an interval much larger than x_K, and consequently outside this interval the annihilated momentum fluctuation must reappear as a next neighboring pair creation event. But this regenerates the energy conservation violation and so on, leading to a self-perpetuating chain of transient pair creation events. The chain must continue, in frustrated fashion, until the unbalanced momentum fluctuation is terminated by a second absorbing particle.

Actually the fluctuon propagates in a superposition of all possible directions. The mode of propagation is helical, due to the fact that in the absence of gravity (or acceleration) the intervals separating vacuum potentialities should be the same in all directions. Thus we are free (after the fact) to choose r_K to be coincident with x_K, but we are not free to set y_K and z_K equal to zero.

Angular momentum relates to the chain propagation process in the same fashion as linear momentum. The initial appearance of the pair is of special interest, however, due to the fact that spin 1 materializes out of a vacuum that has no spin. Spin is nevertheless conserved, since a quantum of action must be transmitted to the remainder of the universe. The existence of spin can even be understood in terms of the unavoidability of this exchange [8, 9].

The fluctuon principle can also be formulated in covariant terms: a chain, once initiated, must perpetuate itself until it is terminated by a second absorber, since between these two points it is not possible for the pairs and the universe external to them to conterminously satisfy the relativistic mass energy relation, $E^2 = m^2c^4 + p^2c^2$.

4 Pertinent Properties

The propagation of a fluctuon through the vacuum sea might very roughly be analogized to a stone skipping frictionlessly on the surface of a lake. Concrete analogies are problematic, however. Apart from the features mentioned above (superposition, helical mode of propagation) a number of other aspects should be noted.

The energy conservation violation can be locally associated with the chain when it takes the form of pair production. It is associated with absorbers external to the chain when the pair disappears back into the vacuum state. The imbalance exhibited by the initiating absorber when the fluctuation undergoes its initial annihilation spreads throughout the universe as the chain propagates. Thus the chain propagation process has both a local and global aspect.

Manifest charges and masses depress surrounding vacuum density, due to the fact that vacuum particles are only part time absorbers (i.e., only act as absorbers in their trapped fluctuonic modes). The depressions induced by charges are local polarizations, due to the requirement for overall neutrality. Thus the electron and quark subseas are isotopic; the vacuum density is uniform apart from local polarizations. This is not the case for the masson subsea. Mass comes in only one charge. Thus vacuum curvature can build up.

The energy fluctuation required to initiate chain propagation depends on the interval separating the absorber from its immediate neighboring vacuum particles. This energy is always less than that for intervals separating vacuum particles that do not neighbor the absorber or, all else equal, that neighbor an absorber of greater mass (in the case of the masson subsea). There are two possibilities: either the energy conservation violation must increase as the chain propagates into more dense regions of the vacuum or vacuum sea distortions must occur that in effect compensate for the deviations from the initial fluctuation length. The first possibility is untenable, since it requires fluctuations to occur as needed (which means that they are not fluctuations at all). The second possibility, which correlates with the global aspect of chain propagation, manifests itself as a wave motion of the vacuum sea, to be referred to as a compensation wave (since it compensates for the variations in vacuum density).

The wave motion is plausibly identified with electromagnetic waves in the case of the electron subsea. The chain and the wave carry real energy if the initiating absorber undergoes acceleration in the coordinate system in which it is viewed. The chain and the accompanying compensation wave then become detached from the absorber. If the absorber exhibits minimal acceleration the chain and accompanying wave approach pure virtuality. Some acceleration is always exhibited of course, since this is inherent in the initiation and termination of fluctuon chains.

The wave motion retains its form in the case an electromagnetic wave, due to the overall isotropy of the electron subsea. This is not the case for gravitational waves, since density variations can build up in the case of the masson subsea. But this does not mean that the vacuum sea distortion builds up. Propagating fluctuon chains are generally quite short, due to the fact that the interaction between any two manifest particles is inevitably intermediated by intervening trapped fluctuons.

The velocity of chain propagation must be the same in all inertial coordinate systems, corresponding to the constancy of light velocity. This follows from a perpetual mobile argument. Consider a beam of photons traveling parallel to the direction of an observer traveling in coordinate system L. Suppose that our observer transforms from L to L' by undergoing a change in velocity. This, however, requires an acceleration; the beam will appear to undergo an acceleration. If the beam comprises chains of transient electron-positron pairs, as assumed in the fluctuon model, it should emit radiation, therefore yet more propagating chains that carry real energy. The observer could then use these to further accelerate himself, and so forth, leading to unacceptable violation of energy conservation. If the photons have the same velocity in L and L' then the extent to which they will appear to undergo acceleration will be negligible unless the masses that the observer carries with him are extremely large (corresponding to a significant gravitational field and therefore requiring more work to accelerate than could be harvested from the beam). More to the point, the acceleration that the chain must undergo as the observer transforms between inertial frames must be matched by an equal deceleration if the velocity of the chain is constant, thereby precluding any harvesting of radiant energy that does not have to be paid back in order to complete the transformation.

Light velocity does vary as the density curvature of the masson sea varies, since density curvature is the mark of gravity.

In conventional field theories virtual particles can have any energy. The distance they travel increases as the energy violation decreases, in accordance with the time energy uncertainty principle. The momentum transferred can similarly assume any value, provided no arbitrary cutoff is assumed. The fluctuon model adds a new feature: the energy and momentum carried by the virtual transmitter are fixed by the vacuum density in the immediate neighborhood of the absorber. Nevertheless the model appears to recapitulate expressions for macroscopic force in the best known cases: electromagnetism and gravity. Furthermore, it obviates problems of infinite self-energies that arise in field models. The momentum exchanged has a natural cutoff, determined by the vacuum density. Chains initiated by an absorber cannot back interact on that absorber; self-interactions in this sense do not occur. Absorbers can locally exchange fluctuation energy with neighboring vacuum particles if the fluctuation energy is larger than required for pair production. In this case it will be too large to initiate chain propagation. But this is just equivalent to saying that the fluctuation energy and momentum exhibited by the absorber are subject to the time-energy and position-momentum uncertainty principles.

5 Macroscopic Force

Expressions for force are obtained from scattering theory, essentially first order perturbation theory [10]. The first order treatment is actually the most accurate, due to the fact that higher order treatments are designed to deal with intermediate states. But the fluctuation time τ_K is determined by the vacuum density and is therefore not decomposable into constituent fluctuon times.

Let us for the moment consider the simplest case of an isotropic vacuum. The electromagnetic field is the prime example. It is an important feature of the fluctuon model that flat and curved geometries can coexist, for the simple reason that one subsea (say the electron subsea) can be isotropic and nevertheless occupy the same space as the nonisotropic masson subsea. Photons and electrons will of course move in a manner that follows the masson sea density curvature, since all particles gravitate. However, the geometry of the electromagnetic field remains a flat space geometry, since the purely electromagnetic forces are controlled by an isotropic subsea.

Let $P(a,b)$ represent the probability that an absorber interacts with an immediately neighboring vacuum particle to initiate chain propagation. Alternatively, $P(a,b)$ can be interpreted as the probability that the absorber and surrounding vacuum sea undergo a transition from state a to state b in a time interval τ due to a fluctuation in energy compatible with $\Delta E\tau \approx \hbar$. The fluctuation can be viewed as a perturbing potential, V, that is of spontaneous origin. If we take this as constant over the time interval the transition probability is given by

$$P(a,b) = \frac{4\|\langle b|V|a\rangle\|^2 sin^2\left\{\frac{1}{2}\frac{\Delta E}{\hbar}\tau\right\}}{\Delta E^2} \tag{1}$$

where ΔE is the energy difference between state a and state b. Recalling that the pertinent time interval is τ_K and the that the pertinent value of ΔE is therefore $\hbar/\tau_K$,

$$P(a,b) \approx \frac{0.92\|\langle b|V|a\rangle\|^2\tau_K^2}{\hbar^2} \tag{2}$$

The point to note is the quadratic dependence on τ_K. This is a feature of perturbation theory [7]. The probability of undergoing a transition depends linearly on time, but the relevant probability is a transition to an equal energy state and this increases as the square of the time interval. This can be roughly thought of in terms of the time-energy uncertainty principle. If the sea is sparse the pair must exist in violation of energy conservation for a longer time and thus the impetus to couple to an absorbing particle is greater. That force decreases as the density of the vacuum sea tincreases is due to this feature.

The force between two absorbers should be proportional to the probability that a fluctuon initiated by one is terminated by the other. Suppose that the initiator is at the center of a spherical shell and the terminator is somewhere on the shell. The force between the two absorbers is then given by

$$F_K \approx \frac{A_K r_K(a_i,1)^2 r_K(a_f,1)^2}{c_0^2 \hbar^2 r^2} \tag{3}$$

where we have translated from fluctuation time to fluctuon length and where K would be set to em in the case of the electromagnetic force to q in the case of the strong force, and to g when we are ready to consider gravity. The notation $r_K(a_i, 1)$ denotes the fluctuation length in the immediate neighborhood of absorber a_i and $r_K(a_f, 1)$ denotes the fluctuation length in the immediate neighborhood of absorber a_f. The light velocity is denoted by c_0 to emphasize that it is its Lorentz (flat space) value that is relevant to coupling strengths. How this can be the case even though light velocity varies in a gravitational field will be taken up shortly. The prefactor A_K depends on a number of subfactors, but all these multiply to a constant. The perturbation V depends both on the fluctuation energy that triggers the transition and the probability that the fluctuation occurs. The reasonable assumption is that the fluctuations have a Gaussian dependence on energy. The frequency of momentum transfers and the magnitude of the momentum carried by the chain must also be considered.

Suppose that we consider the electron subsea, therefore the case where F_K is taken as F_{em}. If the $r_{em}(a_i, 1)^2$ is interpreted as a measure of charge q_i and $r_{em}(a_f, 1)2$ is interpreted as a measure of charge q_f, our expression for force becomes the Coulomb law. This is a reasonable identification, since the square of the fluctuation length (or equivalently the square of the fluctuation time) controls the coupling strength.

From the Coulomb law it is possible to obtain an expression for magnetism by translating to a different inertial frame and, by translating to an accelerating frame, to obtain Maxwell's equations in full given some technical assumptions, such as conservation of charge, that are reasonable in the fluctuon model [11, 12, 13, 14]. Starting out with the special case of a spherical symmetry is not restrictive so far as the description of the electromagnetic field is concerned.

We can possibly associate the electroweak force with zones of high electron subsea density that are concomitant to particle structures. The sparseness of the quark subsea could reasonably lead to variable fluctuon lengths, thereby yielding a main property of the strong force, namely that it increases with distance. Mesons, as noted earlier, are most plausibly associated with momentum transfers restricted to one fluctuation length; length variation here makes it possible to fit the Yukawa potential. Neutrinos can be associated with fluctuon chains that split into separate spin 1/2 electron and positron excitations when they pass through the high density electron subsea zones that yield the weak force [5, 6].

6 Gravity

Our interest here is gravity, the most fundamental force. Recall the principle of equivalence: gravity is locally indistinguishable from the signature of force, namely, acceleration. It should not be surprising that graviton mediated interactions pose technical problems that are significantly more complicated than those posed by the electron and quark subseas.

The main difficulty is density curvature, corresponding to the relationalism of distance, time, and mass. The spherically symmetric situation used as an entree to the electromagnetic field is strictly speaking not tenable. The fluctuation lengths change with distance from the absorbers of interest. Idealizing the absorbers as being at rest is conceptually contradictory, due to the identity of gravity and acceleration. Coupling strengths mediated by the electron and quark subseas should be immune to the fact that the speed with which fluctuons (including gravitons) propagate is itself controlled by gravitons.

The fluctuon model introduces the additional complication of multiple curvature scales. At the smallest scale, that of the separation between absorber and neighboring vacuum particle, curvature is all important to initiating the chain propagation process. At the extremely large (global) scale density curvature controls the flux of gravitons that is responsible for the net attractive interaction between masses. The viewpoint of general relativity is that space-time can always be treated as locally flat (or Lorentzian). The large scale curvature is modeled by connecting locally flat regions. This is possible in the fluctuon model so far as modeling the overall density structure of the vacuum supersea is concerned, but not for modeling the graviton exchange process. This depends on the curvature in the immediate vicinity of the absorber. Furthermore, the precise character of this local curvature depends on the global curvature structure of the vacuum sea, since it is itself controlled by the meshwork of impinging graviton exchanges. As the density of manifest absorbers increases the fluctuation lengths separating each from its immediate neighboring vacuum particles are increasingly influenced by graviton exchanges with other absorbers. The one-to-one correspondence between absorber mass and immediate neighboring fluctuation length breaks down. The fluctuation energy required for graviton creation accordingly depends on the global distribution of mass. The model is ultimately relational, controlled by a bottomless self-consistency dynamics.

Again we cannot here pursue a detailed development, which in fact is not complete. It must suffice to outline the approach taken and to note pertinent points. The approach has two sides: local and global. The local approach starts in the regime where quantum gravity aspects are quantitatively least important, namely in the extreme low mass, low velocity domain. We can even go so far as to contemplate the gravitational interaction between, say, a neutron (or better its proton component) and an electron. Obviously the gravitational attraction is minuscule. However, it is possible in this domain to elicit process (or mechanistic) aspects of gravity that should also be operative in domains in which space curvature affects the quantitative expression of force in a significant way.

The complementary global approach proceeds by demonstrating that the fluctuon model entails the principle of equivalence, thus should yield an overall description of gravity (in the equilibrium situation) that conforms to the field equations of general relativity.

Consider first, in an essentially qualitative way, the local approach. We assume, undoubtedly as an unreachable idealization, that it is operationally feasible to construct a coordinate system adequate for dealing with fluctuon exchanges between two individual absorbers, a_i and a_f, despite the fact that at the fine level of analysis the discreteness of such exchanges means that unpredictable accelerations will always be occurring. The distance between a_i and a_f could be specified in terms of the fluctuation lengths along the path of a graviton or photon separating them, or it could be specified by using the fluctuation lengths on a spherical surface (defined by rotational symmetry) to define a radial coordinate. The second method, which corresponds to Schwarzschild coordinates, allows for an analysis that proceeds along the lines sketched in the previous section. But as intimated above, the spherical surface is in principle distorted by the absorber that defines the surface, however negligible this may be in the minimalist case that we are considering.

Let us skip details at this point, and proceed directly to the manner in which fluctuation lengths and times relate to rulers and clocks. The distention of fluctuon lengths by mass (i.e., the depression of surrounding vacuum sea) corresponds to the shrinkage of a ruler in a gravitational field. The general relativistic statement is that an observer traveling from a_i to a_f and always at rest relative to his ruler (hence measuring the proper distance) would record an increased distance as the mass of a_i and a_f increase, due to the shrinkage of his ruler. The corresponding fluctuonic statement is that distance increases because the masses repel trapped fluctuons and therefore distend fluctuation lengths by increasing the separation between vacuum particles in the surrounding vacuum sea. As the mass of a_f increases the radial coordinate also increases, due to the fact that a_f distends vacuum lengths in its neighborhood and therefore increases the average surface area of the sphere (or of its distorted analog). However, the radial length defined in this way is still smaller than the proper distance, since a_f is further away from more points on the sphere than it is from the path that a photon would take to reach it from absorber a_i.

The time required by an observer directly traveling between a_i and a_f is, according to general relativity, reduced in comparison to the coordinate time assigned to him by the spherical traveler. The fluctuonic analog is this. The average fluctuon time deduced by the direct traveler will exceed the average fluctuation time deduced by spherical traveler, for the same reason that the average fluctuation length is larger (except that as mass increases the distending effect grows more rapidly for fluctuation times than fluctuation lengths, due to the decrease in light velocity). Increased average fluctuation times means that an observer always at rest relative to his clock will see fewer ticks on that clock for a given number of fluctuation steps, due to the fact that each momentum transfer that could contribute to the occurrence of a tick will itself take longer to occur. This is the fluctuonic interpretation of the slowing down of a clock in a gravitational field.

Now we can briefly consider the direct repulsive force between two small masses, m_1 and m_2, separated by a distance r that is defined as nearly as possible in terms of the spherical surface method. For simplicity we suppose that m_1 and m_2 are isolated from all other interactions and that the coordinate system is chosen in such a way that their motion relative to one another is not combined with any translational motion. The direct repulsive interaction looks like this:

$$F_g \approx \frac{\hat{C}_g^2\left[c(m_1,1)^4 + c(m_2,1)^4\right] A_g r_g(m_1,1)^2 r_g(m_2,1)^2}{2\bar{c}_p^2 c(m_1,1)^2 c(m_2,1)^2 \hbar^2 r^2} \tag{4}$$

where $r_g(m_1,1)$ denotes the fluctuation length of neighboring absorber m_1, $c(m_1,1)$ is the velocity of the initiated chain in the vacuum interval immediately neighboring m_1, and similarly for $r_g(m_2,1)$ and $c(m_2,1)$ with respect to absorber m_2. The prefactor $\hat{C}_g$, to be referred to as the vacuum sea curvature correction, represents the distention of $r_g(m_1,1)$ due to $r_g(m_2,1)$. This scales as $\bar{c}_p/c_0$, where $\bar{c}_p$ denotes the average light velocity over the proper distance traveled by the graviton. That these factors cancel out protects the gravitational constant G from being dependent on light velocity and hence on mass. The velocity $\bar{c}_p$ enters in the first place due the effect of intervening trapped fluctuons (which cannot be idealized away).

Gravitons initiated by m_1 will hardly ever transfer momentum directly to m_2. Thus the momentum received by m_2 due to initiations by m_1 must be corrected for the the fact that the curvature in the immediate neighborhood of the intervening trapped fluctuons is less than that in the neighborhood of m_1. This effect, referred to as the vacuum sea compensation factor, scales as $c(m_1,1)/\bar{c}_p$, and similarly for the influence of m_2 on m_1.

Actually two other self-canceling factors are hidden in the above equation: the initial fluctuon length distention of each mass taken in isolation and the effect of curvature on vacuum density, referred to as the vacuum sea dilution effect. The distention effect scales as $c_0/c(m_i,1)$, where m_i is the mass of absorber i, but enters as a square (due to the quadratic dependence of force on fluctuation length). The dilution effect scales as $c(m_i,1)^2/c_0^2$, consonant with the fact that $2m_v c^2$ is the energy required for a vacuum particle with mass assignment m_v to materialize into a pair. This can slightly break the isotropy of the electron and quark subseas. However, the self-cancellation of these two factors protects the constancy of electron rest mass and charge against the effect of gravity on light velocity.

Shortly (in section 7) we will see that the four light dependent factors noted above are key to adjusting the relation between vacuum density and the fluctuation energy required for masson-antimasson pair production, hence for graviton production in the face of the highly variable density curvatures that are possible in the masson subsea. These adjustments are part of the bottomless relationalism of the fluctuon model, and part of the error and error correction dynamics implicit in this relationalism.

If the masses m_1 and m_2 are too small to have any effect on light velocity, and if no other manifest masses are close enough to exert any detectable effect in this respect, the direct repulsive gravitational force reduces to

$$F_g \approx \frac{A_g r_g(m_1, 1)^2 r_g(m_2, 1)^2}{c_0^2 \hbar^2 r^2} \tag{5}$$

In this domain we can associate the mass of an absorber with the square of its immediate neighboring fluctuation length in the masson subsea, just as we can associate charge with immediate neighboring fluctuation length in the electron sea. The direct repulsive interaction between masses thus takes on the form of Newton's gravitational law, apart from sign.

It is fairly straightforward to demonstrate that the direct repulsive interactions combine to yield a net attraction that conforms to the Newton inverse square law in the low mass, low velocity domain [6]. The derivation, stated verbally, proceeds along the following line. Each of the manifest masses, m_1 and m_2, directly repel trapped fluctuons, leading to local depression and distant elevation in vacuum density. Gravitons emanating from the trapped fluctuons in turn exert repelling effects on the two masses, both from the intervening region and from the region external to them. The density of trapped fluctuons in the intervening region is comparatively low, however, due to the inverse square character of the repulsive effect. The net effect of repulsions pushing m_1 and m_2 apart and the exterior ones pushing them toward each other would perfectly balance except for one factor: mutual screening. Mass m_1 screens m_2 from bombardments from exterior gravitons along the path directly connecting them, and conversely. The direct inverse square repulsion is thus recapitulated as an indirect inverse square attraction.

The direct repulsive interaction provides a process model for metric formation. The induction of vacuum density curvature through the interaction of mass and trapped fluctuons corresponds to the induction of space-time curvature by mass in general relativity. The Schwarzschild metric, the solution of the field equations of general relativity under the idealized assumption of spherical symmetry, is the best known example. The metric in this case can be obtained from the fluctuon model by an argument that is closely related to the derivation of the gravitational red shift formula from the principle of energy conservation [15] (cf.[16]). The new feature is that the energy balance considerations are applied to the graviton interactions between a central manifest mass and the trapped fluctuons of the surrounding vacuum sea.

7 Equivalence Principle

The process based derivation of the Schwarzschild solution is of course not sufficient to demonstrate that the fluctuon model would yield a description of gravity that conforms to the field equations of general relativity, at least as a first (equilibrium) approximation. The difficulty of a direct demonstration is inherent in the self-consistency aspect of the model. A precise description of the local graviton interaction depends on the global meshwork of graviton interactions, and conversely.

However, as indicated earlier, it is possible to show that the fluctuon principle entails the principle of equivalence, the starting point of the general relativity model. The argument is a perpetual mobile argument, essentially a generalization of the argument outlined earlier that light velocity must be constant in an isotropic vacuum [6].

First let us consider the nature of inertia from the point of view of the fluctuon model. The general relativisitic model of gravity asserts that inertia, or resistance to acceleration, is a gravitational phenomenon [17]. The fluctuonic interpretation follows from the fact that a manifest particle in a state of acceleration always moves in advance of the vacuum density depression induced by it, consistent with the fact that the depressive effect of the mass cannot move faster than the velocity of light. For example a rocket ship traveling away from the earth's surface will see a higher vacuum density, due to the decrease in gravitational field; but as long as it is undergoing positive acceleration it will see a higher vacuum density at any given position during the escape process than would an identical rocket ship in a constant state of motion at that locus. The implication is this: *acceleration, whatever its source, necessarily meets graviton bombardments that oppose it.* The resistance to the acceleration is due to these countervailing bombardments.

Now recall that there are two ways of defining mass: gravitational and inertial. In the fluctuon model both methods of definition are quantified by the response of an absorber to graviton bombardments. For the gravitational and inertial method of definition to lead to different results would require the introduction of arbitrary factors into the model.

Suppose, as a reductio hypothesis, that some arbitrary factor were operative that could break the equivalence of gravitational and inertial mass. Consider under this circumstance a test absorber lifted away from the earth and then allowed to fall back to its original position, and suppose that this cycle could be completed in a practically frictionless manner. The test absorber is subject to nongravitational fluctuon bombardments that provide the lifting force, and is subject to graviton bombardments and counterbombardments during both the lifting and falling phases of the cycle. If the gravitational mass were not equal to the inertial mass this would mean that the test absorber would accelerate in response to the different bombardments and counterbombardments in a manner that depends differentially on some internal property, as opposed to depending exclusively on the fluctuation energies and momenta carried by the impinging fluctuons. The density curvature of the masson sea would consequently be different when the test absorber returns to its original position relative to the earth than it was at the beginning of the cycle. The altered curvature would either require additional work to complete the cycle or could be used to perform work beyond that required for completion. In either case energy conservation would fail. The principle of equivalence is thus implied by the principle of energy conservation in the fluctuon framework, thereby affirming the statement above that the fluctuonic processes must yield a macro description of gravity that has a correspondence limit in the general relativisitic description.

8 Mass-Density Relations

But as intimated earlier the correspondence is not exact. The self-consistency can break down in the fluctuon model, due to the following feature: the mass formally assigned to vacuum particles through the gravitational interaction increases as vacuum density decreases, while the mass assigned to the same particles on the basis of the fluctuation energy required for pair production decreases. These two assignments should, however, be the same if fluctuon initiation is to occur.

Consider first the electron subsea. The minimum fluctuation energy required for pair production must satisfy $\Delta E_{pair} = 2m_e c(e,1)^2 + T$, where me is the electron rest mass, T is the kinetic energy of the pair, and c(e,1) is the velocity of light immediately neighboring an absorber carrying charge e in the region of space under consideration. The fluctuation energy required for chain propagation is $\Delta E_{prop} \approx \hbar c(e,1)/r_{em}(e,1)$, where $r_{em}(e,1)$ is the fluctuation length in the electron subsea immediately neighboring the absorber. Equating ΔE_{pair} and ΔE_{prop} yields

$$m_e \approx \frac{\hbar}{2c(e,1)r_{em}(e,1)} - \frac{T}{2c(e,i)^2} \tag{6}$$

For the moment let us suppose that T is zero (which it in fact will turn out to be). It might then appear that m_e must increase with increase in gravitational field, since $c(e,1)$ decreases under this circumstance. However, this is prevented by the distention effect noted earlier. The fluctuation length $r_{em}(e,1)$ increases as $c_0/c(e,1)$ increases, due to the fact the initiating fluctuation length is controlled by a photon mediated interaction of the absorber per se and the vacuum electrons surrounding it.

If T could be greater than zero and nevertheless initiate chain propagation this would mean that pairs of lower energy would be possible that could allow for long jumps in the electron subsea, hence for a stronger electromagnetic force that would have the effect of inducing a compensating decrease in the density of the vacuum sea, thereby regaining the $T = 0$ condition. If the fluctuation length were too large to allow for chain propagation the initiation of photons would be turned off, thereby allowing for a compression of that length by photons emitted by other charged absorbers. The important point is that discrepancies between vacuum particle mass and vacuum sea density engender self-regulatory interactions that remove these discrepancies.

The situation is more complicated for the gravitational interaction. For simplicity let us ignore the possibility that high energy fluctuations of electrons and quarks can participate in graviton chains (since this is a secondary effect). Reasoning parallel to the above yields

$$m_m \approx \frac{\hbar}{2c(m_i,1)r_g(m_i,1;M)} \tag{7}$$

where m_m is the masson rest mass, m_i denotes the mass of absorber i, and the notation $r_g(m_i,1;M)$ is used to express the fact that the fluctuation lengths neighboring mi can be significantly influenced by other masses. We again set T equal to zero, on the basis of a self-corrective process essentially similar to that operative in the electron subsea. The new feature, different from that which obtains for the electron subsea, is that $r_g(m_i,1;M)$ can become quite large if m_i is immersed in or is proximate to a sufficiently dense collection of particles (since there is no requirement for neutrality). The masson rest mass could still be constant, due to the reciprocal relation between $r_g(m_i,1;M)$ and $c(m_i,1)$, but this is subject to the provision that $r_g(m_i,1;M)$ can adjust fast enough. For the electron subsea the adjustment time can always be fast, due to the fact that $r_{em}(e,1)$ is influenced by surrounding masses only through their influence on light velocity, as opposed to influence on electron subsea curvature (which would be restricted to local polarization except under the most extreme conditions). The situation is different for the masson sea, since the curvature around particle m_i is in part due to the curvature induced by other particles (which is the reason for including the reference to M in the notation here used for fluctuation length). Furthermore, the adjustment, including any adjustment of light velocity, is now mediated by graviton chains, therefore must include the chains initiated by m_i. As acceleration becomes very large, therefore as the gravitational field becomes larger, or equivalently, as the extra distension of $r_g(m_i,1;M)$ due to M becomes larger, the time required for adjustment increases; the possibility for error increases.

What can happen under this circumstance? The initial fluctuation length, $r_g(m_i,1;M)$, will be smaller than it should be to match the masson rest mass, due to the fact that the accelerating particle, by moving relative to its local depression, enters a denser region of the masson sea. The absorber can still initiate gravitons (i.e., masson-antimasson chains) but these must have higher fluctuation energies than they would have if the adjustment process were complete. The direct gravitational repulsion exerted by m_i thus decreases. The net attractive effect it appears to exert increases since the repulsion of other particles towards it by particles not so affected becomes comparatively larger. The forces operative in the system undergo changes which for all practical purposes exhibit a highly random character, where random is taken in the algorithmic information theory sense that the rules governing the change are not manageably compressible [18] .

The lack of compressibility is due to the fact that the change depends on a meshwork of graviton exchanges that depends on all the masses in the universe and on all their relative motions. To the extent that the acceleration ceases, at least from some particular observer's point of view, the normal equilibrium relationships between absorber mass, initial vacuum length, and distant vacuum density are restored.

9 Gravitational Collapse

Let us look now at an extreme situation: gravitational collapse. Here a collection of particles becomes so massive that the velocity of light goes to zero. Photons cannot escape. Actually photons cannot even be initiated, due to the fact that the vacuum becomes completed depleted of vacuum particles as soon as the velocity of light goes to zero. Surrounding matter is drawn in; no particles can escape, apart from escapes ordinarily interpreted in terms of pair production and tunneling (i.e., in terms of the Hawking radiation process). Gravitons cannot escape either. From a geometrical point of view, with no process analysis of metric formation, this not a problem; gravitons do not enter the picture. In a virtual particle exchange model of metric formation the question must be asked: if gravitons cannot escape how can the hole exert an attractive gravitational force on surrounding matter?

The fluctuon model gives a simple answer. The collection of particles exerts an even greater attractive force on surrounding matter when it enters the collapse stage, due to the fact that it no longer exerts any direct repulsive gravitational force. The compressing effect of gravitons emanating from distant space thus becomes comparatively stronger, due to the fact that the vacuum sea density in these regions is still elevated. But the elevation must taper off, since it was induced by gravitons emanating from the particles that have now entered the collapse regime and that no longer exert their inductive effect. The indirect attractive force responsible for the collapse declines; the direct repulsive interaction reasserts itself. The collapse process begins to reverse; particles are emitted. The emission looks like Hawking radiation. The disintegration of the hole is not to be thought of merely as a passive evaporation process. The particles fly apart, since direct repulsion now dominates indirect attraction. The process is self-negating, however, since the revival of the direct repulsive interaction means that trapped fluctuons are again repelled into distant space. The repulsive effect even undergoes an initial increase, due to the decrease in density of those regions and to the consequent decrease in the flux of gravitons emanating from them. The relationship between the distribution of manifest mass and vacuum density curvature moves back in the direction of self-consistency, therefore back to the regime where gravitational attraction is restored.

This is a collapse cycle. The collapse never disappears into an ultimate singularity, in complete violation of energy conservation, as might be predicted on the basis of purely classical general relativity. The process inevitably reverses itself, due to the error generation and correction processes that lead in the first phase to the breakdown of the graviton initiation process within the collapsing mass and to the concomitant increase in gravitational attraction, and in the second phase to the dominance of gravitational repulsion and consequent restoration of gravitational attraction. The regime of dominant attraction can be referred to as normal and that of dominant repulsion as anti-normal. The two regimes are in continual interplay. An isolated black hole might actually fly apart. But no hole is an island unto itself. It is embedded in a universe with a most complicated distribution of particles, including many other black holes. The distant regions of the vacuum that respond to and affect the hole also respond to and affect other normal and collapsing masses. It is quite possible for a hole to meander on the edge of collapse due to being more or less regularly dominated by the normal regime of attraction and the anti-normal regime of repulsion. Ultimate gravitational collapse, the so-called great crunch, is precluded. A big bang origin of the universe cannot be absolutely excluded, but would seem more unlikely than a chaotic sequence of different distributions of matter. The fluctuon model suggests that the cosmic background radiation is due to the switching back and forth between the collapse and reversal of collapse regimes rather than to a primordial singularity.

10 Collapse in the Low Mass Domain

Let us compare the collapse cycle as evinced in the extreme high mass, high velocity domain to the processes that accompany acceleration in the low mass, low velocity domain. Recall that when a particle accelerates it enters a higher density region of the vacuum that is inconsistent with the minimum fluctuation energy required for graviton initiation, due to the fact that the initial vacuum length does not adjust as fast as the light velocity. Thus the initiating masson-antimasson pairs have higher fluctuation energies, hence decreased coupling strengths (in accordance with the quadratic dependence of force on initial fluctuation time). The direct repulsive interaction is therefore diminished. This corresponds to the more extreme case of cessation of direct repulsion in the high mass, high velocity domain of black hole formation. The resulting increase in net gravitational attraction relative to the accelerating particle corresponds to the initial increase in gravitational attraction at the inception of black hole collapse. As in the latter process, the decrease in direct repulsion elevates the vacuum density curvature in more distant regions, though to a vastly more modest extent. Gravitational attraction decreases. The vacuum curvature in the immediate neighborhood of the absorber begins to catch its equilibrium value, or rather, would catch its equilibrium value if acceleration ceased. But of course acceleration can only cease from the point of view of a specifically chosen frame, and then only for limited periods of time given the impossibility of isolating an absorber from the multiple fluctuonic bombardments emanating from other absorbers in the cosmos.

The constituent processes of the collapse cycle in the black hole region thus have correlates in all regions in which acceleration, hence gravity, is operative. The necessity for this follows from the principle of relativity. Suppose that in a given frame of reference we see an absorber as being in the low mass, low velocity region and that we then transform to a frame in which the absorber is seen to undergo such an enormous acceleration that it approaches closely to the velocity of light. The mass-energy will become very large; the single absorber initially seen will appear as multiple absorbers due to pair production. The multiple absorbers exert gravitational forces. If the collection becomes dense enough photon and graviton initiation will cease altogether; gravitational collapse will ensue. But according to the principle of relativity the two observers, one in the inertial frame and the other in the rapidly accelerating frame, should agree on the underlying physical description of the processes occurring.

The same applies to the random aspect of the collapse cycle. When the gravitational coupling of the accelerating absorber changes during the collapse cycle the forces acting on it undergo an essentially unpredictable change, due to the fact that the details are contingent on the whole meshwork of graviton exchanges in the universe. However, not all changes are allowable. There is a fundamental restriction: the new complexion of the manifest universe must always chase consistency with the complexion of the unmanifest vacuum sea, and conversely. The consistency restoring forces that spring into action in response to the consistency breaking effect of acceleration are in the vast majority of cases most likely to paste the original and mutated complexion back together in a way that mimics continuity. This is not always the case: a black hole might really fly apart; a measurement might really produce a discontinuity.

11 Unity of Gravitational and Superpositional Collapse

Our picture of the collapse process should be put in a quantum theoretic context. We are not dealing with specific trajectories of particles, but rather with superpositions. The absorber taken together with its surround is in a superposition of possible states, or complexions, that interfere with each other. The superposition, expressible in terms of a wave function, is stationary if all the states are of the same energy. When the states have different energies the interference leads to a nonstationary situation, therefore to acceleration. This is of course the realistic situation, since stationarity is an idealization. The occurrence of acceleration, according to our analysis of the collapse cycle, introduces an inconsistency between the wave function of the manifest universe and the wave function of the vacuum sea, or alternatively, introduces an internal inconsistency into the global wave function that encompasses both the manifest world and the unmanifest sea. The wave function (or superposition) undergoes a random change, essentially a mutation. Each of the constituent states is associated with a phase factor that determines its energy. The essentially random (or unpredictable) change in the forces that come into play due to acceleration introduce random (decorrelating) changes into these phase factor energies. This is the mechanism of superpositional mutation. The inconsistency induces restorative graviton exchanges. These act to recorrelate the phase factors into a pattern that moves in the direction of consistency. The chasing of consistency may bring the superposition back so close to its original form that the transformation appears to be continuous (or, more precisely, unitary). This is the most common situation in the low mass domain. But it is also possible for the system to jump to a distinctly different self-consistent state. The transformation is then nonunitary, meaning that it is nonlinear in the sense of admitting stretching or bending.

The nonunitary changes are the signature of quantum measurement (cf. [19]). This is the place where nonlinearity enters into standard quantum mechanics. Sometimes it is said that the wave function is reduced; the decorrelation of the phases leads to a probability distribution. From our point of view the term superpositonal squeezing is more appropriate. The superposition undergoes a change to a new superposition, but in a purposeful measurement an apparatus is used to squeeze one aspect of the system (say absorber position) into a classical appearing form at the expense of the conjugate aspect (momentum in this case) becoming indeterminate in accordance with the requirements of the uncertainty principle. In reality, according to our picture, all changes of state are nonunitary, but the consistency restoring forces hide this fact. It is because of this that we make no mistake if we think of atoms as actually emitting and absorbing photons, which means undergoing acceleration, and at the same time treat those atoms in principle (though not so easily in practice) as described by a single time dependent wave function that accurately describes the situation until we, the investigator, choose to make a measurement.

To make matters more precise let us rephrase the above in terms of standard quantum mechanical equations. The wave function may be written as

$$\Psi(x,t) = \sum_n c_n \Psi_n(x) e^{-iE_n t/\hbar} \tag{8}$$

where the $\Psi_n(x)$ are a complete, orthonormal set of basis functions (in a position representation), the c_n are weighting coefficients, and the $e^{-iE_n t/\hbar}$ are phase factors. According to the standard square law interpretation the probability that the absorber will be found between x and $x + dx$ at time t may be taken as

$$P(x,t)dx = \Psi^*(x,t)\Psi(x,t)dx \tag{9}$$

where $\Psi^*(x,t)$ denotes the complex conjugate of the wave function. This can of course be generalized to a system of absorbers, but with the provision (to be ignored here) that the position representation is not suitable for propagating fluctuon chains since these necessarily travel at light velocity. A momentum representation could be used in this case.

To keep matters simple let us suppose that it is sufficient to treat the absorber as being in two possible states, $\Psi_1(x)$ and $\Psi_2(x)$. The time dependence of the probability density is then given by

$$\begin{aligned} P(x,t) = \Psi^*(x,t)\Psi(x,t) &= c_1^* c_1 \Psi_1^*(x)\Psi_1(x) + c_2^* c_2 \Psi_2^*(x)\Psi_2(x) \\ &+ c_1^* c_2 \Psi_1^*(x)\Psi_2(x) exp\left[i(E_1 - E_2)t/\hbar\right] \\ &+ c_2^* c_1 \Psi_2^*(x)\Psi_1(x) exp\left[-i(E_1 - E_2)t/\hbar\right] \end{aligned} \tag{10}$$

If $E_1 = E_2$ then the system is stationary; the interference terms are constant since the constituent states vibrate with the same frequency. If the energies are not equal the vibrations occur with different frequencies. The probability changes with time, corresponding to the fact that when the energy of a system changes acceleration must occur.

Now let us consider what happens when a measurement occurs. The usual and quite reasonable interpretation [20] is that during the time of interaction with the measuring apparatus, which means an interaction mediated by a propagating fluctuation, the uncertainty of the energy must be on the order of $\Delta E \approx \frac{\hbar}{\Delta t}$. Thus the phase factors become essentially indefinite. The stationary terms are not changed, and thus the measurement apparatus may be so constructed to detect particular positions (for example, which of two slits the absorber passes through). The interference terms are still present; there is still a superposition. But in an ensemble of experiments interference becomes increasingly likely to cancel out. This is the so-called collapse or reduction of the wave function that yields the probability density $P(x,t)$. But as indicated it does not mean that superpositions disappear. The balloon of possibilities is just squeezed in different ways, so that different choices among possible conjugate variables (i.e., variables whose products have dimensions of angular momentum) can be made more or less precise. The superpositions only appear to disappear when averaged over an ensemble of measurement interactions.

The new feature added by the fluctuon model is that the disturbance of the phase factors is endemic to acceleration itself. The inconsistency between the distribution of manifest absorbers and the distribution of unmanifest vacuum sea particles engenders graviton interactions that alter the phase factors. The superposition mutates to a new superposition. Electrons actually fall to lower levels in atoms, emitting photons, and conversely. Nevertheless the time dependent quantum equations of motion (e.g., Schrödinger equation, Dirac equation) will commonly describe a continuous time evolution so far as the wave function is concerned, due to the consistency restoring graviton chains that are induced by the deviation from consistency.

The continuous, unitary appearance of the time evolution will with high probability obtain if there are many more ways of returning to a superposition near to that of the original one. But situations can occur, such as those set up by a designed measurement apparatus, where it is easier to chase consistency by jumping to a distinctly different superposition.

12 Mirror Image Thermodynamics

The collapse cycle has thermodynamic correlates. Three main features are important: stability of vacuum sea asymmetries, the switching between the normal regime of net gravitational attraction and the anti-normal regime of net repulsion, and the implications of self-consistency dynamics for the emergence of complexity.

Consider first the stability of vacuum sea curvature. Manifest distributions of particles tend to become more symmetrical with time. This is the great law of entropy increase. Gradients of all sorts disappear, due to the fact that the number of complexions of a macroscopic system that are compatible with macroscopic symmetry are vastly greater than those compatible with a low symmetry situation.

Vacuum sea curvature is nevertheless stable, apart from its response to acceleration. The Pauli exclusion principle ensures this. In order for a vacuum particle to migrate through the vacuum sea it must transiently come into existence as a particle-antiparticle pair (since it is otherwise subject to no interactions). The exclusion principle requires that a pathway of migration would occur at the same time. The rule is this: the number of transiently excited particles available for migrating from region I to region II is proportional to the density of region I, but the fraction of these that could actually succeed in entering region II is proportional to the density of region II. A fortiori, density inhomogeneity of the vacuum, most importantly the curvature of the masson sea, is stable to fluctuation [14].

This leads to the second point, the effect of acceleration on curvature. The significant feature is most clearly seen in the high mass, high velocity region of black hole formation. Gravity switches between a net attractive and a net repulsive interaction. This means that there is a potential change. The high potential energy situation (that of bodies falling towards one another) becomes the low potential energy situation. Bodies running away from each other become instead the high potential energy direction. On the surface this would appear to constitute an entropy cycle, and in fact it does for the manifest universe. As particles fall gravitationally into a condensed state entropy increases due to the randomizing effects of collisions. Free energy decreases. When the repulsion takes over a high free energy situation is restored. A statistically unlikely initial condition spontaneously arises. The entropy is decreased. The reinstatement of the normal regime of gravitational attraction can turn this into work.

So we indeed have a great entropy cycle. The universe neither has to suffer a heat death, as in the old thermodynamics, or a disappearance of energy, as in ultimate gravitational collapse. But in fact entropy does not increase and then spontaneously decrease and then increase again, at least if the whole universe, both manifest and unmanifest, is taken into account. The trick is this: in the normal regime of attraction the entropy of the manifest universe increases, but the vacuum curvature in distant space increases, thereby decreasing the entropy of the unmanifest vacuum sea. The increase in curvature after all is equivalent to increase in asymmetry. But it also manifests itself in terms of temperature. As the density of the masson sea becomes comparatively more elevated in distant space the energy fluctuations required for pair production increase, so that in effect a temperature gradient balances the increase in entropy that accompanies the coalescence of manifest absorbers [21].

The same cyclic process, embedded in an overall conservation of entropy, occurs at all mass-energy scales. The gravitational collapse cycle is equivalent to the superpositional collapse cycle. But in the low energy region the cyclic flow of entropy between manifest and unmanifest particle distributions is much more modest. Furthermore, our life is in a regime that is dominantly normal so far as gravitational attraction is concerned. The flow of entropy is consequently in the direction of increase; the increase always drives an undertow, therefore an increase in local organization at the expense of a decrease in global organization. The importance of the entropy cycle, in the large, is that it cyclically recreates the atypical initial conditions necessary for this forward flow of entropy. In the small, as we shall soon see, it contributes to the emergence and stability of complex form in a more specific way.

The cyclic flow of entropy can be understood in terms of the weighting coefficients, c_n, that determine the structure of superpositions. The universe is only in one state, not in an ensemble of states. We think of it as being in an ensemble, say described by a density matrix, when it is useful to specify how many states (or complexions) are compatible with a given macro organization. The higher entropy, more symmetrical macro organizations are compatible with more complexions, hence with the set of collections in which the system is most likely to be found. The collapse cycle, however, means that the cn must change in a cyclic manner. During the stage of phase decorrelation, when the run away from self-consistency occurs, the weighting coefficients become more evenly distributed so far as the distribution of manifest absorbers is concerned. The positive energy universe thus assumes a complexion that belongs to a larger equivalence class, one associated with a state of greater macroscopic symmetry. The opposite happens for the distribution of unmanifest particles. During the phase recorrelation stage, when the system chases self-consistency, the coefficients for the manifest universe become more uneven in their proportions, hence enter into a smaller equivalence class. The manifest entropy decreases, but at the expense of an opposite change in the coefficients for the anti-universe of negative energy particles.

This cyclic process brings us to the door of the third point, the emergence of unlikely organizations, those that are compatible with more asymmetrical macrostructures. Our ordinary experience with the manifest world is one in which such unlikely structures tend to break down, due to the fact that there are many more pathways of decomposition than formation. So we ordinarily think that such structures cannot develop or even persist unless driven to do so by the continual degradation of free energy.

The requirement for consistency between the manifest distribution of particles and the distribution of vacuum sea particles adds another side to this picture. Consider a collection of absorbers undergoing acceleration relative to one another. The curvature of the vacuum sea immediately proximate to these absorbers will undergo a slight change. The absorber motions will be slightly disturbed, the signature of superpositional mutation. Restorative forces come into play that recorrelate phases in a way that brings the manifest and unmanifest distributions into harmony as nearly as possible. From the probabilistic point of view the most accessible organization that approaches self-consistency is often an organization similar to the original one, hence the appearance of a unitary time evolution. As the organization of a manifest collection of particles becomes more unlikely one would ordinarily think that the tendency for decomposition will be greater; but it has to be considered that returning to this organization, or to an organization near to it, may be much more probable than undergoing a much bigger transition to more likely self-consistent organizations. The latter, even if they belong to a much more plentiful class, are less accessible. The unlikely structure is accordingly more likely to persist than the likely structure. Fewer consistent relations are compatible with it, but this favors persistence since the further a system is from consistency the more it induces restorative forces.

There will of course be a balance. The tendency to decomposition is still operative. But another tendency, to preservation and even to transitions to more unusual states enters the field. Free energy decrease is still a driving force, but the very specific combinations of randomness and order that characterize the historical development of biological life finds a support and impetus in the requirement for self-consistency that transcends traditional thermodynamic considerations.

Recall the image we began with in the introduction, that of two wobbly twins helping each other to navigate a tortuous mountain path. One of the pair was a collection of manifest particles; the other its image in the vacuum sea. The manifest member of the pair, taken in isolation, would always tends to fall downhill in terms of increasing randomness. The same would be true for his negative counterpart, if this could be taken in isolation. But neither can be separated from the other. Their every wobble induces gravitational rays that preserve and even enhance their artful balance, due to the fact that they are fated by these induced rays to chase self-consistency and to chase their own dynamic form with tighter embrace as it becomes more removed from more commonplace self-consistent forms.

13 Observer Interface

Here we come to the part-whole relationship. The whole is the universe, in ubiquitous acceleration and its concomitant: continual variation through superpositional mutation and reactive selection engendered by the relational dynamics of self-consistency. It is an exploratory, evolutionary universe. The exploratory variation introduces a freedom of sorts. The restoration of self-consistency constitutes a will to persist and develop. The dynamic of development, as unpopular as the phraseology may be become in these times, has a bit the sense of the Hegelian dialectic: restless deviation from the present state, engendered inconsistency, restorative processes that retreat in the direction of the previously existing consistency in some cases and that lurch to a *de novo* one in others. The evolution is temporally kaleidoscopic, however; initial consistency never was and final consistency never will be caught.

The evolution process generates specific structures. The structures of biological life, with their capability of accumulating historical information in macromolecular sequences, are the most dramatic. The specific structures are the parts generated by the inconsistency dynamics of the whole.

What differentiates these parts; gives them their privacy, so to speak? The key is this: the practical effect of each part on the surrounding vacuum sea is extraordinarily short range, limited so far as notable significance is concerned to a few fluctuation lengths in the masson sea. The exact falloff depends on the detailed geometrical configuration of the part. The interaction between two low mass absorbers is indicative. From section 8 we obtain for the relation between the vacuum length adjacent to the absorbers and the light velocity at that locus velocity

$$r_g(m,1) \approx \frac{\hbar}{2c(m,1)m_m} \tag{11}$$

where m denotes the absorber masses and we here ignore the influences of peripheral masses (therefore omitting the reference to M). From section 6 we can write in the low mass domain

$$Gm^2 \approx \frac{A_g r_g(m,1)^4}{c_0^2\hbar^2} \tag{12}$$

since in this region it is acceptable to associate absorber mass with the square of initial fluctuation length. The relation between the initial light velocity and absorber mass is thus roughly given by the proportionality

$$c(m, 1) \propto m^{-1/2} \tag{13}$$

The slowing effect of mass on initial light velocity increases as m increases, but the decrease is comparatively very slow for small m. This means that the influence exerted on distant elevation of vacuum density will be negligible. In the low mass domain the distinguishable effect on surrounding curvature is restricted to an ultrathin vacuum layer of at most a few fluctuation lengths in the masson sea.

This limited range means that the self-consistency dynamics of low mass objects and their vacuum indents is highly localized. The dialectic of the universe is recapitulated in relatively isolated local units, each of which can be thought of as a pattern in the manifest universe and an anti-pattern in the vacuum sea joined together in a bound state. The joint system thereby gains an individual identity. Hierarchies of individual identities can form, corresponding to hierarchies of self-consistency bindings.

The vast meshwork of graviton exchanges is a heat bath of sorts, a powerful source of randomness that abets the exploratory aspect of superpositional mutation. The consistency-restoring graviton chains that spring into activity as a consequence of these mutations also arrive from throughout the universe; but the specific effects are due to interactions between the manifest object and the ultrathin layer that it distinguishably affects in its immediate proximate vacuum sea.

Self-consistency dynamics is biased: towards existence rather than nonexistence. The collapse cycles that truly collapse rapidly sink into indistinguishability. Their import is as exploratory forays, but they are not what we see. Biological organisms, as history accumulating systems, develop self-consistency dynamics that more and more abet self-preservation and that more and more assume a teleonomic aspect. Specific actions, such as the development and fabrication of measurement apparati that squeeze superpositions in useful ways, come to the fore. The interface between part and whole becomes sharper. The observer comes more clearly into relief.

The twinning of manifest system and vacuum image introduces a deeper level of historical relationship [22]. Such purposive systems could not simply be fabricated by bringing a collection of manifest particles into a pattern that mimics that of a biological organism. The pathway of development must be such that a complementary vacuum image is created, otherwise the collection of particles will decompose into an essentially random appearing self-consistency mode rather than be bound into an unlikely one.

Suppose that two systems share a common history, either as ancestor and offspring or as long abiding consorts. Conceivably they could share a vacuum image and to some slight degree enjoy a merged individuality. As the systems go their separate way in space this merging should be lost, due to the very short range influence of manifest objects on surrounding sea. But perhaps it should not be excluded that Bell type entanglements of quantum superpositions could occur and that even at a distance a certain degree of holism would under some circumstances be possible [23].

14 The Rössler Methodology

Now I would like to return to the discussion with Otto Rössler, circa 1972. At the time I was at the Institute for Information Processing in the Physics Faculty at Tübingen. Professor Rössler called at my office and made some remarks on functional methodology that I have often quoted to my students over the years, though never recapturing the elegance of his formulation.

The essence is this. Try to state the function of a system (even if we hardly ever know what this is). Look for the class of systems that satisfy the functional requirements and that satisfy correspondence with the known phenomenology. The essential features of this class can be viewed as predictions or at least as features that should be exhibited by the system under investigation. If they are not then the model class is wrong; if they are in fact exhibited then refine the functional description and refine the model class until contradiction is reached. The process generates a vast web of model possibilities, each protruding chains of reasoning that stretch like tentacles in all directions in search of contradiction, and that on finding contradiction retract and seek again.

What function is more basic and less arguable then interface? We are observers; our science comes from what is given in our experience; our science cannot be complete unless it includes itself. Here Rössler has identified the function that is sine qua non.

Interface is one of the requirements I have had in mind in the foregoing development. The attempt is to embed observation into the dynamics of the world observed, not treat it as an alien add-on to that world.

There are of course other motivating requirements: correspondence with the established physical phenomenology; compatibility of quantum mechanics with general relativity's intrinsically nonlinear treatment of acceleration; evolvability of complex organization in a way that does not depend on the good luck of initial conditions; a physics that fits with rather than fights the phenomenology of biological life.

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Scale Relativity, Fractal Space-Time and Morphogenesis of Structures

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Abstract

The theory of scale relativity extends Einstein's principle of relativity to scale transformations of resolutions. It is based on the giving up of the axiom of differentiability of the space-time continuum. Three consequences arise from this withdrawal. (i) The geometry of space-time becomes fractal, i.e., explicitly resolution-dependent: this allows one to describe a non-differentiable physics in terms of differential equations acting in the scale space. The requirement that these equations satisfy the principle of scale relativity leads to introduce scale laws having a Galilean form (constant fractal dimension), then a log-Lorentzian form. In this framework, the Planck length-time scale becomes a minimal impassable scale, invariant under dilations, and the cosmic length-scale (related to the cosmological constant) a maximal one. Recent measurements of the cosmological constant have confirmed the theoretically predicted value.

Then we attempt to construct a generalized scale relativity which includes non-linear scale transformations and scale-motion coupling. In this last framework, one can reinterpret gauge invariance as scale invariance on the internal resolutions. This approach has allowed us to make theoretical predictions concerning coupling constants and elementary particle masses (electron, Higgs boson, vacuum energy of the Higgs field), which we update in the present contribution. These predictions are successfully checked using recently improved experimental values. (ii) The geodesics of a non-differentiable space-time are fractal and in infinite number: this leads one to use a fluid-like description and implies adding new terms in the differential equations of mean motion. (iii) Time reversibility is broken at the infinitesimal level: this can be described in terms of a two-valuedness of the velocity vector, for which we use a complex representation.

These three effects can be combined to construct a covariant time derivative operator, which transforms the fundamental equations of classical dynamics into a generalized Schrödinger equation. This provides us with a theory of morphogenesis and self-organization, since the solutions of this equation yield probability densities, which are interpreted as a tendency for the system to make structures. Several new theoretical predictions can be made by applying this approach to the equations of motion of test-particles in various gravitational potentials of astrophysical relevance. These predictions are supported by a comparison with observational data on a wide range of scales, from planetary systems to cosmological structures.

1 Introduction

The theory of scale relativity [13] is an attempt to study the consequences of giving up the hypothesis of space-time differentiability. One can show [13, 14] that a continuous but non-differentiable space-time is necessarily *fractal*. Here the word fractal [11] is taken in a general meaning, as defining a set, object or space that shows structures at all scales, or on a wide range of scales. More precisely, one can demonstrate that a continuous but nondifferentiable function is explicitly resolution-dependent, and that its length $\mathcal{L}$ tends to infinity when the resolution interval tends to zero, i.e. $\mathcal{L} = \mathcal{L}(\varepsilon)_{\varepsilon \to 0} \to \infty$. This theorem and other properties of non-differentiable curves have been recently analysed in detail by Ben Adda and Cresson [4]. It naturally leads to the proposal that the concept of *fractal space-time* citeNoSc84 [24] [13] [6] is the geometric tool adapted to the research of such a new description based on non-differentiability. In such a generalized framework including all continuous functions, the usual differentiable functions remain included, but as very particular and rare cases.

Since a nondifferentiable, fractal space-time is explicitly resolution-dependent, the same is a priori true of all physical quantities that one can define in its framework. We thus need to complete the standard laws of physics (which are essentially laws of motion in classical physics) by laws of scale, intended to describe the new resolution dependence. We have suggested [12] that the principle of relativity can be extended to constrain also these new scale laws.

Namely, we generalize Einstein's formulation of the principle of relativity, by requiring *that the laws of nature be valid in any reference system, whatever its state.* Up to now, this principle has been applied to changes of state of the coordinate system that concerned the origin, the axes orientation, and the motion (measured in terms of velocity and acceleration)

In scale relativity, we assume that the space-time resolutions are not only a characteristic of the measurement apparatus, but acquire a universal status. They are considered as essential variables, inherent to the physical description. We define them as characterizing the "state of scale" of the reference system, in the same way as the velocity characterizes its state of motion. The principle of scale relativity consists of applying the principle of relativity to such a scale-state. Then we set a principle of *scale-covariance*, requiring that the equations of physics keep their form under resolution transformations.

In the present paper, we shall review various levels of development of the theory, then consider some of its consequences in the domains of elementary particles, cosmology and gravitational structure formation.

2 Galilean scale relativity

2.1 Standard fractal laws

Scaling laws have already been studied at length in several domains of science. A power-law scale dependence is frequently encountered in a lot of natural systems, it is described geometrically in terms of fractals, and algebrically in terms of the renormalization group. As we shall see now, such simple scale-invariant laws can be identified with a "Galilean" version of scale-relativistic laws.

Indeed, let us consider a non-differentiable coordinate $\mathcal{L}$. Our basic theorem that links non-differentiability to fractality implies that $\mathcal{L}$ is an explicit function $\mathcal{L}(\varepsilon)$ of the resolution interval ε. As a first step, one can assume that $\mathcal{L}(\varepsilon)$ satisfies the simplest possible scale differential equation one may write, namely, the first order equation:

$$\frac{d \ln \mathcal{L}}{d \ln(\lambda/\varepsilon)} = \delta, \tag{1}$$

where δ is a constant. The solution is a fractal, power-law dependence:

$$\mathcal{L} = \mathcal{L}_0 (\lambda/\varepsilon)^{\delta}, \tag{2}$$

where δ is the scale dimension, i.e., $\delta = D - D_T$, the fractal dimension minus the topological dimension. The Galilean structure of the group of scale transformation that corresponds to this law can be verified in a straightforward manner from the fact that it transforms in a scale transformation $\varepsilon \to \varepsilon'$ as

$$\ln \frac{\mathcal{L}(\varepsilon')}{\mathcal{L}_0} = \ln \frac{\mathcal{L}(\varepsilon)}{\mathcal{L}_0} + \delta(\varepsilon) \ln \frac{\varepsilon}{\varepsilon'} \quad ; \quad \delta(\varepsilon') = \delta(\varepsilon). \tag{3}$$

This transformation has exactly the structure of the Galileo group, as confirmed by the law of composition of dilations $\varepsilon \to \varepsilon' \to \varepsilon''$, which writes $\ln \rho'' = \ln \rho + \ln \rho'$, with $\rho = \varepsilon'/\varepsilon$, $\rho' = \varepsilon''/\varepsilon'$ and $\rho'' = \varepsilon''/\varepsilon$.

2.2 Breaking of the scale symmetry

More generally, one can write a first order equation where the scale variation of $\mathcal{L}$ depends on $\mathcal{L}$ only, $d\mathcal{L}/d \ln \varepsilon = \beta(\mathcal{L})$. The function $\beta(\mathcal{L})$ is a priori unknown but, always taking the simplest case, we may consider a perturbative approach and take its Taylor expansion. We obtain the equation:

$$\frac{d\mathcal{L}}{d \ln \varepsilon} = a + b\mathcal{L} + \ldots \tag{4}$$

This equation is solved in terms of a standard power law of power $\delta = -b$, broken at some relative scale λ (which is a constant of integration):

$$\mathcal{L} = \mathcal{L}_0 \, [1 + (\frac{\lambda}{\varepsilon})^{\delta}]. \tag{5}$$

Depending on the sign of δ, this solution represents either a small-scale fractal behavior (in which the scale variable is a resolution), broken at larger scales, or a large-scale fractal behavior (in which the scale variable ε would now represent a changing window for a fixed resolution λ), broken at smaller scales.

2.3 Euler-Lagrange scale equations

In the previous approach, we have considered as primary variables the position $\mathcal{L}$ and the resolution ε. However, we are naturally led, in the scale-relativistic approach, to reverse the definition and the meaning of variables. The scale dimension δ can be generalized in terms of an essential, fundamental *variable*, that would remain constant only in very particular situations (namely, in the case of scale invariance, that corresponds to "scale-freedom"). It plays for scale laws the same role as played by time in motion laws. We have proposed to call "djinn" this varying scale dimension. The new approach amounts to work in a "space-time-djinn" rather than only in space-time, thus including motion and scale behaviour in the same 5-dimensional description. The resolution can now be defined as a derived quantity in terms of the fractal coordinate and of the djinn:

$$\bar{V} = \ln(\lambda/\varepsilon) = \frac{d \ln \mathcal{L}}{d\delta}. \tag{6}$$

Our identification of standard fractal behavior as Galilean scale laws can now be fully proven. We assume that, as in the case of motion laws, scale laws can be constructed from a Lagrangian approach. A scale Lagrange function $\bar{L}(\ln \mathcal{L}, \bar{V}, \delta)$ is introduced, from which a scale-action is constructed:

$$\bar{S} = \int_{\delta_1}^{\delta_2} \bar{L}(\ln \mathcal{L}, \bar{V}, \delta) d\delta. \tag{7}$$

The action principle, applied on this action, yields a scale-Euler-Lagrange equation that writes:

$$\frac{d}{d\delta} \frac{\partial \bar{L}}{\partial \bar{V}} = \frac{\partial \bar{L}}{\partial \ln \mathcal{L}}. \tag{8}$$

The simplest possible form for the Lagrange function is the equivalent for scales of what inertia is for motion, i.e., $\bar{L} \propto \bar{V}^2$ and $\partial \bar{L}/\partial \ln \mathcal{L} = 0$ (no scale "force"). The Lagrange equation writes in this case:

$$\frac{d\bar{V}}{d\delta} = 0 \Rightarrow \bar{V} = cst. \tag{9}$$

The constancy of $\bar{V} = \ln(\lambda/\varepsilon)$ means here that it is independent of the scale-time δ. Then Eq. (6) can be integrated in terms of the usual power law behavior, $\mathcal{L} = \mathcal{L}_0(\lambda/\varepsilon)^\delta$. This reversed viewpoint has several advantages which allow a full implementation of the principle of scale relativity:

(i) The scale dimension takes its actual status of "scale-time", and the logarithm of resolution $\bar{V}$ its status of "scale-velocity", $\bar{V} = d \ln \mathcal{L}/d\delta$.

(ii) This leaves open the possibility of generalizing our formalism to the case of four independent space-time resolutions. Indeed, from $\mathcal{L}^\mu, \mu = 0, 1, 2, 3$ and δ one can now build a 4-component resolution vector, $\bar{V}^\mu = \ln(\lambda^\mu/\varepsilon^\mu) = d \ln \mathcal{L}^\mu/d\delta$.

(iii) As we shall see in what follows, scale laws more general than the simplest self-similar ones can be derived from more generalized scale-Lagrangians.

3 Special and generalized scale-relativity

3.1 Special scale relativity

It is well known that the Galileo group of motion is only a degeneration of the more general Lorentz group. The same is true for scale laws. Indeed, if one looks for the general linear scale laws that come under the principle of scale relativity, one finds that they have the structure of the Lorentz group [12]. Therefore, in special scale relativity, we have suggested to substitute to the Galilean law of composition of dilations $\ln(\varepsilon'/\lambda) = \ln \rho + \ln(\varepsilon/\lambda)$ the more general log-Lorentzian law:

$$\ln \frac{\varepsilon'}{\lambda} = \frac{\ln \rho + \ln(\varepsilon/\lambda)}{1 + \ln \rho \ln(\varepsilon/\lambda)/\ln^2(\lambda_P/\lambda)}, \tag{10}$$

while the scale dimension becomes a variable according to the law:

$$\delta(\varepsilon) = \frac{1}{\sqrt{1 - \ln^2(\varepsilon/\lambda)/\ln^2(\lambda_P/\lambda)}}, \tag{11}$$

where λ is the fractal / nonfractal transition scale. In the microphysical domain, the invariant length-scale is naturally identified with the Planck scale, $\lambda_P = (\hbar G/c^3)^{1/2}$, that now becomes impassable and plays the physical role that was previously devoted to the zero point. The same is true in the cosmological domain, with an inversion of the scale laws: there appears a maximal, impassable scale of resolution that plays the physical role of the infinite, that we have identified with the length-scale $\mathbb{L} = \Lambda^{-1/2}$ related to the cosmological constant Λ. The consequences of this new interpretation of the cosmological constant have been considered in [13] [14].

3.2 From scale dynamics to general scale relativity

The whole of our previous discussion indicates to us that the scale invariant behavior corresponds to freedom in the framework of a scale physics. However, in the same way as there exists forces in nature that imply departure from inertial, rectilinear uniform motion, we expect most natural fractal systems to also present distorsions in their scale behavior respectively to pure scale invariance. Such distorsions may be, as a first step, attributed to the effect of a scale "dynamics", i.e. to "scale-forces". In this case the Lagrange scale-equation takes the form of Newton's equation of dynamics:

$$\bar{F} = \mu \frac{d^2 \ln \mathcal{L}}{d\delta^2}, \tag{12}$$

where μ is a "scale-mass", which measures the way the system resists to the scale-force.

3.2.1 Constant scale-force

Let us first consider the case of a constant scale-force. We set $\bar{G} = \bar{F}/\mu =$ constant. Equation (12) is easily integrated as:

$$\delta = \delta_0 + \frac{1}{\bar{G}} \ln\left(\frac{\lambda}{\varepsilon}\right) \quad ; \quad \ln\frac{\mathcal{L}}{\mathcal{L}_0} = \frac{1}{2\bar{G}} \ln^2\left(\frac{\lambda}{\varepsilon}\right). \tag{13}$$

The scale dimension δ becomes a linear function of resolution, and the $(\ln \mathcal{L}, \ln \varepsilon)$ relation is now parabolic rather than linear as in the standard power-law case. There are several physical situations that could come under such a "scale-dynamical" description, where a clear curvature appears in the $(\ln \mathcal{L}, \ln \varepsilon)$plane (e.g., turbulence, sand piles,...). In these cases it might be interesting to identify and study the scale-force responsible for the scale distorsion.

3.2.2 Harmonic oscillator

Another interesting case of scale-potential is that of a harmonic oscillator $\phi = -(1/2)(\ln \mathcal{L}/\alpha)^2$. It is solved as

$$\ln\frac{\mathcal{L}}{\mathcal{L}_0} = \alpha \sqrt{\ln^2\left(\frac{\lambda}{\varepsilon}\right) - \frac{1}{\alpha^2}}. \tag{14}$$

For $\varepsilon \ll \lambda$ it gives the standard Galilean case $\mathcal{L} = \mathcal{L}_0(\lambda/\varepsilon)^\alpha$, but its large-scale behavior is particularly interesting, since it does not permit the existence of resolutions larger than a scale $\lambda_{max} = \lambda\, e^{-1/\alpha}$. Such a behavior could provide a model of confinement in QCD.

More generally, we shall be led to look for the general non-linear scale laws that satisfy the principle of scale relativity. Such a generalized framework implies working in a five-dimensional fractal space-time. The development of such a "general scale-relativity" lies outside the scope of the present paper and will be considered in forthcoming works.

3.3 Scale-motion coupling and mass-charge relations

The theory of scale relativity also allows to get new insights about the physical meaning of gauge invariance [14]. In the scale laws recalled hereabove, only scale transformations at a given point were considered. But we may also wonder about what happens to the structures in scale-space of a scale-dependent object such as an electron or another charged particle, when it is displaced. Consider anyone of these structures, lying at some (relative) resolution ε (such that $\varepsilon < \lambda$, where λ is the Compton length of the particle) for a given position of the particle. In a displacement, the relativity of scales implies that the resolution at which this given structure appears in the new position will a priori be different from the initial one. In other words, $\varepsilon = \varepsilon(x,t)$ is now a function of the space-time coordinates, and we expect the occurrence of *dilations of resolutions induced by translations*, so that we are led to introduce a covariant derivative:

$$e\,\frac{D\varepsilon}{\varepsilon} = e\,\frac{d\varepsilon}{\varepsilon} - A_\mu dx^\mu, \tag{15}$$

where a four-vector A_μ must be introduced since dx^μ is itself a four-vector and $d\ln\varepsilon$ a scalar (in the case of a global dilation).

However, if one wants such a "field" A_μ to be physical, it should be defined whatever the initial scale from which we started. Starting from another scale $\varepsilon' = \rho\varepsilon$, we get the same expression as in Eq.15, but with A_μ replaced by A'_μ. Therefore, we obtain the relation:

$$A'_\mu = A_\mu + e\,\partial_\mu \ln\rho, \tag{16}$$

which depends on the relative "state of scale", $\bar{V} = \ln\rho = \ln(\varepsilon/\varepsilon')$, that is now a function of the coordinates.

One may therefore identify A_μ with the electromagnetic potential, and Eq.(16) with the property of gauge invariance. Now we know that applying a gauge transformation to the electromagnetic field implies to change also the wave function of the electron, that becomes:

$$\psi' = \psi\, e^{i4\pi\alpha\ln\rho} \tag{17}$$

where α is the square of charge in units of $\hbar c$, i.e., a coupling constant. While in Galilean scale relativity, the scale ratio ρ is unlimited, in the more general framework of special scale relativity it is limited by the Planck-scale/Compton-scale ratio. This limitation implies the quantization of charge, following the general mass-charge relation [14]:

$$\alpha \ln\left(\frac{m_P}{m}\right) = k/2, \tag{18}$$

where k is integer. Such a relation between the electron mass and the electroweak coupling $8\alpha/3$ (where $\alpha^{-1} = 137.036$) is implemented with a relative precision of 2×10^{-3}, becoming 10^{-4} when accounting for threshold effects [14].

This approach can be generalized, since we can define four different and independent dilations along the four space-time resolutions instead of only one global dilation. The above U(1) field is then expected to be embedded into a larger field, in agreement with the electroweak and grand unification theories, and the charge e to be one element of a more complicated, "vectorial" charge. Some hints about such a generalization will be given in what follows.

4 Theoretical predictions of masses and couplings

In the new framework, theoretical predictions of some of the free parameters of the standard model become possible. We have presented and checked such predictions in previous works [12] [13] [14]. But in the recent years, there has been an improvement of several experimental measurements [27], so that it may now be interesting to check them again with these new values. They are, respectively for the top quark mass, Higgs boson mass, W and Z boson masses, strong coupling constant at Z scale, fine structure constant at Z scale, and $\sin^2\theta$ of weak mixing angle at Z scale in the modified minimal substraction scheme (where it is defined through the SU(2) charge g and the U(1) charge g'):

$$
\begin{aligned}
m_t &= 174.3 \pm 5.1\,\mathrm{GeV} \\
m_H &= 108 - 220\,\mathrm{GeV} \\
m_W &= 80.42 \pm 0.04\,\mathrm{GeV} \\
m_Z &= 91.1872 \pm 0.0021 \\
\alpha_S(m_Z)^{-1} &= 0.118 \pm 0.002 \\
\alpha(m_Z)^{-1} &= 128.92 \pm 0.03 \\
\hat{s}_Z^2 &= \frac{g'^2}{g^2 + g'^2} = 0.23117 \pm 0.00016
\end{aligned}
$$

4.1 Fine structure constant

In [14], we derived a prediction of the fine structure constant (i.e. the electromagnetic coupling). It was based on the suggestion that the bare (infinite energy) value of the electroweak coupling (which becomes finite in special scale-relativity) is $4\pi^2$. The fact that 3 among the 4 gauge bosons acquire mass through the Higgs mechanisms leads to a multiplying factor 8/3, so that one expects that $\alpha_\infty^{-1} = 32\pi^2/3$. The difference between the infinite energy and Z or low energy values was computed using the solutions to the renormalization group equation for the running coupling. The prediction at the Z value for 1 Higgs doublet was:

$$\alpha(m_Z)^{-1} = \frac{32\pi^2}{3} + \frac{11}{6\pi} \ln\left(\frac{m_P}{m_Z}\right) + \text{2nd order term}, \tag{19}$$

where m_P is the Planck mass ($= 1.2210(9) \times 10^{19} GeV/c^2$). The second order term is given by Eq. 112 of [14]. Now we can combine this expression with another prediction of the theory, according to which the electroweak scale and the inverse coupling $\alpha_\infty^{-1} = 4\pi^2$ are linked by a mass-charge relation:

$$\ln\left(\frac{m_P}{m_Z}\right) \approx 4\pi^2. \tag{20}$$

Replacing this expression in the first and second order terms we obtain:

$$\alpha(m_Z)^{-1} = \frac{32\pi^2}{3} + \frac{22\pi}{3} + \frac{6}{\pi^2} = 128.922\,. \tag{21}$$

Though Eq. 20 is only an approximation for the Z scale (see below), it occurs in Eq. 19 as a first order correction and in terms of the logarithm of the mass ratio, so that the final result (Eq. 21) finally gives a good approximation of our theoretical prediction. It indeed compares very well with the experimental value, 129.92 ± 0.03.

4.2 Strong coupling

From the conjecture that the strong coupling value reaches the critical value $1/4\pi^2$ at unification scale (i.e. $m_P/2\pi$ in the special scale-relativistic modified standard model), we obtained a predicted value $\alpha_S(m_Z)^{-1} = 0.1155 \pm 0.0002$ from the solution to the renormalization group equation of the running coupling [12] [14]. This expectation remains in agreement (within about one σ) with the recently improved experimental value 0.118 ± 0.002.

4.3 SU(2) coupling

In ref. [14], we also attempted to apply the mass-charge relation to the SU(2) coupling α_2. We found that the relation

$$3\,\alpha_{2Z}\,C_Z = 4 \tag{22}$$

was precisely achieved at the Z scale. However the factor 3 was not accounted for in that work. The solution to this problem relies on the generalization of scale (i.e. gauge) transformations to dilations which are no longer global, but instead may be different on the resolutions corresponding to the various coordinates. The group SU(2) corresponds to rotations in a 3-dimensional scale space. Therefore the phase term in a fermion field will write:

$$\alpha_2\,\ln(\frac{\varepsilon_x}{\lambda}) + \alpha_2\,\ln(\frac{\varepsilon_y}{\lambda}) + \alpha_2\,\ln(\frac{\varepsilon_z}{\lambda}) < 3\,\alpha_2\,\ln(\frac{\lambda_P}{\lambda}), \tag{23}$$

since the same coupling applies to the three variables, and since all three resolutions are limited at small scales by the Planck scale. From Eq. (22) we expect a value $\alpha_{2Z}^{-1} = 29.8169 \pm 0.0002$. The present precise experimental value is:

$$\alpha_{2Z}^{-1} = \alpha_Z^{-1} \times \hat{s}_Z^2 = 29.802 \pm 0.027, \tag{24}$$

which lies within 1σ of the theoretical prediction.

4.4 Vacuum expectation value of the Higgs field

As recalled hereabove, there are fundamental arguments for introducing a bare inverse coupling at infinite energy (i.e., in special scale relativity, at Planck length-scale) given by the critical value $4\pi^2$. Moreover, our re-interpretation of gauge invariance as scale-invariance on space-time resolution led us to construct general relations between couplings and scale ratios. Therefore one expects the emergence of a new fundamental scale given by:

$$\ln\left(\frac{\lambda}{\lambda_P}\right) = 4\pi^2, \tag{25}$$

where λ_P is the Planck length-scale. This relation may provide a solution to the hierarchy problem, according to which there is a misunderstood factor $\approx 10^{17}$ between the electroweak scale and the Planck scale (expected to be the full unification scale). Indeed the scale λ defined above is $e^{4\pi^2} = 1.397 \times 10^{17}$ larger than the Planck scale. As a first approximation, we can apply this relation to mass ratios. This leads a mass scale of 87.39 GeV, intermediate between the Z and W masses. However, mass-scales and length-scales are no longer directly inverse in the scale-relativity framework. There is a "log-Lorentz" factor between them (when they are referred to low energies). Namely, by taking as reference the electron Compton scale, the new mass-scale is more precisely given by:

$$\ln\left(\frac{m}{m_e}\right) = \frac{\ln(\lambda_e/\lambda)}{\sqrt{1-\ln^2(\lambda_e/\lambda)/C_e^2}}. \tag{26}$$

With the currently accepted value of the gravitational constant (for which the error is now thought to be 12 times larger than previously given, see [27]), we obtain for the fundamental constant $C_e = \ln(\lambda_e/\lambda_P) = 51.52797(70)$. Then the new theoretically predicted mass scale is

$$m_v = 123.23 \pm 0.09\,\mathrm{GeV}, \tag{27}$$

which is closely linked to the vacuum expectation value v of the Higgs field, since the present experimental value of $v/\sqrt{2} = m_W/g$ (where g is the SU(2) weak charge) is $123.11 \pm 0.03\,\mathrm{GeV}$. Now some work remains to be done to really understand why the new mass-scale should have precisely this interpretation.

Let us finally note that the previously pointed out coincidence of the top quark mass ($174.3 \pm 5.1\,\mathrm{GeV}$) and of the vacuum expectation value of the Higgs field ($174.10 \pm 0.05\,\mathrm{GeV}$) remains remarkable.

4.5 Mass of the Higgs boson

The framework of generalized scale-relativity provides one with possibilities to make theoretical predictions of the value of the Higgs boson mass. The (summarized) argument is as follows.

In today's electroweak scheme, the Higgs boson is considered to be separated from the electroweak field. Moreover, a more complete unification is mainly seeked in terms of attempts of "grand" unifications with the strong field. However, one may wonder whether, maybe in terms of an effective, intermediate energy, theory, one could not achieved a more tightly unified purely electroweak theory. Recall indeed that in the present standard model, the weak and electromagnetic fields are mixed, but there remains four free parameters, which can e.g. be taken to be the Higgs boson mass, the vacuum expectation value of the Higgs field and the Z and W masses.

The structure of the present electroweak boson content is as follows. There is an SU(2) gauge field, then involving three fields of null mass (i.e. $2 \times 3 = 6$ degrees of freedom), a U(1) null mass field (2 d.f.) and a Higgs boson complex doublet (4 d.f.), which makes 12 d.f. in all. Through the Glashow-Salam-Weinberg mechanism, 3 of the 4 components of the Higgs doublet become longitudinal components of the weak field which therefore acquires mass ($3 \times 3 = 9$ d.f.), while the photon remains massless (2 d.f.), so that there remains a Higgs scalar which is nowadays experimentally searched (1 d.f.).

Now, we have suggested a new interpretation of gauge invariance as being scale invariance on the internal resolutions, considered as intrinsic to the description of the particle-fields (at scale smaller than their Compton length in restframe). As a first step we considered only global dilations, which led us to a U(1) invariance and to the relations between mass scale and coupling constant recalled above. But more generally one may consider four independant scale transformations on the four space-time resolutions, i.e., $(\ln \varepsilon_x, \ln \varepsilon_y, \ln \varepsilon_z, \ln \varepsilon_t)$. This means that the scale space (i.e., here the gauge space) is at least four-dimensional (but note that this is not the final word on the subject, since this does not yet include the fifth "djinn" dimension δ). Moreover, the mixing relation between the B (U(1)) and W_3 (SU(2)) fields may also be interpreted as a rotation in the full gauge space. We therefore expect the appearance of a 6 component antisymmetric tensor field (linked to the rotations in this space), corresponding in the simplest case to a SO(4) group. Such a zero mass field would yield 12 degrees of freedom by itself alone.

What about the Higgs boson in such a unified framework ? We shall tentatively explore the possibility that it appears as a separated scalar only as a low energy approximation, while in the new framework it would be one of the components of the unified field (in analogy with energy appearing as scalar at low velocity, while it is ultimately a component of the energy-momentum four-vector in the relativistic framework).

Such an attempt is supported by the form of the electroweak Lagrangian (we adopt Aitchison's [3] notations). Its Higgs scalar boson part writes:

$$L_H = \frac{1}{2}\,\partial_\mu \sigma \partial^\mu \sigma - \frac{1}{2}\,m_H^2 \sigma^2 - \frac{1}{2}\lambda^2 \sigma^4. \tag{28}$$

The vacuum expectation value v of the Higgs field is computed from the square (mass term) and quartic term, so that the Higgs mass is related to v and λ as:

$$m_H = \sqrt{2}\, v\, \lambda. \tag{29}$$

A prediction of the constant λ would therefore lead to a prediction of the Higgs mass. Now, a non-Abelian field writes in terms of its potential :

$$F^{\alpha\mu\nu} = \partial^\mu W^{\alpha\nu} - \partial^\nu W^{\alpha\mu} - g\, c^\alpha_{\beta\gamma} W^{\beta\mu} W^{\gamma\nu}, \tag{30}$$

where g is the (now unique) charge and $c^\alpha_{\beta\gamma}$ the structure coefficients of the Lie algebra associated to the gauge group. Its Lagrangian writes:

$$L_W = -\frac{1}{4} F^{\mu\nu} F_{\mu\nu}. \tag{31}$$

It therefore includes W^4 terms coming from the W^2 terms in the field. Now our ansatz consists of identifying some of these W^4 terms, of coefficient $-\frac{1}{4}\, g^2\, (c^\alpha_{\beta\gamma})^2$, with the Higgs boson σ^4 term of coefficient $-\frac{1}{2}\, \lambda^2$. This allows a determination of the constant λ:

$$\lambda^2 = \frac{g^2 (\Sigma c^2)}{2}, \tag{32}$$

where the sum is on the terms that contribute to the final effective Higgs boson. Provided the global charge is identical to the SU(2) charge, and since the W mass is given by $m_W = gv/\sqrt{2}$, one finally obtains a Higgs boson mass :

$$m_H = \sqrt{2(\Sigma c^2)}\, m_W. \tag{33}$$

For a large class of groups (like e.g. SO(4)), the c's take the values 0, ± 1, so that we expect $m_H = \sqrt{2k}\, m_W$ with k integer. In particular, the case $k = 1$, yields a theoretical prediction:

$$m_H = \sqrt{2}\, m_W = 113.73 \pm 0.06\, \mathrm{GeV}, \tag{34}$$

which is in agreement with current constraints. Although this calculation is still incomplete and although the self-consistency of this model remains to be established, we hope that at least some of its ingredients could reveal to be useful in more complete attempts [Lehner and Nottale, in preparation].

4.6 Cosmological constant and gravitational coupling

In [14], we were able to make a theoretical prediction of the value of the cosmological constant. Recall that, in the special scale-relativistic framework, new dilation laws having a log-Lorentz form have been introduced [12], that lead to re-interpret the length-scale of the cosmological constant $\mathbb{L} = \Lambda^{-1/2}$ and the Planck length-scale λ_P as impassable, respectively maximal and minimal length-scales, invariant under dilations of resolutions.

Their ratio defines a fundamental pure number, $\mathbb{K} = \mathbb{L}/\lambda_P$. From an analysis of the vacuum energy density problem, the logarithm of this ratio has been found to have the numerical value $C_U = \ln \mathbb{K} = 139.83 \pm 0.01$, i.e. $\mathbb{K} = 5.3 \times 10^{60}$ [13] [14]. This value corresponds to a reduced cosmological constant $\Omega_\Lambda = 0.36 h^{-2}$, where $h = H_0/100$ km/s.Mpc. Now the Hubble constant has been recently determined with an improved precision to be $H_0 = 70 \pm 10$ km/s.Mpc. Therefore we predicted a reduced cosmological constant $\Omega_\Lambda = 0.70 \pm 0.25$. Recent measurements using the Hubble diagram of SNe I [8] [29] [30] and the angular power spectrum of the cosmic microwave radiation [5] point precisely toward the same value, 0.7 ± 0.2.

5 Gravitational structuration

5.1 Generalized Schrodinger equation

One can demonstrate [13] [14] [16] that Newton's fundamental equation of dynamics can be integrated in the form of a Schrödinger-like equation under the three following hypotheses:

(i) The test-particles can follow an infinity of potential trajectories: this leads one to use a fluid-like description, $v = v(x(t), t)$.

(ii) The geometry of each trajectory is fractal (of dimension 2). Each elementary displacement is then described in terms of the sum, $dX = dx + d\xi$, of a mean, classical displacement $dx = v\,dt$ and of a fractal fluctuation $d\xi$ whose behavior satisfies the principle of scale relativity (in its simplest "Galilean" version). It is such that $< d\xi >= 0$ and $< d\xi^2 >= 2\mathcal{D}dt$. The existence of this fluctuation implies introducing new second order terms in the differential equations of motion.

(iii) The motion is assumed to be locally irreversible, i.e., the $(dt \leftrightarrow -dt)$ reflection invariance is broken, leading to a two-valuedness of the velocity vector that we represent in terms of a complex velocity, $\mathcal{V} = (v_+ + v_-)/2 - i(v_+ - v_-)/2$.

These three effects can be combined to construct a complex time-derivative operator which writes

$$\frac{\acute{d}}{dt} = \frac{\partial}{\partial t} + \mathcal{V} \cdot \nabla - i\,\mathcal{D}\,\triangle \tag{35}$$

where the mean velocity $\mathcal{V} = \acute{d}\,x/dt$ is now complex and $\mathcal{D}$ is a parameter characterizing the fractal behavior of trajectories (namely, it defines the fractal-nonfractal transition in scale space).

Since the mean velocity is complex, the same is true of the Lagrange function, then of the generalized action $\mathcal{S}$. Setting $\psi = e^{i\mathcal{S}/2m\mathcal{D}}$, Newton's equation of dynamics becomes $m\,\acute{d}\,\mathcal{V}/dt = -\nabla\phi$, and can be integrated in terms of a generalized Schrödinger equation [13]:

$$2\mathcal{D}^2 \triangle \psi + i\mathcal{D}\frac{\partial}{\partial t}\psi = \frac{\phi}{2m}\,\psi. \tag{36}$$

This equation becomes, for a Kepler potential and in the time-independent case:

$$2\mathcal{D}^2 \triangle \psi + \left(\frac{E}{m} + \frac{GM}{r}\right)\psi = 0. \tag{37}$$

Since the imaginary part of this equation is the equation of continuity, $\rho = \psi\psi^\dagger$ can be interpreted as giving the probability density of the particle position.

Even though it takes this Schrödinger-like form, this equation is still in essence an equation of gravitation, so that it must keep the fundamental properties it owns in Newton's and Einstein's theories. Namely, it must agree with the equivalence principle [15] [9] [1], i.e., it must be independent of the mass of the test-particle and GM must provide the natural length-unit of the system under consideration. As a consequence, the parameter $\mathcal{D}$ takes the form:

$$\mathcal{D} = \frac{GM}{2w}, \tag{38}$$

where w is a fundamental constant that has the dimension of a velocity.

Actually, the ratio

$$\alpha_g = \frac{w}{c}. \tag{39}$$

stands out as a macroscopic gravitational coupling constant [1] [2] [22]. This can be seen from the fact that w is the average velocity in the fundamental orbit, in the same manner as $v_0 = \alpha c$ (where α is the fine structure constant, i.e., the electromagnetic coupling) gives the mean velocity of an electron in a Bohr orbital. Moreover, contrarily to what happens in the classical theory, the equation of motion (Eq. 36) can be shown to be gauge invariant. If the potential ϕ is replaced by $\phi + GMm\,\partial\chi(t)/c\partial t$, where the factor GMm ensures a correct dimensionality, then Eq. (36) remains invariant provided ψ is replaced by $\psi\, e^{-i\alpha_g \chi}$, with α_g related to $\mathcal{D}$ by:

$$\alpha_g \times 2m\mathcal{D} = \frac{GMm}{c}, \tag{40}$$

which is the previously established relation for $\alpha_g = w/c$.

As an example, let us briefly show how such an approach can be applied to formation of planetary systems. We assume that the probability density solution of Eq.37 describes the distribution of planetesimals in a protoplanetary nebula. Then they form a planet by accretion as in the standard models of planetary formation. But the new point here is that only some particular orbitals are allowed, so that the semi-major axes of the orbits of the resulting planets are quantized according to the law:

$$a_n = \frac{GMn^2}{w^2}, \tag{41}$$

where n is an integer. In an equivalent way, using Kepler's third law that relates the semimajor axis a to the orbital period P, $(a/GM)^3 = (P/2\pi GM)^2$, the average velocity of the planet, $v = 2\pi a/P = (GM/a)^{1/2}$, is expected to have a distribution peaked at $v_n = w/n$. Therefore, we predict that the values of $\tilde{n}$ defined, in Solar System units (AU, year, $M_\odot$ and Earth velocity) as:

$$\tilde{n} = w\,(a/M)^{1/2} = w\,(P/M)^{1/3} = \frac{w}{v} \tag{42}$$

be clustered around integer numbers.

5.2 Comparison with observational data

We have shown [13], that this approach accounts for several structures observed in the Solar System, including planet distances, eccentricities, and mass distribution [21], obliquities and inclinations of planets and satellites [17]), giant planet satellite distances [10], parabolic comet perihelions [Nottale & Schumacher, in preparation]. Moreover, it also allows one to predict and understand structures observed on a large range of scales, from binary stars [20], to binary galaxies [14], [Tricottet & Nottale, in preparation], and the distribution of galaxies at the scale of the local supercluster [20]. A similar kind of approach has been applied by Perdang [28] to a statistical description of HR diagrams.

It has been also demonstrated that the first newly discovered extra-solar planetary systems come under the same structures, in terms of the same universal constant as in our own Solar System [15] [22] [23] (see Fig. 1). Their distribution shows peaks of probability density that are consistent with the law $a/GM = n^2/{w_0}^2$, where the constant w_0 takes the value 144 km/s as in our own inner Solar System and in extragalactic data. Moreover, most of these exoplanets (51 Peg-type objects) fall in the fundamental probability density peaks ($n = 1$, $a/M = 0.043$ AU/$M_\odot$) and in the second orbital ($n = 2$, $a/M = 0.17$ AU/$M_\odot$) predicted by the theory. The system of three planets discovered around the pulsar PSR B1257+12 also agree with the theoretical prediction with a very high precision of some 10^{-4} [15] [18].

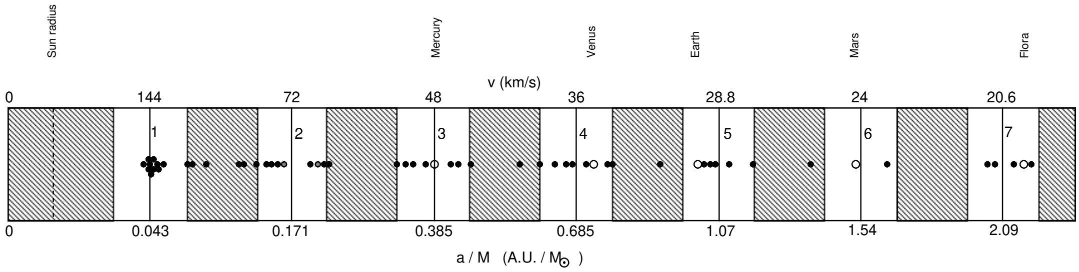

Figure 1: *Observed distribution of* $\tilde{n} = 4.83\,(P/M)^{1/3} = 144/v$*, where* v *is the average planet velocity in km/s, and where the orbital period* P *and the star mass* M *are taken in Solar System units (AU and* $\mathrm{M}_\odot$*), for the recently discovered exoplanet candidates (black dots) and for the planets of our inner Solar System (white dots). The grey zone stands for the theoretically predicted low probability density of planets and the white zones for high probability. The error bars are typically of the order of* $0.03\,\tilde{n}$*. The probability to obtain such a non uniform distribution by chance is about* 10^{-4}.

6 Conclusion

After having summarized the main lines of development of the scale-relativity theory, we have, in the present contribution, updated some of its theoretical predictions, then we have shown that they continue to agree with recently improved experimental results.

Moreover, we have recalled that scale relativity, when combined with the laws of gravitation, provides us with a general theory of the structuring of gravitational systems [14] [16]. In this new approach, we do not any longer follow individual trajectories, but we jump to a statistical description in terms of probability amplitudes. Indeed, under only three simple hypotheses (large number of potential trajectories, fractal geometry of each trajectory and differential irreversibility), Newton's equation of dynamics can be transformed and integrated in terms of a generalized Schrödinger equation. This result suggests, in accordance with recent similar conclusions [31] [25] [26] [7] that the Schrödinger equation could be universal, i.e. that it may have a larger domain of application than previously thought, but with an interpretation different from that of standard quantum mechanics.

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On a General Theory for Quantum Gravity[1]

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1 Introduction

The author's interest in quantum physics started with his interest in the wave-particle duality and the two-slit experiment with quantum "particles". That was also the beginning of his contact with Otto Rössler's theory of the interface and the author's attempt to give a topological explanation for this interface and the paradoxical outcome of the two-slit experiment as parodied in the photomontage of Fig 1.

The aim of the present paper is to outline the $\mathcal{E}^{(\infty)}$ space approach for constructing the space-time topology required by the theory of Heterotic superstings [1]–[12]. In so doing the beauty and power of the HSS theory become even more pronounced in its new transfinite setting [10], [13]–[16].

We start from the main topological invariants of $\mathcal{E}^{(\infty)}$ [10] namely the expectation value of its dimensionality $\langle dim_\tau \rangle = 4 + \phi^3$ and proceed from there to derive the topology of Heterotic string theory [1]–[12] and all the relevant coupling constants including that of quantum gravity [11, 12]. We give nowhere detailed derivations and instead we try to give a general up-to-date account of the results obtained so far.

2 The Topology of $\mathcal{E}^{(\infty)}$

2.1 The Dimension $\sim \langle n \rangle = 4 + \phi^3$

The $\mathcal{E}^{(\infty)}$ theory rests crucially on a fundamental number fixing the dimensionality of this transfinite discrete space namely [10]

$$\sim \langle n \rangle = 4 + \phi^3 \tag{1}$$

where $\phi = (\sqrt{5} - 1)/2$. There are at least a dozon ways of how to derive this number. In the present work, it is sufficient to mention one derivation which may be described as mathematically and two others which may be seen as physically motivated.

2.1.1 Derivation Using Random Cantor Sets

The first derivation we give here is based on a deceptively simple theorem due to Mauldin and Williams [10]. This theorem states that a randomly constructed triadic Cantor set will have with a probability equal to 1 a Hausdorff dimension equal to the Golden Mean ϕ. In our notation this means [10]

$$dim\ S^{(0)}_{c,R} = d^{(0)}_{c,R} = \frac{\sqrt{5} - 1}{2}, \tag{2}$$

[1]Dedicated to Prof. O. E. Rössler on the occasion of his 60^{th} birthday.

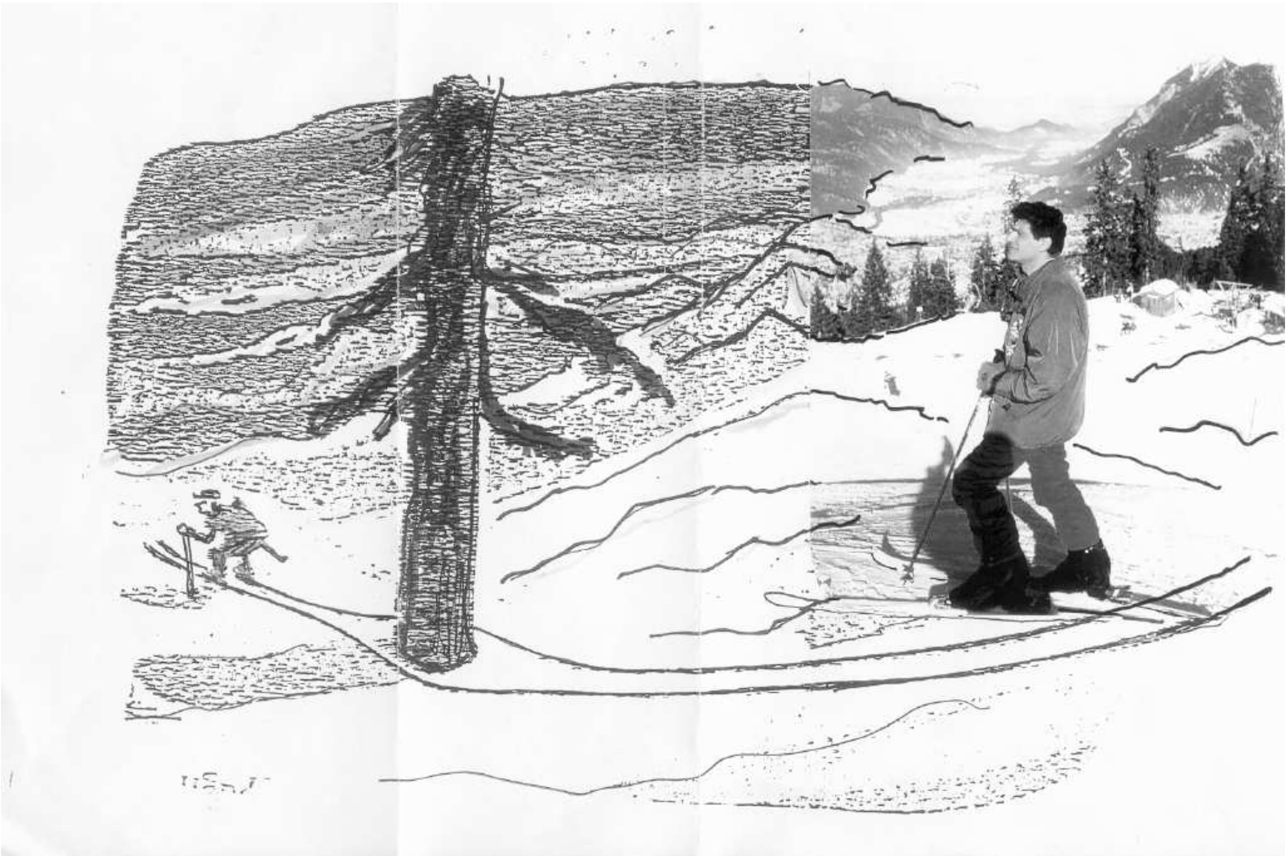

Figure 1: *The author observing a skier in fractal land through the classical-quantum interface.*

where $S_c^{(0)}$ denotes a zero-dimensional Cantor set which lives in a one-dimensional topological space $n = 1$.

Now we have in $\mathcal{E}^{(\infty)}$ theory a simple formula at our disposal with the help of which it is possible to lift any topological one-dimensional Cantor set $d_c^{(0)}$ to any arbitrary higher dimension. This is the so-called bijection formula which states that [10]

$$d_c^{(n)} = \left(\frac{1}{d_c^{(0)}}\right)^{n-1}. \tag{3}$$

Thus for $n = 4$ and $d_c^{(0)} = \phi$ one finds that [10]

$$d_c^{(4)} = \left(\frac{1}{\phi}\right)^{4-1} = \left(\frac{1}{\phi}\right)^3 = 4 + \phi^3. \tag{4}$$

This is exactly our dimension $\sim \langle n \rangle$ which we can also describe as the Hausdorff dimension of a four-dimensional random Cantor set [10].

2.1.2 Derivation Using Probability Theory

The second for the understanding of $\mathcal{E}^{(\infty)}$ theory vital derivation of $\sim \langle n \rangle = 4 + \phi^3$ is that which interprets $4 + \phi^3$ as an expectation value. To understand this derivation we need to recall that $\mathcal{E}^{(\infty)}$ is made of an infinite number of elementary Cantor sets with dimensions varying between zero and one and each dimension is assigned a probability weight. Assuming a gamma black body-like distribution it is easily shown that [10]

$$\langle n \rangle = E(n) = 2/ln\left(1/d_c^{(0)}\right). \tag{5}$$

Expanding this Planckian expectation and keeping only linear terms one finds [10]

$$\sim \langle n \rangle = \frac{1 + d_c^{(0)}}{1 - d_c^{(0)}} = \frac{\sum_0^\infty n^2 \left(d_c^{(0)}\right)^n}{\sum_0^\infty n \left(d_c^{(0)}\right)^n}. \tag{6}$$

Setting $d_c^{(0)} = \phi$ one finds that [10]

$$\sim \langle n \rangle = \frac{1+\phi}{1-\phi} = \frac{1}{\phi^3} = 4 + \phi^3 \tag{7}$$

as expected. It is important to note that $\sim \langle n \rangle$ is not simply an approximation to $\langle n \rangle$. It is in fact an exact expression for a transfinite space. By contrast $\langle n \rangle$ is not truly transfinite discrete because it involves integration while $\sim \langle n \rangle$ involves infinite sums [10]. In this derivation we have made a tacit assumption namely that space-time behaves similar to quantum black body radiation [10].

2.1.3 Derivation Based on the Dimensional Regularization Method of Quantum Field Theory

Dimensional regularization is a powerful and well-known method employed in quantum field theory to deal with the notorious singularities which appear there. These singularities are related to gravitational effects of the four-dimensional space-time. Thus one has to deal with poles of the form $1/(4 - D)$ and take usually D to be slightly smaller than 4 to start with. Now one could also imagine a theory which could work if D is slighly larger than 4. In such hypothetical theory one should be able to remove the poles using a dimension which eliminates singularities. In other words

$$\frac{1}{D-4} \Rightarrow D. \tag{8}$$

This leads us to

$$D(D-4) = 1 \tag{9}$$

or

$$D^2 - 4D - 1 = 0. \tag{10}$$

This simple quadratic equation has two solutions and one of these is precisely our $4 + \phi^3$. That means

$$D_1 = 4 + \phi^3 = 1/\phi^3. \tag{11}$$

The second solution is the negative inverse of D_1 namely $D_2 = -\phi^3$. Thus, we have established a connection between the remarkable number [10]

$$\sim \langle n \rangle = 4 + \phi^3 = \frac{1}{\phi^3} = 4 + (\bar{4}) = 4 + \cfrac{1}{4 + \cfrac{1}{4 + \cfrac{1}{4 + \dots}}} \tag{12}$$

and the dimensionality of a mathematical space $\mathcal{E}^{(\infty)}$. This relation involves random Cantor sets, the statistical mechanics of black body radiation and the infinities of quantum field theory. Now we will examine if this idealized "Cantorian" space could describe real physics or not and we may mention here that while the formal dimension of $\mathcal{E}^{(\infty)}$ is $n_F = \infty$ and the Hausdorff dimension is $d_c^{(4)} = \sim \langle n \rangle = 4 + \phi^3$, the topological dimension of the surrounding space is surprisingly smaller and is exactly equal to four ($n = 4$).

2.2 The Spin Structure of $\mathcal{E}^{(\infty)}$ and Chirality

On its own only $\sim\langle n\rangle = 4 + \phi^3$ cannot give a complete description for the intricate topology of $\mathcal{E}^{(\infty)}$ in a simple way. For a space to be potentially relevant to particle physics, spin and chirality are needed. In $\mathcal{E}^{(\infty)}$ these are easily added following Penrose [17] by noting that in $\mathcal{E}^{(\infty)}$ spin S is given by half the inverse of $\sim\langle n\rangle$, the so-called universal fluctuation $\mathcal{E} = \frac{1}{\sim\langle n\rangle} = \phi^3$ [17]. That means

$$S = \phi^3/2. \tag{13}$$

In addition chirality in $\mathcal{E}^{(\infty)}$ is given by [17]

$$\overset{+}{C}h = \phi = d_c^{(0)} \tag{14}$$

and

$$\overset{-}{C}h = \phi^2 = 1 - d_c^{(0)} = \bar{d}_c^{(0)}. \tag{15}$$

Now to give $\mathcal{E}^{(\infty)}$ through $\sim\langle n\rangle$ a spin structure we multiply $\sim\langle n\rangle$ with the spinor γ

$$\gamma_{(m/n)S} = 1 + (m/n)S \tag{16}$$

as following

$$\sim\langle n\rangle_F = \sim\langle n\rangle\gamma_{2S} = (4+\phi^3)(1+2S) = (4+\phi^3)(1+\phi^3) = (4+\phi^3)+1 = 5+\phi^3. \tag{17}$$

Thus multiplication with γ_{2S} has added one dimension to $4+\phi^3$ which we will be interpreting as the extra spin 1/2-dimension required by fermions. We should note at this point that there is another nonfluctuating and nonhierarchical $\mathcal{E}^{(n)}$ space corresponding to $5+\phi^3$ namely $\mathcal{E}^{(5)}$ with $n = 5$ as in the original Klein-Kaluza theory [1, 6] and where $n = (4+\phi^3)(1+k)$ with $k = \phi^3(1-\phi^3) = 0.18033989$.

2.3 The Euler Number and Generation Number

It was established in previous publications that the Euler number per Cantorian dimension is given by [18]

$$\chi_0 = 1 + \phi^3 \tag{18}$$

and that

$$\text{Indix } \bar{S}_0 = \chi_0/2. \tag{19}$$

Consequently, the generation number per Cantorian dimension is [18]

$$n_{ge(0)} = \text{Indix } \bar{S}_0 = \chi_0/2 = \phi. \tag{20}$$

That means for instance that a five-dimensional Cantorian space will have

$$n_{ge(5)} = (5)(1+\phi^3)/2 = (5)(\phi) = 3.09016 \tag{21}$$

and

$$n_{ge(4+\phi^3)} = (4+\phi^3)(1+\phi^3)/2 = 2+\phi. \tag{22}$$

3 The Topology of Heterotic String Theory

The first thing we will use $\sim \langle n \rangle = 4 + \phi^3$ for will be to give an incredibly simple derivation of all the dimensionalities of Heterotic string theory. In following this aim we will encounter a new version of Heterotic strings which is related to $\mathcal{E}^{(\infty)}$ theory and which we call transfinite Heterotic string theory. We may recall that the main dimensions of Heterotic strings are $D^{(-)} = 26$ and $D^{(+)} = 10$. In addition we have the 16 extra bosonic dimensions and six dimensions of the orbifold [1]. Finally, we know that every thing must compactify first from 26 to 10 and thereafter from 10 to four-dimensional space. Now all the preceding dimensions are easily derivable as intersection between $\sim \langle n \rangle = 4 + \phi^3$ and $n_F = 5$ amplified by γ_{2S} and scaled repeatedly using ϕ as following:

$$
\begin{aligned}
D_T^{(-)} &= (\sim \langle n \rangle)(n_F)(\gamma_{2S}) = (4+\phi^3)(5)(1+\phi^3) = 26.18033989 = 26 + k, && (23)\\
D_T^{(16)} &= \left(D_T^{(-)}\right)\left(\overset{+}{C}h\right) = (26+k)(\phi) = 16 + k, && (24)\\
D_T^{(+)} &= \left(D_T^{(16)}\right)\left(\overset{+}{C}h\right) = (16+k)(\phi) = 10, && (25)\\
D_T^{(6)} &= \left(D_T^{(10)}\right)\left(\overset{+}{C}h\right) = \left(D_T^{(+)}\right)(\phi) = 6 + k, && (26)\\
D_T^{(4)} &= \left(D_T^{(6)}\right)\left(\overset{+}{C}h\right) = 4 - k, && (27)
\end{aligned}
$$

where $k = \phi^3(1-\phi^3) = 0.18033606$ is quite small compared to unity.

The exceedingly interesting point in the above context is that in $\mathcal{E}^{(\infty)}$ theory the Weinberg mixing parameter $sin^2\theta_W$ is given at the electroweak scale by

$$sin^2\theta_W|_{ew} = \phi^3 \tag{28}$$

and consequently k is

$$k = sin^2\theta_W cos^2\theta_W|_{ew}. \tag{29}$$

Therefore, setting $k = 0$ implies not only one, but two points. First we find all the exact classical dimensions of Heterotic strings $D^{(-)} = 26$, $D^{(16)} = 16$, $D^{(6)} = 6$, $D^{(4)} = 4$ and $D^{(+)} = 10$. Second we see that $k = 0$ must mean for reasons of consistency that the Weinberg mixing parameter vanishes [2]. This point may well turn out to be of a far more fundamental importance than would initially appear for a correct interpretation of the general results obtained using H string theory [1]–[12].

4 The Electromagnetic Fine Structure Constant in $\mathcal{E}^{(\infty)}$ and the Dimensionalities of H-Strings

One of the most astonishing results of $\mathcal{E}^{(\infty)}$ theory is undoubtedly the fact that the inverse of the electromagnetic fine structure constant $\bar{\alpha}_0$ in $\mathcal{E}^{(\infty)}$ is given approximately by the three-fold intersection of $\langle n \rangle_F = \langle n \rangle + 1$ and exactly by the intersection of $\sim \langle n \rangle, \sim \langle n \rangle_F$ and the orbifold dimension $D_T^{(6)}$. That means [7]–[9]

$$\bar{\alpha}_0 \simeq (\langle n \rangle_F)^{4-1} \simeq (\langle n \rangle + 1)^3 \simeq ((2/ln(1/\phi)) + 1)^3 \simeq (5.156173841)^3 \simeq 137.0827012 \tag{30}$$

[2]This is clearly a contradiction which the transfinite Hetereotic theory does not have.

and

$$\begin{aligned}\bar{\alpha}_0 &= (\sim\langle n\rangle)(\sim\langle n\rangle_F)\left(D_T^{(6)}\right) = (4+\phi^3)(5+\phi^3)(6+k)\\ &= (4+\phi^3)(5+\phi^3)(6.18033989) = (22+k)(6+k)\\ &= 137.0820393925 = 137+k_0,\end{aligned} \tag{31}$$

where $k_0 = \phi^5(1-\phi^5) = 0.082039325$.

The last exact $\mathcal{E}^{(\infty)}$ expression for $\bar{\alpha}_0$ means that the inverse of the fine structure constant is equal to the intersection of the dimension of the second and to the total compactified THSS space

$$\bar{\alpha}_0 = \left(D_T^{(6)}\right)\left(D_T^{(22)}\right) = (6+k)(22+k) = 137+k_0. \tag{32}$$

In addition, because of the relation between k and k_0

$$k = (k_0+1)/6 \tag{33}$$

setting $k=0$ implies that the classical Heterotic strings are consistent with an electromagnetic fine structure constant [11, 12]

$$\bar{\alpha}_0(k=0) \equiv 136 \tag{34}$$

and not 137 as superficial reasoning might initially lead us to believe. It is simply a matter of consistency and uniform approximation as seen from the view point of $\mathcal{E}^{(\infty)}$ theory that $D^{(-)} = 26$ and $D^{(+)} = 10$ implies $\bar{\alpha}_0 = 136$ rather than $\bar{\alpha}_0 = 137$.

Next we show how we can derive all the dimensions of Heterotic strings starting from $\bar{\alpha}_0 = 137 + k_0$ in a systematic way and simultaneously gain a preliminary insight into the problem of determining the coupling constant of quantum gravity. To do that we convert $\bar{\alpha}_0$ into $\bar{\alpha}_0/2$ which corresponds to a "Cooper pair" fine structure constant and then scale it down using $\mathcal{E}^{(\infty)}$ by successive multiplication with $d_c^{(0)} = \phi$. Proceeding in this way one finds [7]–[9], [11, 12]

$$\begin{aligned}(\bar{\alpha}_0/2)\phi &= 42.36067979,\\ (\bar{\alpha}_0/2)\phi^2 &= 26.1803399,\\ (\bar{\alpha}_0/2)\phi^3 &= 16.180399,\\ (\bar{\alpha}_0/2)\phi^4 &= 10,\\ (\bar{\alpha}_0/2)\phi^5 &= 6.180399,\\ (\bar{\alpha}_0/2)\phi^6 &= 3.819660121.\end{aligned} \tag{35}$$

Except for the first figure these are exactly the values obtained earlier on and on close examination they are nothing but 10 copies of the Cantorian dimensions

$$\begin{aligned}d_c^{(4)} &= 4.23606,\\ d_c^{(3)} &= 2.6180,\\ d_c^{(2)} &= 1.6180,\\ d_c^{(1)} &= 1,\\ d_c^{(0)} &= 0.618033989,\\ \left(d_c^{(0)}\right)^2 &= 0.381966121.\end{aligned} \tag{36}$$

In particular and as will be made much clearer later on we interpret $(\bar{\alpha}_0/2)(\phi) = (10)(\sim\langle n\rangle) = 42 + 2k$ as the 10-dimensional gravity coupling charge or the inverse of the coupling constant at complete unification [3] of all the nongravitational forces with the force of gravity. In fact we will be showing that $\bar{\alpha}_g$ is an upper bound [11, 12]

$$\bar{\alpha}_{g(max)} = (10)(\sim \langle n \rangle) = 42.36067977 = 42 + 2k. \tag{37}$$

Adopting the same uniform approximation consistent with the classical form of H-superstrings, and by setting $k = 0$ one finds

$$\bar{\alpha}_{g(max)} = 42. \tag{38}$$

We may note on passing that

$$dim\ G/H = 42 = \bar{\alpha}_{g(max)}, \tag{39}$$

where $G \simeq E_6(+6)$ and $H = USP(8)$.

5 The Electroweak and GUT Coupling

With $\bar{\alpha}_{g(max)} = 42 + 2k$ we are now in a position to express all the three inverse coupling constants $\bar{\alpha}_0, \bar{\alpha}|_{ew}$ and $\bar{\alpha}|_{GUT}$ in terms of $\bar{\alpha}_g$. This is simply [11, 12]

$$\begin{aligned} \bar{\alpha}_0 &= (\bar{\alpha}_g)(3)\left(1 + \frac{\phi^3}{3}\right) = (\bar{\alpha}_g)(3 + \phi^3) = 137 + k_0, && (40) \\ \bar{\alpha}|_{ew} &= (\bar{\alpha}_g)(3) = 127 + k_0, && (41) \\ \bar{\alpha}|_{GUT} &= (\bar{\alpha}_g)(3 - \phi^2) = 110.9016994. && (42) \end{aligned}$$

Again all the three results are within a very reasonable agreement with direct and indirect experimental results ($\bar{\alpha}_0 = 137.036, \bar{\alpha}|_{ew} = 128$). It is also of interest to note that $\bar{\alpha}|_{GUT}$ is simply 10 copies of the Cantorian dimension $d_c^{(5)} = 11.09016994$ and that $\bar{\alpha}|_{ew}$ is equal to $\bar{\alpha}_0$ minus 10, where 10 is the classical Heterotic supersymmetric string dimension. Note that $D^{(+)} = 10$ is the only Heterotic dimension which remain exactly the same in the transfinite theory as in the classical theory.

6 The Weinberg Mixing Parameter

Within $\mathcal{E}^{(\infty)}$ theory and disregarding all nontopological aspects the Weinberg parameters were found to be [7]–[9], [11, 12]

$$sin^2\theta_W|_{ew} = \phi^3 = 0.2360679 \tag{43}$$

at the electroweak scale ($\lambda \simeq 10^{-16}cm$) and

$$sin^2\theta_W|_{GUT} = \phi^2 = 0.381 \tag{44}$$

at the GUT scale ($\lambda \simeq 10^{-29}cm$).

Furthermore, it was conjectured that at the Planck quantum gravity scale we should have locally speaking

$$sin^2\theta_W|_{QG} = \phi = 0.6180\ldots \tag{45}$$

The last value may be opened to several restrictions which need not be discussed at this stage. We note that while $sin^2\theta_W|_{ew}$ is in a fine agreement with experimental finding $sin^2\theta_W|_{ew} \simeq 0.236$, the GUT value is in good agreement with the theoretical prediction of the SU(5) symmetry group theory of Glashow and Georgi namely $sin^2\theta_W|_{GUT} = 3/8 = 0.375$.

[3] If supersymmetry is accounted for then $\bar{\alpha}_g = 26.18033989 = D^{(-)} = (10)(1/\phi)^2$.

7 The Coupling Constant at the Quantum Gravity (Planck) Scale

We have already established that $\bar{\alpha}_g = (10)(\sim \langle n \rangle)$. There are various exact and heuristic derivations for this result of which we would like to give here a few. We may start by some heuristic arguments and derivations based on translating results obtained earlier by others to the language of $\mathcal{E}^{(\infty)}$ theory.

7.1 The Conformal Quantum Length Interpretation

Following for instance the excellent presentation of Green, Schwarz and Witten in their classical book [1] we know that the conformal length needed for a cylindrical string of a circumference length 2π in order to be conformally equivalent to another string with a circumference length $ln(w)$ and length π is given by

$$l_{con} = 2\pi^2/|ln(w)|, \tag{46}$$

where $w \leq 1$.

Now the preceding conformal transformation is clearly an expression of a scale relativistic transformation as discussed in [11, 12] and is thus relevant to the Cantorian $\mathcal{E}^{(\infty)}$ approach. Let us remember first that $l_{con} \to \infty$ for $w \to 1$, which is the same behaviour of $\langle n \rangle$ when $d_c^{(0)} \to d_c^{(1)} = 1$ and therefore $\langle n \rangle \to n_F = \infty$. This diversion is anything but not a malady of the $\mathcal{E}^{(\infty)}$ theory. On the contrary the entire theory would fail if we would not have $\langle n \rangle \to n_F = \infty$ for $d_c^{(0)} \to 1$. Let us replace w with the Cantorian dimensions $d_c^{(0)}$. That way one finds that

$$l_{con} = (2/|ln(\phi)|)(\pi^2) = (2/ln(1/\phi))(\pi^2). \tag{47}$$

We notice that l_{con} is made of two brackets and the first is nothing but $\langle n \rangle$ while the second is $\pi^2 = 9.8696 \simeq 10$. In other words l_{con} and $\bar{\alpha}_g$ as given by

$$\bar{\alpha}_g =\sim \langle n \rangle \left(D^{(+)}\right) = (4+\phi^3)(10) \tag{48}$$

become identical if we replace $\langle n \rangle$ by $\sim \langle n \rangle$ and π^2 by 10. The fascinating point is that this is exactly the transformation needed to move from a quasi-smooth, integrable space to a generally "fractal" Cantorian space, where integration is strictly not possible and explicitly forbidden. From the point of view of a purist the preceding reasoning for the deep relation between string theory, scale relativity and $\mathcal{E}^{(\infty)}$ may be objectionable. However, in the present context it has an air of needed reassurance in a difficult field with several competing theories and no clear-cut answer showing up.

7.2 Scale Relativity

In the preceding derivation we made use of the similarity between the conformal transformation leading to l_{con} and Nottale's scale relativity. So, it is quite instructive to see what scale relativity has to say about determining $\bar{\alpha}_g$. A determination of $\bar{\alpha}_g$ was indeed achieved and a conjecture was stated based on the relation between quantum gravity and the Planck scale. This fundamental conjecture is stated in [19] as

$$\bar{\alpha}\,(\Lambda) = 4\pi^2. \tag{49}$$

Now we suggest that in transforming this result to $\mathcal{E}^{(\infty)}$ we proceed as following.

The factor 4 in $\bar{\alpha}(\Lambda)$ will be regarded as the dimension of space-time which translated to $\mathcal{E}^{(\infty)}$ should become $4+\phi^3$. Second and as in the previous l_{con} calculation we must make the transfinite correction by replacing π by $\sqrt{D^{(+)}} = \sqrt{10}$. That way one finds that

$$\bar{\alpha}\left(\Lambda\left(\mathcal{E}^{(\infty)}\right)\right) = (4+\phi^3)(10) = \bar{\alpha}_g, \tag{50}$$

which is an elementary but highly satisfying derivation of a nontrivial result.

7.3 Relation to 10-dimensional Newton's Constant and Dilaton

Consider the relation between the charges of strings and five-branes involving the 10-dimensional Newton's constant K_g, which is given for instance in [3, p. 316] by

$$K_g = \sqrt{\left(\frac{1}{2}\right)(2\pi)^5\sqrt{\alpha'\beta'}}. \tag{51}$$

For $\alpha' = 1/2, \beta' = 0.6$ and transforming to $\mathcal{E}^{(\infty)}$ by making the transfinite changes $2\pi \to 2\sqrt{10}$ one finds

$$K_g = \sqrt{(5542.562584)/2} = \sqrt{2771.281292} = 52.6429605. \tag{52}$$

The connection to $D^{(-)}$ is found by noting the flux quantization factor $1/2$ leading to $\bar{\alpha}_0 = \bar{\alpha}_0/2 = 68.541$. Thus

$$D_T^{(-)} \simeq K_g/2 = 26.321 \simeq 26 + k, \tag{53}$$

while $\bar{\alpha}_g$ is found from

$$\bar{\alpha}_g \simeq (K_g/2)(1/\phi) = 42.589, \tag{54}$$

which is quite close to our exact $\mathcal{E}^{(\infty)}$ value $\bar{\alpha}_g = 42.36067 \simeq 42$ in the nonsupersymmetric case.

Next we consider the expression for the dilaton S_D which is given for instance in [3, p. 332] by

$$S_D = 4\pi/g^2 - (\sqrt{-1})(\theta/2\pi). \tag{55}$$

Transforming the real part to $\mathcal{E}^{(\infty)}$ by making the replacement $\pi \to 3+\phi^3 =\sim \langle n\rangle - 1$, $4 \to 4+\phi^3 =\sim \langle n\rangle$ and $S_R \to 16+k$ one finds that

$$g = 0.723606797. \tag{56}$$

Consequently,

$$\left[\left(D^{(+)}\right)\otimes(g)\right]^2 = ((10)(0.7236067977))^2 = 52+2k \simeq K_g \tag{57}$$

and therefore

$$D_T^{(-)} = \frac{1}{2}\left(D^{(+)}\otimes g\right)^2 = 26+k = (K_g)(\phi) = S_R, \tag{58}$$

which is the expected result. We note that in [3] S_R was estimated at $S_R \simeq 25$.

We will be showing shortly some numerical evidence that the value $D^{(-)} \simeq S_R \simeq 26$ is very close if not identical to $\bar{\alpha}_g$ in the presence of supersymmetry [20].

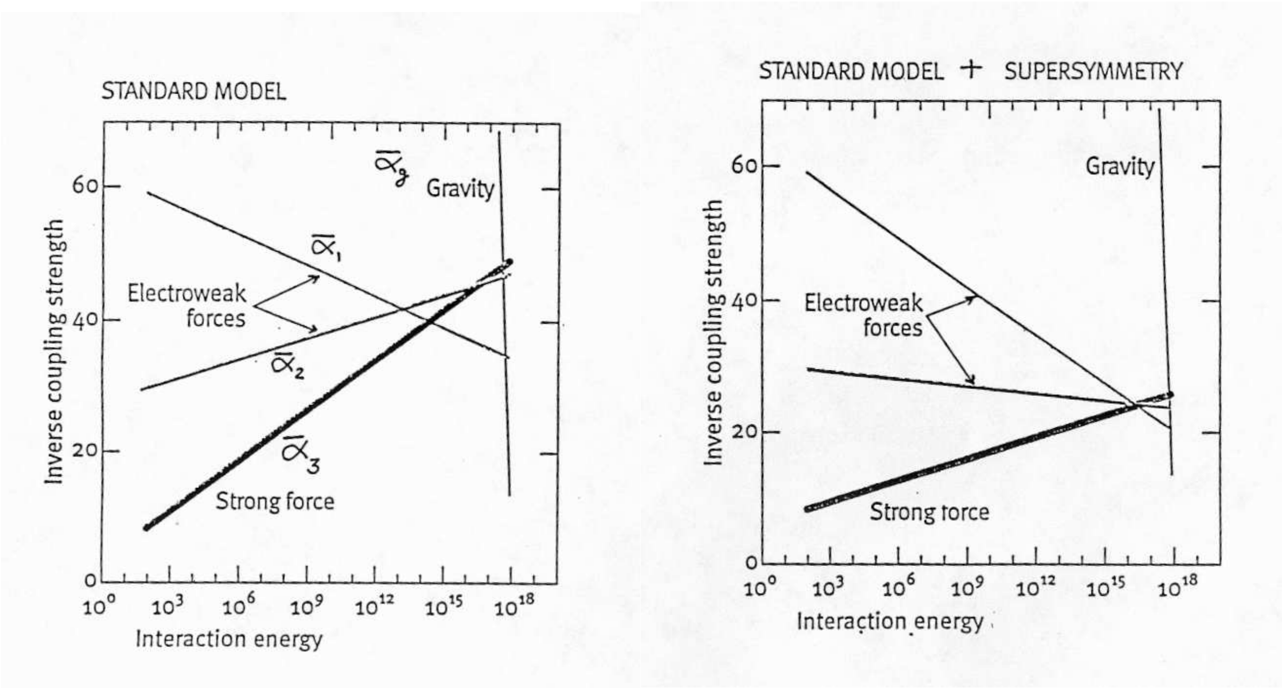

Figure 2: *Unification and the running coupling constants.*

7.4 Relation to Einstein's Coupling Constant K_E

Consider Einstein's field equation [21]

$$G_{ab} - \Omega g_{ab} = K_E T_{ab}. \tag{59}$$

In relativistic units the coupling constant K_E is given by [4] [21]

$$K_E = 8\pi. \tag{60}$$

Transforming K_E to $\mathcal{E}^{(\infty)}$ we make the replacement $8 \Rightarrow D_T^{(16)}/2 = (16+k)/2$ and $\pi \rightarrow 3+\phi^3$. Consequently, one finds that

$$K_E\left(\mathcal{E}^{(\infty)}\right) = (8+k/2)\left(3+\phi^3\right) = 26+k. \tag{61}$$

That means

$$K_E\left(\mathcal{E}^{(\infty)}\right) \equiv D^{(-)} \equiv K_g/2 = 26+k \tag{62}$$

and

$$K_E\left(\mathcal{E}^{(\infty)}\right) \equiv S_R \equiv (\bar{\alpha}_g)(\phi) = 26+k. \tag{63}$$

7.5 Determining $\bar{\alpha}_g$ by Averaging the Intersection Values in $E - \bar{\alpha}_1$ space

Considering that the running coupling constant of the three nongravitational forces as a function of energy does not intersect with the line of gravitational coupling in one point, one may be tempted to think that optimization could give at least an indication about the order of

[4]Note that in $\mathcal{E}^{(\infty)}$ we do not quantize anything. We only discretize transfinitely.

magnitude of $\bar{\alpha}_g$. Following this admittedly very naive line of thinking gave in fact a surprinsing good estimate for $\bar{\alpha}_0$. However, we have to distinguish between two cases following S. Weinberg exposition of the subject [20] namely when we do and when we do not add supersymmetry. In the absence of supersymmetry (see Fig. 2a) the average was found to be [12]

$$\langle \bar{\alpha}_g \rangle \simeq \frac{1}{3}(36 + 46 + 48) \simeq 43.333 \simeq \bar{\alpha}_g, \tag{64}$$

while in the case of adding supersymmetry (see Fig. 2b) one finds as announced earlier on that [12]

$$\langle \bar{\alpha}_g \rangle_s \simeq \frac{1}{3}(24 + 26 + 29) \simeq 26.333 \simeq \bar{\alpha}_g(\phi) \simeq D^{(-)}. \tag{65}$$

Both results may be easily deduced from Ref. [12, Fig. 1] and [20]

8 Ramond Sector Function and $D^{(-)} = 26 + k$

In the following we will give numerical confirmation to the conjecture that the following should be true:

Conjecture.

$$log \left(P_R \left(\mathcal{E}^{(\infty)} \right) \right)^2 = D_T^{(-)}. \tag{66}$$

Here P_R denotes Ramond sector function [1], $P_R\left(\mathcal{E}^{(\infty)}\right)$ is the same function transformed to $\mathcal{E}^{(\infty)}$ space and $D_T^{(-)} = D_T^{(26)} = 26 + k$.

Now P_R is definded as [1, 2]

$$P_R = 8 \prod_{n=1}^{\infty} \left(\frac{1 + q^n}{1 - q^n} \right)^8 = 8Tr(q^k). \tag{67}$$

Setting $q = \phi$ one finds that

$$P_R|_\phi = 8 \prod_{n=1}^{\infty} \left(\frac{1 + \phi^n}{1 - \phi^n} \right)^8 \simeq (8)((8)(4))^8 \simeq (8.796093022)(10)^{12}. \tag{68}$$

Thus

$$log \left(P_R|_\phi \right)^2 = 2(12.944289811) = 25.88857963 \simeq 26 \simeq D^{(-)}. \tag{69}$$

This result can be improved considerably when we attempt a more accurate transformation of P_R to $\mathcal{E}^{(\infty)}$ space. Such more accurate transformation should take into account that $(4)(6) = 32$ should be replaced by the $\mathcal{E}^{(\infty)}$ value of $32 + 2k$ which is found from

$$\left(\bar{\alpha} \left(\mathcal{E}^{(\infty)} \right) \right) \phi^3 = (137 + k_0)(\phi^3) = 32 + 2k = 32.36067977. \tag{70}$$

Also the multiplication factor 8 should become $D_T^{(16)}/2 = (16 + k)/2 = 8 + (k/2)$. Thus

$$P_R \left(\mathcal{E}^{(\infty)} \right) \simeq (8 + k/2)(32 + 2k)^8 \simeq 9.729683909(10)^{12} \tag{71}$$

and

$$log \left(P_R \left(\mathcal{E}^{(\infty)} \right) \right)^2 \simeq 25.97619746 \simeq 26. \tag{72}$$

There are two other numerical estimations which come near to what we have conjectured to be the exact value. The first estimation is found by transferring P_R to $P_R\left(\mathcal{E}^{(\infty)}\right)$ through amplification using the positive chirality $\overset{+}{C}h = \phi$. That means

$$P_R\left(\mathcal{E}^{(\infty)}\right) = P_R\left(1 + \overset{+}{C}h\right) = P_R(1+\phi). \tag{73}$$

Proceeding this way one finds

$$log\left(P_R\left(\mathcal{E}^{(\infty)}\right)\right)^2 \simeq 26.17 \simeq D^{(-)} \simeq 26.1803. \tag{74}$$

The second estimation is obtained by replacing only the 8 inside the bracket by $8+k$ and find that

$$P_R\left(\mathcal{E}^{(\infty)}\right) = 8((4)(8+k))^8 = (1.05303172)(10)^{13}. \tag{75}$$

Thus

$$log\left(P_R\left(\mathcal{E}^{(\infty)}\right)\right)^2 \simeq 26.0438. \tag{76}$$

This result may encourage us to make a second conjecture regarding the well-known bound on the classical positive function $P(x)$ namely

$$ln\left(P(x)\right) < \left(\frac{x}{1-x}\right)\sum_{m=1}^{\infty}\frac{1}{m^2} = \left(\frac{x}{1-x}\right)\left(\frac{\pi^2}{6}\right). \tag{77}$$

Conjecture.
The dimension $D^{(-)} = 26+k$ is given by

$$D^{(-)} = \left[ln\left(P_{(x)}\left(\mathcal{E}^{(\infty)}\right)\right)\right](10) = \left[\left(\frac{\phi}{1-\phi}\right)\frac{(\sqrt{10})^2}{(6+k)}\right](10) = 26+k, \tag{78}$$

where we have made the $\mathcal{E}^{(\infty)}$ replacement $6 \to 6+k, \pi^2 \to 10$ and $x \to \phi$.

9 The Relation Between $\sim \langle n \rangle = 4+\phi^3$ and the $f(w)$ Function of String Theory

In the classical book of Green et al. [1] it is stated that

$$\begin{aligned} f(w) &= exp\left(\sum_{n=1}^{\infty} ln(1-w^n)\right) \sim exp\left(-\sum_{m=1}^{\infty}\frac{w^m}{m(1-w^m)}\right) \\ &\sim exp\left(-\frac{\pi^2}{6(1-w)}\right) \sim \frac{1}{e^{\pi^2/6(1-w)}}. \end{aligned} \tag{79}$$

That means

$$1/f(w) \sim e^{\pi^2/6(1-w)}. \tag{80}$$

Transforming to $\mathcal{E}^{(\infty)}$ one finds that

$$1/f(w) \Rightarrow exp\left(\frac{10}{(6+k)(1-\phi)}\right). \tag{81}$$

That means

$$ln\,(1/f(w)) \Rightarrow \frac{10}{(6+k)(1-\phi)} = 4 + \phi^3. \tag{82}$$

Thus

$$ln\,(1/f(w))\,|_{\mathcal{E}^{(\infty)}} \equiv\sim \langle n \rangle = 4 + \phi^3. \tag{83}$$

This is a remarkable result showing the intimate connection between H-string theory and $\mathcal{E}^{(\infty)}$ which should be regarded now as the natural space-time required by the transfinite Heterotic string theory.

10 Super Manifold, Super Gravity and $\mathcal{E}^{(\infty)}$

Following for instance [2, vol.II,p. 107] a discussion of super manifolds, superstrings and supergravity leads to the conclusion that

$$\frac{K_{10}}{g_{10}^2} = \frac{1}{2} \Rightarrow \frac{\bar{\alpha}|_s}{4}. \tag{84}$$

Now identifying K_{10} with what we have determined for K_g namely $K_g = K_{10} = 52 + 2k$ and transforming to $\mathcal{E}^{(\infty)}$ by setting $4\pi \to (4)(3+\phi^3)$ one finds that

$$\frac{g_{10}^2}{4\pi} = \frac{2K_{10}^2}{4\pi} = \frac{104+k}{4\pi} \to \bar{\alpha}_{g10}\left(\mathcal{E}^{(\infty)}\right) = \frac{104+4k}{(4)(3+\phi^3)}. \tag{85}$$

Therefore, we have

$$\bar{\alpha}_{g10} = D_T^{(16)}/2 = 8.090169946, \tag{86}$$

$$\frac{K_{10}^2}{g_{10}^2} \to \frac{(52+2k)(2)}{16+k} = 6.472135953 \tag{87}$$

and

$$\bar{\alpha}_s| = (4)(6.472135953) = 25.88854381. \tag{88}$$

This result is numerically speaking practically identical to $(log(P_R|_\phi))^2 = 25.8885$. We would have obtained the exact result if we have made the replacement

$$4 \Rightarrow \frac{8.090169946}{2} = D_T^{(16)}/4 = 4.045084973 \tag{89}$$

and obtain

$$\bar{\alpha}_{gs}| = (4.045084973)(6.472135953) = 26.18033989, \tag{90}$$

which means that

$$\bar{\alpha}_{gs}| \equiv D_T^{(-)} \equiv K_E \equiv S_R \equiv K_g/2 = K_{10}/2 \equiv (\bar{\alpha}_g)(\phi). \tag{91}$$

Consequently, $\bar{\alpha}_{gs}| = 26 + k$ is the expected quantum gravity inverse coupling in the presence of supersymmetry and this confirms the crude numerical estimation based on Weinberg's graphical representation of the running coupling constants [20] namely

$$\langle \bar{\alpha}_g \rangle_s \simeq \frac{1}{3}(24 + 26 + 29) \simeq 26.333 \simeq \bar{\alpha}_g(\phi). \tag{92}$$

11 The Connection Between the Number of Gauge Bosons, the Generation Number, the Dimensionality of $\mathcal{E}^{(\infty)}$ and the Electromagnetic Fine Structure Constant

As well-known the 10-dimensional string coupling g_s is related to the radius of compactification by the relation [1]–[4]

$$R = (g_s)^{3/2}. \tag{93}$$

This is valid for type IIA string as well as Heterotic strings [1]–[6]. It is extremely intriguing to notice that by a simple duality

$$\begin{aligned} N_0 &\rightarrow 1/R, \\ \bar{\alpha}_0 &\rightarrow 1/g_s, \end{aligned} \tag{94}$$

this is the same equation which determins the number N_0 needed for determining the number of gauge bosons $\langle n_{GS} \rangle$. Thus one finds

$$1/N_0 = (1/\bar{\alpha}_0)^{3/2} \tag{95}$$

or

$$N_0 = (\bar{\alpha}_0)^{3/2} = (137 + k_0)^{3/2} = 1604.984471. \tag{96}$$

Having found N_0, the number of gauge bosons is found from

$$\langle n_{GS} \rangle = \frac{N_0}{n_{gc}}, \tag{97}$$

where n_{gc} is the number of generations. Taking $n = 5 + \phi^3$ one finds that

$$n_{gc} = \chi/2 = (n)(\phi) = (5 + \phi^3)(\phi) = 3 + \phi^3 \tag{98}$$

and therefore

$$\langle n_{GS} \rangle = \frac{1604.984471}{3 + \phi^3} = 495.9674771 = (\bar{\alpha}_0)(3 + \phi) = 496 - k^2. \tag{99}$$

This is remarably close to the Grenn-Schwarz number [1] $n_{GS} = 496$ as discussed in previous work. Thus all three fundamental numbers N_0, the number of generation n_{gc} and $\langle n_{GS} \rangle$ are all determinded by the topology of $\mathcal{E}^{(\infty)}$ and are directly linked to the electromagnetic fine structure constant $\bar{\alpha}_0(\mathcal{E}^{(\infty)}) = 137 + k_0$ as well as $\langle dim_H \mathcal{E}^{(\infty)} \rangle =\sim \langle n \rangle = 4.23606$. In this context there is a subtle point which is sufficently persuasive to convince one of the importance of the transfinite modification of superstrings to warrant mentioning here.

The number $\langle n_{GS} \rangle$ could be determined to a very high degree of accuracy using the results of Green et al. provided we include the transfinite corrections. Thus one finds

$$\langle n_{GS} \rangle = \frac{(26 + k)^3}{36 + k} = \frac{(D^{(-)})^3}{n_{gc}} = 495.9674 = 496 - (0.18033989)^2, \tag{100}$$

where $n_{gc} = (72 + 2k)/2 = 36 + k$. However, if we would have neglected k we would have found

$$\langle n_{GS} \rangle = \frac{26^3}{36} = 488.222, \tag{101}$$

which is 7.77 less than the correct number expected based on the dimensionality 496 of the $E_g \otimes E_g$ and $SO(32)$ groups used in formulating the H-string theory [1]–[4].

12 Renormalization in $\mathcal{E}^{(\infty)}$ and P-Adic Representation

To motivate our next discussion, we consider first a highly accurate determination of $\bar{\alpha}_0$ in terms of $\mathcal{E}^{(\infty)}$ within six parts in one million as compared to the most accurate experimental value by writing

$$\begin{aligned}\bar{\alpha}_0 &= \left(d_c^{(2)}\right)^{\left(D_T^{(+)}+\frac{1}{(1/\sim\langle n\rangle)}\right)} + \left(d_c^{(2)}\right)^{(\sim\langle n\rangle)} + \left(d_c^{(0)}\right)^{\left(d_c^{(1)}\right)} + \left(d_c^{(0)}\right)^0 \\ &= (1+\phi)^{(10+(\phi^3/3))} + (1+\phi)^{(4+\phi^3)} + \phi + 1 \\ &= 127.7384081 + 7.679667 + 0.618033989 + 1 = 137.0351094.\end{aligned} \tag{102}$$

The experimental value is 137.036 and the $\mathcal{E}^{(\infty)}$ value is 137.082039325. It is interesting to see from the above that the first term is very close to the experimental and the theoretical value of $\bar{\alpha}_0$ at the electroweak scale

$$\bar{\alpha}|_{ew} \simeq 128 \simeq 127.7384081. \tag{103}$$

We could speculate on this result and interpret either the second or the sum of the second and third terms as the inverse of the strong coupling constant

$$\bar{\alpha}_3 \simeq (7.678667 + 0.618033989) \simeq 8.29 \tag{104}$$

and therefore

$$(\bar{\alpha}_3)^{-1} = \alpha_3 \simeq 1/8.29 \simeq 0.12, \tag{105}$$

which is not far from the experimentally established value [22].

Finally, we may see in the last term which comes from raising the zero set $d_c^{(0)}$ to the power of zero as representing the vacuum or the largest quantum gravity coupling possible. This is of course an unrealistic upper bound and we know by now that a more reasonable bound is probably that given by including supersymmetric consideration, for instance $\bar{\alpha}_g|_s \simeq 26+k$. Also there are other possibilities which depend on more detailed physical considerations connected to the inclusion of Higgs particles if they exist.

Next let us consider the case of complete unification of all forces at the Planck scale in the absence of supersymmetry. In such a case we would have

$$\bar{\alpha}_1 = \bar{\alpha}_2 = \bar{\alpha}_3 = \bar{\alpha}_4 = \bar{\alpha}_g = 42.36067977. \tag{106}$$

Combining these values in the usual way one finds that

$$\begin{aligned}\bar{\alpha}_0 &= (\bar{\alpha}_1)(1/\phi) + \bar{\alpha}_2 + \bar{\alpha}_3\phi^2 + \bar{\alpha}_4\phi^3 \\ &= 68.54101967 + 42.36067977 + 16.18033989 + 10 \\ &= 10(6.854101967 + 4.236067977 + 1.618033989 + 1) \\ &= 10\left((1+\phi)^4 + (1+\phi)^3 + (1+\phi) + (1+\phi)^0\right).\end{aligned} \tag{107}$$

We see again that $\bar{\alpha}_4$ is related to unity although this time we have 10 copies of this unity which represents the vacuum of quantum gravity. The third term on the other hand, when multiplied with 10 is nothing but the dimension of the extra bosonic sector of Heterotic strings. Of course we can write the last expression in slightly different form and see that

$$\begin{aligned}\bar{\alpha}_0 &= (\bar{\alpha}_1)(1/\phi) + \bar{\alpha}_2 + \bar{\alpha}_3\phi^2 + \bar{\alpha}_4\phi^3 \\ &= \bar{\alpha}_g(2+\phi+\phi^2+\phi^3) = \bar{\alpha}_g(3+\phi^3) = 3\bar{\alpha}_g\left(1+\frac{\phi^3}{3}\right) = 137 + k_0.\end{aligned} \tag{108}$$

Setting $\phi^3/3 = 0$ compared to unity in the above expression we find the classical result

$$\bar{\alpha}|_{ew} = 127 + k_0. \tag{109}$$

This corresponds to ignoring the contribution stemming from the last "vacuum" term. By contrast if we ignore the contribution of the last two terms $\bar{\alpha}_3\phi^2$ and $\bar{\alpha}_4\phi^3$, then we find $\bar{\alpha}_0$ at the GUT scale

$$\bar{\alpha}|_{GUT} = 110.9016994. \tag{110}$$

The theoretical drawback in the preceding calculation is that conformal unitarity is violated. If we exclude gravity, unitarity can be however restored in a very simple way.

Consider the following three-term conformal weight equation:

$$[U] = \phi + \phi^3 + \phi^4 = 1, \tag{111}$$

Now we can include the vacuum without destroying unitarity by setting $d_c^{(0)} = \left(d_c^{(0)}\right)^{n_F} = \left(d_c^{(0)}\right)^{\infty} = 0$. Thus, we have

$$[U] = \phi + \phi^3 + \phi^4 + 0 = 1, \tag{112}$$

which corresponds to

$$[U] = d_c^{(0)} + \left(d_c^{(0)}\right)^3 + \left(d_c^{(0)}\right)^4 + d_c^{[0]} = 1. \tag{113}$$

After that we follow the procedure introduced previously by inverting each term separately and adding the eigenvalues of the coupled oscillations while remembering that by virtue of the normalization conditions in $\mathcal{E}^{(\infty)}$ the inverse of $d_c^{[0]}$ is unity. Proceeding in this manner one finds

$$[\bar{U}]|_\phi = 1/d_c^{(0)} + \left(1/d_c^{(0)}\right)^3 + \left(1/d_c^{(0)}\right)^4 + 1 = 13.7082639325. \tag{114}$$

This last equation seems to confirm beyond doubt that Heterotic string theory and its space-time topology are real and that numerical predictions would be excellent once the transfinite corrections are added to it. In addition it is clear that the smallest quantum gravity coupling constant is given by

$$(\alpha_g)_{min} = 1/42.36067977 = 0.0236067977, \tag{115}$$

which is exactly 10 times smaller than the value of the Weinberg mixing parameter at the electroweak scale of the $\mathcal{E}^{(\infty)}$ theory.

By contrast $\bar{\alpha}_g$ could be as large as $\bar{\alpha}_g \sim 1$ in theory but it is more reasonable to think that it cannot be larger than

$$(\alpha_g)_{max} = 1/10 = 0.1. \tag{116}$$

Should super gravity exist, it is reasonable to expect that α_g would be

$$\alpha_g|_s = 1/26.18033989 = 0.038196601, \tag{117}$$

which is 10 times smaller than the Weinberg parameter at the scale of GUT.

Taking 10 copies of $[\bar{U}]$ and evaluating at $d_c^{(0)} = \phi$ one finds

$$(10) \otimes [\bar{U}]|_\phi = 137.082039325 = \bar{\alpha}_0. \tag{118}$$

Interestingly superstings can offer a similar unitarity formulation by noting that

$$[U_s] = \frac{D^{(16)}}{D^{(26)}} + \frac{D^{(6)}}{D^{(26)}} + \frac{D^{(4)}}{D^{(26)}} + 0 = \frac{16}{26} + \frac{6}{26} + \frac{4}{26} + 0 = 1. \tag{119}$$

Consequently, one finds

$$[\bar{U}_s] = \frac{26}{16} + \frac{26}{6} + \frac{26}{4} + 1 = 1.625 + 4.333 + 6.5 + 1 = 13.458333 \tag{120}$$

and thus

$$(10) \otimes [\bar{U}_s] = 134.58333, \tag{121}$$

which is substantially smaller that $\bar{\alpha}_0 = 137 + k_0$. However, taking the transfinite correction one finds

$$\begin{aligned} (10)[\bar{U}_s] &= (10)(1.618033989 + 4.236067977 + 6.854101 + 1) \\ &= (10)(13.7082039325) = 137.082039325. \end{aligned} \tag{122}$$

We could shed some light on the problematic with $d_c^{[0]} = 1$ by looking at the remarkable fact that 137 have P-Adic representation equal to unity. Thus the norm $||137||_{P=2} = 1$ could be written as [8, 23]

$$||137||_{P=2} = ||(2)^7 + (2)^3 + 1||_{P=2} = ||128 + 8 + 1||_{P=2} \equiv 1. \tag{123}$$

This may be written using the bijection formula as [8, 23]

$$||137|| = (2)^{8-1} + (2)^{4-1} + (2)^{1-1} = (2)^7 + (2)^3 + (2)^0 \tag{124}$$

and it is tempting to view $(2)^7 = 128$ as $\bar{\alpha}|_{ew} = 128$ amd $(2)^3$ as $\bar{\alpha}_s = 8$ of the strong coupling. That leaves a single possibility for interpreting $(2)^0 = 1$, namely as the state of vacuum responsible for quantum gravity. We may also recall that the geometry required by P-Adic numbers is that of $\mathcal{E}^{(\infty)}$ as indicated by Augenstein [8]. Armed with the preceding insight one is almost compelled to return to the unitarity equation given by $\phi + \phi^3 + \phi^4 + 0$ and try to introduce certain modifications which eliminate inconsistency with all the results as given by the previous relevant equation and in the same time eliminates any trace of ad hoc assumptions regarding the renomalization of the vavuum state. To achieve this goal we suggest the following way. First we introduce a sum $[U]$, which is invariant towards the inversion of the individual terms of the sum. That means a sum for which $[U] = [\bar{U}]$. This condition is obviously satisfied by

$$[U] = 1/\phi + 1/\phi^2 + \phi + \phi^2 =\sim \langle n \rangle_F = 5 + \phi^3. \tag{125}$$

Next we normalize the sum by dividing by $\sim \langle n \rangle_F$. Thus

$$\begin{aligned} [U_R] &= [U]/(\sim \langle n \rangle) = \frac{1}{(n_F)\left(d_c^{(0)}\right)} + \frac{1}{\langle d_c^{(2)} \rangle} + \frac{1}{(2)\left(\langle n \rangle_F\right)} + \frac{D^{(+)}}{\langle \bar{\alpha}_0 \rangle} \\ &= \frac{1}{3+\phi^3} + \frac{1}{2} + \frac{1}{8.472359} + \frac{1}{13.708033}. \end{aligned} \tag{126}$$

Therefore, one finds that

$$[\bar{U}_R] = (3 + \phi^3) + 2 + 8.473591 + 13.7082039. \tag{127}$$

Thus

$$[\bar{U}_R]/2 = (13.7082039325). \tag{128}$$

Taking 10 copies of $[\bar{U}_R]/2$ one finds

$$(5)[\bar{U}_R] = (10)([\bar{U}_R]/2) = 137 + k_0 = \bar{\alpha}_0 \tag{129}$$

writing $[\bar{U}_R]/2$ explicitly one finds

$$\begin{aligned}(5)[\bar{U}_R] &= (10)(3+\phi^3) + (10) + (42+2k) + 68.5410965 \\ &= (16+k) + (10) + (42+2k) + 68.541096.\end{aligned} \tag{130}$$

Comparing with Eq. (107) term by term it is clear that the (10) in the above expression corresponds to the vacuum term $(10)(1+\phi)^0$ in Eq. (107) and that the total sum is exactly the same namely $\bar{\alpha}_0 = 137 + k_0$. Thus, our normalization of the vacuum of $\mathcal{E}^{(\infty)}(0) \to (1)$ as $[U] \to [\bar{U}]$ is fully justified as being mathematically identical to the above analysis. The last step in establishing complete validity of the Golden Mean renormalization of the equation of the four coupling constants is done by returning to the classical equation of the electroweak unification.

In this case the two U(1) and SU(2) coupling constants are given by

$$\bar{\alpha}_1 = (3/5)\bar{\alpha}_0 cos^2\theta_W \tag{131}$$

and

$$\bar{\alpha}_2 = \bar{\alpha}_0 sin^2\theta_W. \tag{132}$$

Formally speaking one finds $\bar{\alpha}_0$ by combining the two values as following:

$$\bar{\alpha}_0 = (\bar{\alpha}_1)(5/3) + \bar{\alpha}_2 = \bar{\alpha}_0(cos^2\theta_W + sin^2\theta_W) = (\bar{\alpha}_0)(1). \tag{133}$$

However, the so obtained values are too large and one needs the well-known "Higgs" modification.

Consequently, the two "running" coupling constants must be corrected to [19]

$$\bar{\alpha}_1 = \bar{\alpha}_1(\lambda_W) - \left(\frac{2}{\pi} + \frac{N_H}{20\pi}\right) ln\left(\frac{\lambda_W}{\gamma}\right) \tag{134}$$

and

$$\bar{\alpha}_2 = \bar{\alpha}_2(\lambda_W) + \left(\frac{5}{3\pi} - \frac{N_H}{12\pi}\right) ln\left(\frac{\lambda_W}{\gamma}\right). \tag{135}$$

In theory as well as experimentally we surely neither know the number of Higgs nor their masses. However, the variation in $\bar{\alpha}_0$ can be easily estimated at [19]

$$\bar{\alpha}(M_W) - \bar{\alpha} \simeq -9.2. \tag{136}$$

Taking only this value into account $\bar{\alpha}_1$ and $\bar{\alpha}_2$ are found to be

$$\bar{\alpha}_1 \simeq 59.2 \tag{137}$$

and

$$\bar{\alpha}_2 \simeq 29.1. \tag{138}$$

Now within $\mathcal{E}^{(\infty)}$ theory we proceed as following. First, we transform this fundamental equation to $\mathcal{E}^{(\infty)}$ space and find that

$$\bar{\alpha}_1 = (\bar{\alpha}_0)(\phi^3(1-\phi^3)) \tag{139}$$

and

$$\bar{\alpha}_2 = (\bar{\alpha}_0)(\phi^3(1-\phi^3)). \tag{140}$$

Second we disregard the contribution of the vacuum to $\bar{\alpha}_0$ which gives us a reduction of 10 which we equate to the correction given by the running constants equation and what is equivalent to disregarding the inverse strong coupling and gravity. Thus, we replace $\bar{\alpha}_0$ by

$$\bar{\alpha} = \bar{\alpha}_0 - 10 = 127 + k_0, \tag{141}$$

which is equal to

$$\bar{\alpha}|_{ew} = 127 + k_0. \tag{142}$$

Inserting back in $\bar{\alpha}_1$ and $\bar{\alpha}_2$ one finds

$$\bar{\alpha}_1 = (\bar{\alpha}|_{ew})(\phi^3(1-\phi^3)) = 60 \tag{143}$$

and

$$\bar{\alpha}_2 = (\bar{\alpha}|_{ew})(\phi^3) = 30. \tag{144}$$

Combining the two values one finds

$$\bar{\alpha}|_{ew} = \bar{\alpha} = (60)(1+\phi) + 30 = 97.08203934 + 30 = 127.082039325 = \bar{\alpha}_0 - 10. \tag{145}$$

Thus, we conjecture that the influence of running the coupling constants and taking the effect of the Higgs boson is equivalent to taking the inverse strong coupling or the gravity minimal inverse coupling $(\bar{\alpha}_g)_{min} = 1$ and $\bar{\alpha}_S = 8$ into account. One could even go one step further and say that the absence of gravity is most probably the real cause of all difficulties encountered in the standard model and including gravity in the right way simplifies things rather than introduce complications. Our vacuum gravity concept is thus related to that of A. Sakharov.

To show more clearly what we mean let us take $\bar{\alpha}(M_W) - \bar{\alpha}$ to be -9 rather than -10. That way $\bar{\alpha}|_{ew}$ becomes $\bar{\alpha}|_{ew} = 128.082039$. Now the inverse strong coupling is well established experimentally to be close to $\bar{\alpha} = 8$. That leaves for quantum gravity correction only one possibility namely $(\bar{\alpha}_g)_{min} = 1$ so that one finds

$$\bar{\alpha}_0 = (128 + k_0) + (8) + (1) = 137 + k_0. \tag{146}$$

This seems to agree almost completely with the P-Adic representation of $\|\bar{\alpha}_0\|$ as

$$\|\bar{\alpha}_0\|_{P=2} = \|(128) + (8) + (1)\| = \|137\|_{P=2} \equiv 1. \tag{147}$$

13 Some Experimental Conformation of the Prediction of Transfinite Heterotic String Theory and $\mathcal{E}^{(\infty)}$

Apart from the fact that almost all the results reported here are either directly of indirectly based on the experimentally well-founded electromagnetic fine structure constant, there are many other predictions of the theory of transfinite H-strings which are in excellent agreement with the known experimental values measured. We may mention her a view.

13.1 The Ratio of the Mass of M_μ and M_e

The experimental value of the ratio of the mass of the meyon to that fo the electron is [24, 25, 26, 22, 19]

$$M_\mu/M_e = 206.768262. \tag{148}$$

The present work theoretical prediction is given in terms of $\bar{\alpha}_0, S = \phi^3/2$ and $\overset{+}{C}h = \phi$ as

$$M_\mu/M_e = \bar{\alpha}_0 \left(\frac{1 + (\overset{+}{C}h\ /2S)}{1 + (2S/(3(1 + (2/3)S)))} \right) = \bar{\alpha}_0 \left(\frac{1 + \phi}{1 + (\phi^3/(3 + \phi^3))} \right) = 206.7231485, \tag{149}$$

which is in good agreement with the experimental value.

13.2 The Ratio of M_W and M_Z

The experimental value for the ratio of the masses of the W and Z bosons of the electroweak is [24, 25, 26, 22, 19]

$$M_W/M_Z = \frac{79.9}{91.77} = 0.87064896. \tag{150}$$

The present prediction is

$$M_W/M_Z = \sqrt{1 - \phi^3} = \sqrt{\frac{2D_T^{(10)}}{D_T^{(26)}}} = \sqrt{\frac{20}{26 + k}} = \sqrt{\frac{10}{13 + k/2}} = 0.874032049. \tag{151}$$

Again this is quite close to the experimental value.

13.3 The Weinberg Mixing Parameter

In the case of $sin^2\theta_W$, the experimental value at the electroweak scale is [24, 25, 26, 22, 19]

$$sin^2\theta_W \simeq 0.23, \tag{152}$$

while the theoretical value is

$$sin^2\theta_W = \phi^3 = 0.236067977. \tag{153}$$

13.4 The Mass of the b Quark

The observer value of the b quark mass M_b in relation to τ lepton is given by

$$M_b/M_\tau \simeq 2.38. \tag{154}$$

As an encouraging demonstration of the prediction power of the Cantorian scaling we give the prediction of $\mathcal{E}^{(\infty)}$ as

$$2 + \phi^2 = 2.381 \leq (M_b/M_\tau) \leq 2 + \phi = 2.618. \tag{155}$$

13.5 The Ratio of the Wavelength of w, z and the electron e

The measured values are

$$ln\left(\frac{\lambda_e}{\lambda_w}\right) = 11.65 \quad \text{and} ln\left(\frac{\lambda_e}{\lambda_z}\right) = 11.772. \tag{156}$$

The predicted value before symmetry breaking is

$$\sqrt{\bar{\alpha}_0} = \sqrt{137 + k_0} = 11.70820393. \tag{157}$$

Finally, the measure values for $log\left(\frac{\lambda_e}{\lambda_w}\right)$ and $log\left(\frac{m_w}{m_e}\right)$ are given by

$$log\left(\frac{\lambda_e}{\lambda_w}\right) = 5.059 \quad \text{and} \quad log\left(\frac{m_w}{m_e}\right) = 5.156165542. \tag{158}$$

The predicted value before symmetry breaking is

$$log\left(\frac{\lambda_e}{\lambda_w}\right) = log\left(\frac{m_w}{m_e}\right) = \sqrt[3]{\bar{\alpha}_0} = \sqrt[3]{137 + k_0} = 5.156165542. \tag{159}$$

One may note in this context that [5]

$$(5.059)(5.149) \simeq D_T^{(26)} = 26 + k \tag{160}$$

and

$$(5.156165542)^2 \simeq 26.586 \simeq D_T^{(26)} = 26 + k. \tag{161}$$

13.6 The Coupling Constants at the Electroweak Scale

The experimental values at the electroweak scale of the three nongravitational coupling constants are [24, 25, 26, 22, 19]

$$\begin{aligned} \bar{\alpha}_1(Z) &\simeq 59.2, \\ \bar{\alpha}_2(Z) &\simeq 30.1, \\ \bar{\alpha}_3(Z) &\simeq 8.9. \end{aligned} \tag{162}$$

The theoretical predictions of $\mathcal{E}^{(\infty)}$ are

$$\begin{aligned} \bar{\alpha}_1 &= (\bar{\alpha}|_{ew})(\phi(1-\phi^3)) = 60 \\ \bar{\alpha}_2 &= (\bar{\alpha}|_{ew})(\phi^3) = 30.236 \\ \bar{\alpha}_3 &= \bar{\alpha}_0 - \bar{\alpha}|_{ew} = \bar{\alpha}_3 = 10. \end{aligned} \tag{163}$$

14 Connection between the Geometry of Dynamical Triangulation and Strings

In their book [27] Ambjørn et al. gave the following formula:

$$b_0(n) = \frac{1\pi}{cos^{-1}(1/n)}. \tag{164}$$

[5]For a line of bundle the Riemann-Roch formula for K_S and $S = S + \phi^3$ gives $\chi = S(S-1) + 4 = (5+\phi^3)(4+\phi^3) + 4 = 26.18033989$.

It is quite interesting to see how $b_0(n)$ gives some of the most important topological invariants of $\mathcal{E}^{(\infty)}$ space and Heterotic string theory.

First setting $n = n_F = \infty$ which is the formal dimension of $\mathcal{E}^{(\infty)}$ one finds that $cos^{-1}(0) = \pi/2$ and thus

$$b_0(0) = 4, \tag{165}$$

which is the topological dimension of $\mathcal{E}^{(\infty)}$ for which we have the important Hausdorff dimension of $\mathcal{E}^{(\infty)}$ namely $d_c^{(4)} = 4 + \phi^3 =\sim \langle n \rangle$.

Second for $n = 2$ one finds

$$b_0(2) = 6, \tag{166}$$

which is the dimension of the compactified manifold of the second Heterotic compactification from 10 down to 4. The corresponding transfinite dimension is found from $n = 0.52622546$ to be $b_0 = 6 + k = 6.18033989$.

The 10 dimensionality is found for the fundamental $\mathcal{E}^{(\infty)}$ value $n = 1 + \phi^3$ to be

$$b_0(1 + \phi^3) = \frac{2\pi}{0.62831853} = 10, \tag{167}$$

which is the exact $D^{(+)} = D^{(10)}$ in the case of the Heterotic and transfinite Heterotic string theory.

Finally for $n = 1 + (\phi^3/8)$ one finds that

$$b_0\left(1 + \frac{\phi^3}{8}\right) = \frac{2\pi}{cos^{-1}0.971337290} = 26.17962726 \simeq 26 + k \simeq 26.18033989, \tag{168}$$

which is very close to the exact value of the transfinite Heterotic string theory namely $26 + k$. Now the reason we look at the behaviour of $b_0(n)$ is that this function is relevant to the geometry of triangulation which is used in quantum gravity. The fact that relevant topological invariants of H-string appear when using the Golden Mean dimensions of $\mathcal{E}^{(\infty)}$ shows the strong connection between H-strings and $\mathcal{E}^{(\infty)}$ on the one side and the topology of quantum space-time on the other including the very important two fundamental dimensions $4 + \phi^3$ for $n = 11.43828103$ and $n = n_F = 5$ for $n = 3 + \phi^3$.

15 Connection to the Four-colour Problem and Beraha Numbers

The Beraha number plays an important role in the theoretical poof of the famous four-colour problem. In turn, this problem is related to the topology of space and it is therefore not entirely surprising that the Beraha numbers are related to the Golden as well as the topological invariants of Heterotic strings. The Beraha numbers are given by [28]

$$B(n) = 2 + 2cos(2\pi/n). \tag{169}$$

The first interesting point is that for both $n = 1$, which is the string dimension and for $n = \infty$, which is the formal dimension of $\mathcal{E}^{(\infty)}$ we have $B(1) = B(\infty) = 4$.

In addition for $n = 4, 5, 6$ and 10 we have $B(n)$ equal to $2, 2 + \phi, 3$ and $3 + \phi$, respectively. Finally, we note that $D_T^{(-)} = 26 + k$ of the transfinite Heterotic string may be defined using

$$L = n(B(n)) - n \tag{170}$$

for $n = 10$ which gives

$$L|_{10} = 10(3 + \phi) - 10 = 36 + k - 10 = 26 + k = 26.18033989 = D_T^{(-)}. \tag{171}$$

16 Conclusion

Feynman wrote a paper once which was entitled "Simulating physics with computer". In the present work we feel that one could paraphrase Feynman's stimulating title to "Simulating physics without a computer". This is possible because the immense richness coupled with analytical simplicity encountered in working with transfinite Cantor sets seems to enable us to reproduce almost all relevant physical constants, pertinent to particle physics without using any complex numbers, matrices or operator algebra or in fact any of the advanced sophisticated mathematics which is usually employed in this field. In theoretical terms we have used as our main analytical tool, transfinite sets instead of symmetry groups. In practical terms we have extented the classical Heterotic string theory to a transfinite Heterotic string theory. Without the pioneering work of Green, Schwarz, Witten and Gross such extension would have been impossible to even contemplate. The results of the present work seem to confirm that many of the predictions of string theory can be confirmed experimentally and that Heterotic string in the transfinite form reflects a substantial part of the physical reality of the quantum world.

Our general conclusion is that all coupling constants are independent from details of the "physical" model. They depend mainly on the topology of quantum space-time and we do not need to solve a differential equation or write a Lagrangian in order to determine them exactly.

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Quantum Interfaces

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Abstract

Rational agents acting as observers use "knowables" to construct a vision of the outside world. Thereby, they are bound by the information exchanged with what they consider as objects. The cartesian cut or, in modern terminology, the interface mediating this exchange, is again a construction. It serves as a "scaffolding," an intermediate construction capable of providing the necessary conceptual means.

An attempt is made to formalize the interface, in particular the quantum interface and quantum measurements, by a symbolic information exchange. A principle of conservation of information is reviewed and a measure of information flux through the interface is proposed.

We cope with the question of why observers usually experience irreversibility in measurement processes if the evolution is reversible, i.e., one-to-one. And why should there be any meaningful concept of classical information if there is merely quantum information to begin with? We take the position here that the concept of irreversible measurement is no deep principle but originates in the practical inability to reconstruct a quantum state of the object.

Many issues raised apply also to the quantum's natural double, virtual reality.

An experiment is proposed to test the conjecture that the self is transcendent.

Reality construction by "knowables"

Otto Rössler, in a thoughtful book [1], has pointed to the significance of object-observer interfaces, a topic which had also been investigated in other contexts (cf., among others, refs. [2, 3, 4, 5, 6, 7, 8]). By taking up this theme, the following investigation is on the epistemology of interfaces, in particular of quantum interfaces. The informal notions of "cartesian cut" and "interface" are formalized. They are then applied to observations of quantum and virtual reality systems.

A generic interface is presented here as any means of communication or information exchange between some "observer" and some observed "object." The "observer" as well as the "object" are subsystems of some larger, all-encompassing system called "universe."

Generic interfaces are totally symmetric. There is no principal, *a priori* reason to call one subsystem "observer" and the other subsystem "object." The denomination is arbitrary. Consequently, "observer" and "object" may switch identities.

Take, for example, an impenetrable curtain separating two parts of the same room. Two parties — call them Alice and John — are merely allowed to communicate by sliding through papers below the curtain. Alice, receiving the memos emanating from John's side of the curtain, thereby effectively constructs a "picture" or representation of John and *vice versa*.

The cartesian cut spoils this total symmetry and arbitrariness. It defines a distinction between "observer" and "object" beyond doubt. In our example, one agent — say Alice — becomes the observer while the other agent becomes the observed object. That, however, may be a very arbitrary convention which not necessarily reflects the configuration properly.

A cartesian cut may presuppose a certain sense of "rationality," or even "consciousness" on the "observer's" side. We shall assume that some observer or agent exists which, endowed with rational intelligence, draws conclusions on the basis of certain premises, in particular the agent's *state of knowledge*, or "knowables" to (re)construct "reality." Thereby, we may imagine the agent as some kind of robot, some mechanistic or algorithmic entity. (From now on, "observer" and "agent" will be used as synonyms.) Note that the agent's state of knowledge may not necessarily coincide with a complete description of the observed system, nor may the agent be in the possession of a complete description of its own side of the cut. Indeed, it is not unreasonable to speculate that certain things, although knowable "from the outside" of the observer-object system, are principally unknowable to an intrinsic observer [7].

Although we shall come back to this issue later, the notion of "consciousness" will not be reviewed here. We shall neither speculate exactly what "consciousness" is, nor what may be the necessary and sufficient conditions for an agent to be ascribed "consciousness". Let it suffice to refer to two proposed tests of consciousness by Turing and Greenberger [9].

With regards to the type of symbols exchanged, we shall differentiate between two classes: classical symbols, and quantum symbols. The cartesian cuts mediating classical and quantum symbols will be called "classical" or "quantum" (cartesian) cuts, respectively.

Formalization of the cartesian cut

The task of formalizing the heuristic notions of "interface" and "cartesian cut" is, at least to some extent, analogous to the formalization of the informal notion of "computation" and "algorithm" by recursive function theory via the Church-Turing thesis.

In what follows, the informal notions of interface and cartesian cut will be formalized by symbolic exchange; i.e., by the mutual communication of symbols of a formal alphabet. In this model, an object and an observer alphabet will be associated with the observed object and with the observer, respectively.

Let there be an *object alphabet* $\mathcal{S}$ with symbols $s \in \mathcal{S}$ associated with the outcomes or "message" of an experiment possible results. Let there be an *observer alphabet* $\mathcal{T}$ with symbols $t \in \mathcal{T}$ associated with the possible inputs or "questions" an observer can ask.

At this point we would like to keep the observer and object alphabets as general as possible, allowing also for quantum bits to be transferred. Such quantum bits, however, have no direct operational meaning, since they cannot be completely specified. Only classical bits have a (at least in principle) unambiguous meaning, since they can be completely specified, copied and measured. We shall define an interface next.

- An interface I is an entity forming the common boundary between two parts of a system, as well as a means of information exchange between those parts.

- By convention, one part of the of the system is called "observer" and the other part "object."

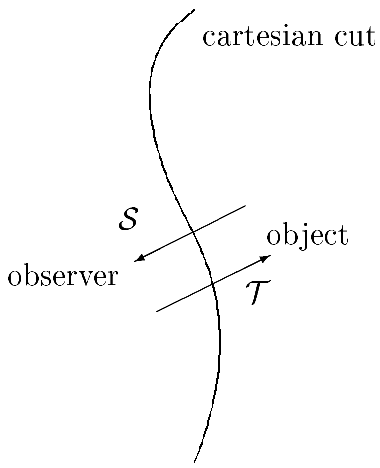

Figure 1: *An interface as a cartesian cut between observer and object. The information flow across the interface is formalized by symbols.*

- Information between the observer and the object via the interface is exchanged by symbols. The corresponding functional representation of the interface is a map $I : \mathcal{T} \mapsto \mathcal{S}$, where $\mathcal{T}$ and $\mathcal{S}$ are the observer and the object alphabets, respectively. Any such information exchange is called *"measurement."*

- The interface ist *total* in the sense that the observer receives *all* symbols emanating from the object. (However, the object needs not receive all symbols emanating from the observer.)

- Types of interface include purely classical, quasi-classical, and purely quantum interfaces.

  – Classical scenario I: A classical interface is an interface defined in a classical system, for which the symbols in $\mathcal{S}$ and $\mathcal{T}$ are classical states encodable by classical bits "0" and "1" corresponding to "`true`" and "`false`," respectively. This kind of binary code alphabet corresponds to yes-no outcomes to dichotomic questions; experimental physics in-a-nutshell. An example for a dichotomic outcome associated with is "there is a click in a counter" or "there is no click in a counter," respectively.

  – Quasi-classical scenario II: a quasi-classical interface is an interface defined in a quantum system, whereby the symbols in $\mathcal{S}$ and $\mathcal{T}$ are classical states encoded by classical bits. This is the picture most commonly used for measurements in quantum mechanics.

  – Quantum scenario III: A quantum interface is an interface defined in a quantized system. In general, the quantum symbols in $\mathcal{S}$ and $\mathcal{T}$ are quantum states.

Informally, in a measurement, the object "feels" the observer's question (in $\mathcal{T}$) and responds with an answer (in $\mathcal{S}$) which is felt by the observer (cf. Fig. 1).

The reader is encouraged to view the interface not as a static entity but as a *dynamic* one, through which information is constantly piped back and forth the observer and the object and the resulting time flow may also be viewed as the dynamic evolution of the system as a whole. In what follows it is important to stress that we shall restrict our attention to cases for which the interface is total; i.e., the observer receives *all* symbols emanating from the object.

One-to-one quantum state evolution and "haunted" measurements

On a microphysical scale, we do not wish to restrict quantum object symbols to classical states. The concept pursued here is rather that of the quantum scenario III: a uniform quantum system with unitary, and thus reversible, one-to-one evolution. Any process within the entire system evolves according to a reversible law represented by a unitary time evolution $U^{-1} = U^{\dagger}$. As a result, the interface map I is one-to-one; i.e., it is a bijection.

Stated pointedly, we take it for granted that the wave function of the entire system—including the observer and the observed object separated by the cartesian cut or interface—evolves one-to-one. Thus, in principle, previous states can be reconstructed by proper reversible manipulations.

In this scenario, what is called "measurement" is merely an exchange of quantum information. In particular, the observer can "undo" a measurement by proper input of quantum information via the quantum interface. In such a case, no information, no knowledge about the object's state can remain on the observer's side of the cut; all information has to be "recycled" completely in order to be able to restore the wave function of the object entirely in its previous form.

Experiments of the above form have been suggested [10] and performed under the name "haunted measurement" and "quantum eraser" [11]. These matters are very similar to the opening, closing and reopening of Schrödinger's catalogue of expectation values [12, p. 823]: At least up to a certain magnitude of complexity, any measurement can be "undone" by a proper reconstruction of the wave-function. A necessary condition for this to happen is that *all* information about the original measurement is lost. In Schrödinger's terms, the prediction catalog (the wave function) can be opened only at one particular page. We may close the prediction catalog before reading this page. Then we can open the prediction catalog at another, complementary, page again. By no way we can open the prediction catalog at one page, read and (irreversible) memorize the page, close it; then open it at another, complementary, page. (Two non-complementary pages which correspond to two co-measurable observables can be read simultaneously.)

Where exactly is the interface located?

The interface has been introduced here as a scaffolding, an auxiliary construction to model the information exchange between the observer and the observed object. One could quite justifyable ask (and this question *has* indeed been asked by Professor Bryce deWitt), "where exactly *is* the interface in a concrete experiment, such as a spin state measurement in a Stern-Gerlach apparatus?"

We take the position here that the location of the interface very much depends on the physical proposition which is tested and on the conventions assumed. Let us take, for example, a statement like

"the electron spin in the z-direction is up."

In the case of a Stern-Gerlach device, one could locate the interface at the apparatus itself. Then, the information passing through the interface is identified with the way the particle took.

One could also locate the interface at two detectors at the end of the beam paths. In this case, the informaton penetrating through the interface corresponds to which one of the two detectors (assumed lossles) clicks (cf. Fig. 2).

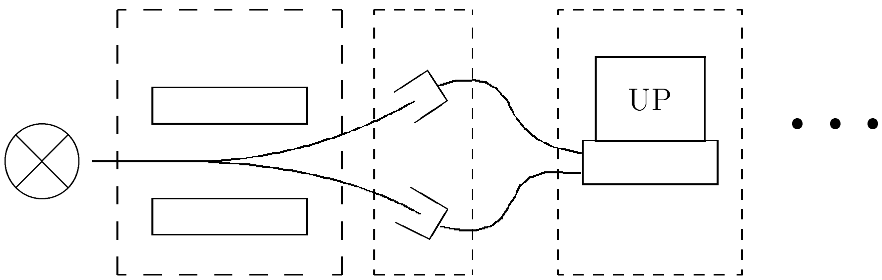

Figure 2: *Where exactly is the interface located? Different dashed boxes indicate different possibilities to locate it.*

One could also situate the interface at the computer interface card registering this click, or at an experimenter who presumably monitors the event (cf. Wigner's friend [13]), or at the persons of the research group to whom the experimenter reports, to their scientific peers, and so on.

Since there is no material or real substrate which could be uniquely identified with the interface, in principle it could be associated with or located at anything which is affected by the state of the object. The only difference is the reconstructibility of the object's previous state (cf. below): the "more macroscopic" (i.e., many-to-one) the interface becomes, the more difficult it becomes to reconstruct the original state of the object.

From one-to-one to many-to-one

If the quantum evolution is reversible, how come that observers usually experience irreversibility in measurement processes? We take the position here that *the concept of irreversible measurement is no deep principle but merely originates in the practical inability to reconstruct a quantum state of the object.*

Restriction to classical state or information exchange across the quantum interface—the quasi-classical scenario II—effectively implements the standard quantum description of the measurement process by a classical measurement apparatus: there exists a clear distinction between the "internal quantum box," the quantum object—with unitary, reversible, one-to-one internal evolution—and the classical symbols emanating from it. Such a reduction from the quantum to the classical world is accompanied by a loss of internal information "carried with the quantum state." This effectively induces a many-to-one transition associated with the measurement process, often referred to as "wave function collapse." In such a case, one and the same object symbol could have resulted from many different quantum states, thereby giving raise to irreversibility and entropy increase.

But also in the case of a uniform one-to-one evolution (scenario I), just as in classical statistical physics, reconstruction greatly depends on the possibility to "keep track" of all the information flow directed at and emanating from the object. If this flow is great and spreads quickly with respect to the capabilities of the experimenter, and if the reverse flow of information from the observer to the object through the interface cannot be suitably controlled [14, 15] then the chances for reconstruction are low.

This is particularly true if the interface is not total: in such a case, information flows off the object to regions which are (maybe permanently) outside of the observer's control.

The possibility to reconstruct a particular state may widely vary with technological capabilities which often boil down to financial commitments. Thus, irreversibility of quantum measurements by interfaces appears as a gradual concept, depending on conventions and practical necessities, and not as a principal property of the quantum.

In terms of coding theory, the quantum object code is sent to the interface but is not properly interpreted by the observer. Indeed, the observer might only be able to understand a "higher," macroscopic level of physical description, which subsumes several distinct microstates under one macro-symbol (cf. below). As a result, such macro-symbols are no unique encoding of the object symbols. Thus effectively the interface map I becomes many-to-one.

This also elucidates the question why there should be any meaningful concept of classical information if there is merely quantum information to begin with: in such a scenario, classical information appears as an effective entity on higher, intermediate levels of description. Yet, the most fundamental level is quantum information.

Do conscious observers "unthink"?

Because of the one-to-one evolution, a necessary condition for reconstruction of the object wave function is the complete restoration of the observer wave function as well. That is, the observer's state is restored to its previous form, and no knowledge, no trace whatsoever can be left behind. An observer would not even know that a "measurement" has taken place. This is hard to accept, in particular if one assumes that observers have consciousness which are detached entities from and not mere functions of the quantum brain. Thus, in the latter case, one might be convinced that conscious observers "unthink" the measurement results in the process of complete restoration of the wave function. In the latter case, consciousness might "carry away" the measurement result via a process distinct from the quantum brain. (Cf. Wigner's friend [13].)

But even in this second, dualistic, scenario, the conscious observer, after reconstruction of the wave function, would have no direct proof of the "previously measured fact," although subsequent measurements might confirm his allegations. This amounts to a proposal of an experiment involving a conscious observer (*not* merely a rational agent) and a quantized object. The experiment tests the metaphysical claim that consciousness exists beyond matter [16]. As sketched above, the experiment involves four steps.

- Step I: The conscious observer measures some quantum observable on the quantized object which occurs irreducibly random according to the axioms of quantum theory. As a consequence, the observer "is aware of" the measurement result and ascribes to it an "element of physical reality" [17].

- Step II: The original quantum state of the quantized object is reconstructed. Thereby, all physical information about the measurement result is lost. This is also true for the brain of the conscious observer. Let us assume that the observer "is still aware of" the measurement result. In this case, the observer ascribes to it an "element of metaphysical reality."

- Step III: The observer guesses or predicts the outcome of the measurement despite the fact that no empirical evidence about the outcome of the previous measurement exists.

- Step IV: The measurement is "re-done" and the actual measurement result is compared with the conscious observer's prediction in step III. If the prediction and the actual outcome do not coincide, the hypothesis of a consciousness beyond matter is falsified.

As an analogy, one might think of a player in a virtual reality environment. Although at the observation level of the virtual reality, the measurement is undone, the player himself "knows" what has been there before. This knowledge, however, has been passed on to another interface which is not immanent with respect to the virtual reality. That is, it cannot be defined by intrinsic (endo-) means. Therefore, it can be called a *transcendent interface* with respect to the virtual reality. However, if we start with the real universe of the player, then the same interface becomes intrinsically definable. The hierarchical structure of meta-worlds has been the subject of conceptual and visual art [18, 19, 20] and literature [21].

Parallels in statistical physics: from reversibility to irreversibility

The issue of "emergence" of irreversibility from reversible laws is an old one and subject of scientific debate at least since Boltzmann's time [22]. We shall shortly review an explanation in terms of the emergence of many-to-one (irreversible) evolution relative to a "higher" macroscopic level of description from one-to-one (reversible) evolution at a more fundamental microscopic "complete" level of description. These considerations are based on the work of Jaynes [23, 24], Katz [25] and Hobson [26], among others. See Buček *et al.* [27] for a detailed review with applications.

In this framework, the many-to-one and thus irreversible evolution is a simple consequence of the fact that many different microstates, i.e., states on the fundamental "complete" level of physical description, are mapped onto a *single* macroscopic state (cf. Fig. 3). Thereby, knowledge about the microphysical state is lost; making impossible the later reconstruction of the microphysical state from the macroscopic one. (In the example drawn in Fig. 3, observation of the "macrostate" II could mean that the system is either in microstate 1 or 2.) on some intermediate, "higher" level of physical description, whereas it remains reversible on the complete description level.

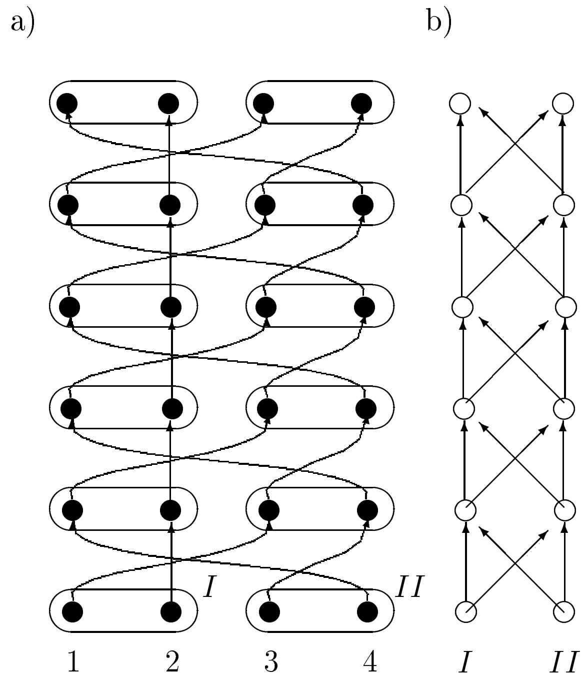

Figure 3: *Full circles represents the "complete" level of description, open circles or the corresponding ovals represent intermediate or macroscopic levels of description. The microphysical states* $1, 2$ *are mapped onto* I *and* $3, 4$ *are mapped onto* II *by a many-to-one mapping. a) The temporal evolution in terms of the microstates is one-to-one; b) The evolution with respect to the macro-states is irreversible.*

Here, just as in the quantum interface case, irreversibity in statistical physics is a gradual concept, very much depending on the observation level, which depends on conventions and practical necessities. Yet again, in principle the underlying complete level of description is one-to-one. As a consequence, this would for example make possible the reconstruction of the Library of Alexandria if one takes into account all smoky emanations thereof. The task of "reversing the gear," of reconstructing the past and constructing a different future, is thus not entirely absurd. Yet fortunately or unfortunately, for all practical purposes it remains impossible.

Principle of information conservation

In another scenario (closely related to scenario I), classical information is a primary entity. The quantum is obtained as an effective theory to represent the state of knowledge, the "knowables," of the observer about the object [28, 29, 30]. Thereby, quantum information appears as a derived theoretical entity, very much in the spirit of Schrödinger's perception of the wave function as a catalogue of expectation values (cf. above).

The following circular definitions are assumed.

- An elementary object carries one bit of (classical) information [28].
- n elementary objects carry n bits of (classical) information [28]. The information content present in the physical system *is exhausted* by the n bits given; nothing more can be gained by any perceivable procedure.
- Throughout temporal evolution, the amount of (classical) information measured in bits is conserved.

One immediate consequence seems a certain kind of irreducible randomness associated with requesting from an elementary object information which has not been previously encoded therein. We may, for instance, think of an elementary object as an electron which has been prepared in spin state "up" in some direction. If the electron's spin state is measured in another direction, this must give rise to randomness since the particle "is not supposed to know" about this property. Yet, we may argue that in such a case the particle might respond with no answer at all, and not with the type of irreducible randomness which, as we know from the computer sciences [31, 32], is such a preciously expensive quality.

One way to avoid this problem is to assume that the apparent randomness does not originate from the object but is a property of the interface: the object always responds to the question it has been prepared for to answer; but the interface "translates" the observer's question into the appropriate form suitable for the object. In this process, indeterminism comes in.

As a result of the assumption of the temporal conservation of information, the evolution of the system has to be one-to-one and, for finite systems, a permutation.

Another consequence of the conservation of information is the possibility to define continuity equations. In analogy to magnetostatics or thermodynamics we may represent the information flow by a vector which gives the amount of information passing per unit area and per unit time through a surface element at right angles to the flow. We call this the *information flow density* $\mathbf{j}$. The amount of information flowing across a small area ΔA in a unit time is

$$\mathbf{j} \cdot \mathbf{n}\, \Delta A,$$

where $\mathbf{n}$ is the unit vector normal to ΔA. The information flow density is related to the average flow velocity v of information. In particular, the information flow density associated with an elementary object of velocity v per unit time is given by $\mathbf{j} = \rho v$ bits per second, where ρ stands for the information density (measured in bits/m^3). For N elementary objects per unit volume carrying one bit each,

$$\mathbf{j} = Nvi.$$

Here, i denotes the elementary quantity of information measured in bit units. The information flow I is the total amount of information passing per unit time through any surface A; i.e.,

$$I = \int_A \mathbf{j} \cdot \mathbf{n}\, dA.$$

We have assumed that the cut is on a closed surface $\mathcal{A}_c$ surrounding the object. The conservation law of information requires the following continuity equation to be valid:

$$\int_{\mathcal{A}_c} \mathbf{j} \cdot \mathbf{n}\, dA = -\frac{d}{dt}(\text{Information inside})$$

or, by defining an information density ρ and applying Gauss' law,

$$\nabla \cdot \mathbf{j} = -\frac{d\rho}{dt}.$$

To give a quantitative account of the present ability to reconstruct the quantum wave function of single photons, we analyze the "quantum eraser" paper by Herzog, Kwiat, Weinfurter and Zeilinger [11]. The authors report an extension of their apparatus of $x = 0.13$ m, which amounts to an information passing through a sphere of radius x of

$$I_{\text{qe}} = 4\pi x^2 c\rho = 6 \times 10^7 \text{bits/second}.$$

Here, $\mathbf{j} = c\rho$ (c stands for the velocity of light in vacuum) with $\rho = 1\text{bit/m}^3$ has been assumed. At this rate the reconstruction of the photon wave function has been conceivable.

We propose to consider I as a measure for wave function reconstruction. In general, I will be astronomically high because of the astronomical numbers of elementary objects involved. Yet, the associated diffusion velocity v may be considerably lower than c.

Let us finally come back to the question, *"why should there be any meaningful concept of classical information if there is merely quantum information to begin with?"* A tentative answer in the spirit of this approach would be that *"quantum information is merely a concept derived from the necessity to formalize modes of thinking about the state of knowledge of a classical observer about a classical object. Although the interface is purely classical, it* appears *to the observer as if it were purely quantum or quasi-classical."*

Virtual reality as a quantum double

Just as quantum systems, virtual reality universes can have a one-to-one evolution. We shall shortly review reversible automata [33, 34] which are characterized by the following properties:

- a finite set S of states,
- a finite input alphabet I,
- a finite output alphabet O,
- temporal evolution function $\delta : S \times I \to S$,

$S\backslash I$	δ 1	2	3	λ 1	2	3
s_1	s_1	s_1	s_2	1	2	2
s_2	s_2	s_2	s_1	1	3	3

Table 1: Transition and output table of a reversible automaton with two states $S = \{s_1, s_2\}$ and three input/output symbols $I = \{1, 2, 3\}$. Neither its transition nor its output function is one-to-one.

- output function $\lambda : S \times I \to O$.

The combined transition and output function U is reversible and thus corresponds to a permutation:

$$U : (s, i) \to (\delta(s, i), \lambda(s, i)), \tag{1}$$

with $s \in S$ and $i \in I$. Note that neither δ nor λ needs to be a bijection.

As an example, take the perturbation matrix

$$U = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{pmatrix}.$$

It can be realized by a reversible automaton which is represented in Table 1. Neither its evolution function nor its transition function is one-to-one, since for example $\delta(s_1, 3) = \delta(s_2, 1) = s_2$ and $\lambda(s_1, 2) = \lambda(s_1, 3) = 2$. Its flow diagram throughout five evolution steps is depicted in Figure 3, where the microstates $1, 2, 3, 4$ are identified by $(s_1, 1)$, $(s_1, 2)$, $(s_2, 1)$ and $(s_2, 2)$, respectively.

Metaphysical speculations

Although the contemporaries always attempt to canonize their relative status of knowledge about the physical world, from a broader historical perspective this appears sentimental at best and ridiculous at worst. The type of natural sciences which emerged from the Enlightenment is in a permanent scientific revolution. As a result, scientific wisdom is always transitory. Science is and needs to be in constant change.

So, what about the quantum? Quantum mechanics challenges the conventional rational understanding in the following ways:

- by allowing for randomness of single events, which collectively obey quantum statistical predictions;

- by the feature of complementarity; i.e., the mutual exclusiveness of the measurement of certain observables termed complementary. Complementarity results in a non-classical, non-distributive and thus non-boolean event structures;

- by non-standard probabilities which are based on non-classical, non-boolean event structures. These quantum probabilities cannot be properly composed from its proper parts, giving rise to the so-called "contextuality."

I believe that, just as so many other formalisms before, also quantum theory will eventually give way to a more comprehensive understanding of fundamental physics, although at the moment it appears almost heretic to pretend that there is something "beyond the quantum". Exactly how this progressive theory beyond the quantum will look like, nobody presently can say [35]. (Otherwise, it would not be beyond anymore, but there would be another theory lurking beyond the beyond.) In view of the quantum challenges outlined before, it may be well worth speculating that the revolution will drastically change our perception of the world.

It may well be that epistemic issues such as the ones reviewed here will play an important role therein. I believe that the careful analysis of conventions which are taken for granted and are never mentioned in standard presentations of the quantum and relativity theory [36] will clarify some misconceptions.

Are quantum-like and relativity-like theories consequences of the modes we use to think about and construct our world? Do they not tell us more about our projections than about an elusive reality?

Of course, physical constants such as Planck's constant or the velocity of light *are* physical input. But the *structural form* of the theories might be conventional.

Let me also state that one-to-one evolution is a sort of "Borgesian" nightmare, a hermetic prison: the time evolution is a constant permutation of one and the same "message" which always remains the same but expresses itself through different forms. Information is neither created nor discarded but remains constant at all times. The implicit time symmetry spoils the very notion of "progress" or "achievement," since what is a valuable output is purely determined by the subjective meaning the observer associates with it and is devoid of any syntactic relevance. In such a scenario, any gain in knowledge remains a merely subjective impression of ignorant observers.

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Quasi-Order of Resources – a New Concept for the Thermodynamic Theory of Quantum State Preparation

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Abstract

Every preparation of non-equilibrium states in microphysical systems has to be driven by other non-equilibrium physical systems, the 'resources'. *Large* deviations from thermal equilibrium can only be generated by resources also showing *large* deviations. We show that the precise preparation of pure quantum states has to be driven by an energy source with 'good' statistical properties. We present a general formalism for classifying quantum energy sources with respect to their ability for driving other quantum systems to non-equilibrium states. This leads to a quasi-order of resources which implies essentially stronger statements than those given by the linear order of resources defined by their *free energy*.

1 Introduction

Finding new techniques for the manipulation of microscopic particles is a challenging problem for modern research. For instance the realization of quantum computers would require the ability to control and manipulate quantum systems with high precision and flexibility. After all, during the last decade there has been considerable experimental progress in manipulating *simple* quantum systems (e.g. see[7, 8, 1, 2]). Such systems can be for instance the spin degree of freedom of a single nucleolus, the inner degrees of freedom of a single atom or ion, or the quantum state of a field mode. At the moment it is not amazing that the experimental expense for controlling the quantum world is huge compared to the tininess of the controlled system, one should rather consider recent experimental success as pioneer work and expect that miniaturized devices for controlling quantum systems will be developed in the future. This miniaturization might be essential for information technology: Even if future computation will not be quantum computation in the sense that it makes use of the quantum superposition principle it might be scaled down to the quantum level nevertheless. In this case computation requires also flexible manipulations of quantum systems by devices which are small themselves. At the moment it is unknown what kind of fundamental bounds on scaling down the *controlling* system might appear. After all, the process of scaling down is contradicting the macroscopic limit which is required for having *classical fields* constituting a control mechanism. In particular, it is of interest whether the amount of *energy* for manipulating the microscopic world can be reduced arbitrarily and there is one well-known bound given by the second law of thermodynamics: Preparing certain pure quantum state from a mixed one requires energy since it is connected with the extraction of entropy. In other words: the reason why state preparation requires energy is the same why a refrigerator requires energy. In the context of computation this observation had first been formulated by Landauer [5], who noticed that the initialization of a memory which is in an unknown state requires at least the energy $\ln 2kT$ per bit, where k

is Boltzmann's constant and T the environment's temperature[6]. However, the amount S of entropy which has to be extracted for preparing single quantum systems is tiny (for a two-level system it is at most one bit!) hence the energy SkT is negligible. For our purpose, we rather care about the fact that an energy source is required *at all* than about the tiny amount of energy which has to be supplied. The reason why we consider this as important is that we could show that it is not sufficient to have an energy source which can supply the required amount of energy, it is rather necessary that the source provides energy of *high quality* in a sense which is formalized by the quasi-order of resources explained below (for further details see [3]). This 'quality' depends in a sophisticated way on statistical properties of the energy source, in other words, it depends on *our knowledge* about the state of the resource system. It can be shown that *reliable* state preparation can only be driven by an energy source about which we have *reliable* knowledge in a certain sense. We consider this as a refinement of the second law, since one of the central ideas of the latter is the fact that the worth of an amount of energy depends on our *knowledge* about the state of the energy source. Accordingly, the inner energy of such a thermal heat bath is completely worthless without making use of other systems with deviations from equilibrium. This can be expressed by the quantity 'free energy': An energy source containing the energy E and the entropy S contains the free energy $E - SkT$, i.e., the worthless part of the energy is subtracted. The amount SkT of energy would be necessary in order to bring the energy source into a perfectly known pure state. The quasi-order is a refinement of these statements in the sense that the useability of energy resources cannot be expressed by a single quantity like free energy: For the purpose of exact state preparation we do not have the statement like 'the amount $E - kTS$ of inner energy[7] is useable', we rather have statements like 'the energy source is able to drive a unprecise preparation procedure but it cannot drive a precise one'. It is even possible that an energy source is able to drive *many unreliable* preparations but is not able to drive *a single reliable* one.

2 The Quasi-Order

We formalize what means that 'an energy source is able to drive' a preparation process. Our model consists of three quantum systems:

- The *resource system* which is the energy source driving the process. It is initially in the mixed state ρ (see appendix 3.1.2). After the preparation procedure its state is closer to the thermal equilibrium state γ (see appendix 3.1.5), because the free energy has been used up.

- The *environment* which can be any quantum system starting in its equilibrium state $\hat{\gamma}$. This is not a restriction of the theory, it is rather our point of view, since every system in a non-equilibrium state should be regarded as resources. The environment should be thought of as a large quantum system.[8]

- The *target system* which is initially in its thermal equilibrium state (see appendix) $\tilde{\gamma}$ and should be driven into another state $\tilde{\rho}$.

Now we define:

[6]Here and in the following T is a fixed reference temperature. By 'thermal equilibrium states' we mean states with temperature T.

[7]Here and in the following we use the convention that the free energy of the equilibrium state is zero.

[8]It might possess an infinite dimensional Hilbert space. In our formalism, we work therefore with a sequence of finite dimensional Hilbert spaces.

Definition 1 *The resource system is able to drive the preparation of $\tilde{\rho}$ in the target system if and only if there is an environment such that there is an energy conserving physical process involving the three systems described above such that the target system ends up in the state $\tilde{\rho}$. We write*

$$(\rho, \gamma) \geq (\tilde{\rho}, \tilde{\gamma})$$

for short. For a formal definition see appendix 3.2.1.

One may wonder why γ appears in the notation although it appears neither in the initial nor in the final state of the composed system. Actually γ appears in a subtile way since the term 'energy conserving' refers to the Hamiltonian of the resource system which is (up to an irrelevant constant) determined by γ. (see appendix 3.1.5)

Due to the conservation of free energy the final amount of free energy of the target system can never exceed the initial amount of the resource system. This gives a necessary condition for $(\rho, \gamma) \geq (\tilde{\rho}, \tilde{\gamma})$ which is well-known in standard thermodynamics. But this condition is by no means sufficient. In appendix 3.2.2 and 3.2.3 we give some necessary conditions formulated in the language of quantum stochastics which are hard to express in another way. Under the special assumption that $\tilde{\rho}$ or ρ are time-invariant states we could characterize the quasi-order in a quite explicit way.

An important observation is that it is not a linear order, i.e., we do not have $(\rho, \gamma) \geq (\tilde{\rho}, \tilde{\gamma})$ or $(\tilde{\rho}, \tilde{\gamma}) \geq (\rho, \gamma)$ necessarily. We illustrate this by the following example:

Assume we want to prepare a two-level system with energy gap E in such a way that the upper level is occupied with probability 1. Assume the preparation should be driven by a collection of n identical two-level systems having the energy gap E as well. Furthermore assume that the occupation probability for their upper levels is $1 - \epsilon$ each. One might think that $n = 2$ copies would be sufficient to drive this preparation since their free energy is enough, even $n = 1$ system provides *almost* enough free energy. Nevertheless, as shown in [3], the demanded exact preparation can only be attained in the limit $n \to \infty$, an observation we called the 'thermodynamic cost of reliability'. The state of the resource system is *too unprecise* to enable a *precise* preparation. Conversely, one two-level system having occupation probability one for its uppper state cannot drive the preparation of more than one two-level system with occupation probability $1 - \epsilon$ since this would require an amount of free energy greater than E. Hence neither the collection of n unprecise upper states can drive the preparation of the single precise one nor the other way round.

One might paraphrase this result by claiming that the worth is not a linear order (given by the free energy) and 'precision' defines an additional 'dimension' for instance.

The reason why an infinite number of copies of 'unprecise' two-level system is required for preparing one precise system is an information theoretic argument illustrated by the following Gedankenexperiment:

Situation a) Assume that a box contains some two-level systems with energy gap E perfectly initialized in their upper states. Assume another box to contain two-level systems of the same type with temperature T, i.e., their occupation probabilities p and q for the upper and lower states (respectively) are given by the Boltzmann formula $p/q = e^{-E/kT}$. Now we draw randomly one two-level system without knowing whether it was taken from the first or the second box. In order to guess it we measure whether the upper or the lower state is occupied. Assume we decide for the first box if and only if we obtain the result 'up'. This strategy has no error of the first kind ($F_1 = 0$), i.e., we never decide for the second box when the system was taken from the first one. If the system stems from the second box we are sometimes right and sometime wrong, i.e., for the error of the second kind F_2 we get $1 \neq F_2 \neq 0$. We paraphrase this observation by claiming that there is a *decision rule* distinguishing a two-level system in its upper state from a two-level system in its equilibrium with error probabilities $F_1 = 0$ and $1 \neq F_2 \neq 0$.

Situation b) Now assume that the systems in the first box are not perfectly prepared in their upper state, i.e., the occupation probability is only $1 - \epsilon$. Then there cannot be any decision rule distinguishing between a system taken from box 1 and a system taken from box 2 with error probabilities $F_1 = 0$ and $F_2 \neq 1$. Neither the result 'up' nor the result 'down' allows sure statements. Even if we are allowed to draw n copies from the box we can never be sure, we can only decrease F_1 while keeping F_2 fixed. Only in the limit $n \to \infty$ we would obtain $F_1 = 0$.

We show that this observation can be used for showing that an infinite number of copies of two-level systems with $p = 1 - \epsilon$ is required for preparing one system with $p = 1$: Assume n copies of systems with $p = 1 - \epsilon$ would be sufficient. Then we can define a decision rule for the situation b) in the following way: Imagine that we have n two-level systems taken either from the first or from the second box. Then we try to use it as an energy source for the preparation of a perfect upper state in the target system. In case they were taken from box 1 we will succeed, in case we have drawn from box 2 the target system will stay in its equilibrium since resource systems in thermal equilibrium cannot drive any process at all due to the Second Law. Those two cases can be distinguished with $F_1 = 0$ and $F_2 \neq 1$. This is a contradiction to the observation explained in Situation b).

The decision theoretic argument explained here might be called the principle that 'distinguishability can never increase'. It shows that much more sophisticated information theoretic quantities than entropy play a fundamental role in thermodynamics. But apart from this one should expect that the worth of resources is given by quantities which do not have any obvious information theoretic meaning. Assume for instance that the resources state is time-invariant (see appendix 3.1.4). Then it can never drive the preparation of a non-time-invariant state. This can be formulated quantitatively in 'the principle of conserved speed' (see appendix 3.2.3) where the speed quantifies to what extent a state is not time-invariant. Finding further interesting quantities for quantifying deviation from equilibrium has to be left to the future.

3 Mathematical Appendix

3.1 Basic quantum mechanics

3.1.1 Pure states

Every quantum system is described by a Hilbert space $\mathcal{H}$, such that its *pure states* are the one-dimensional subspaces of $\mathcal{H}$.

3.1.2 Mixed states

If one does not know which pure state is present or if there is quantum entanglement between the system and another system the state of the system is not pure, i.e., it is mixed. A mixed state is described by a density matrix, i.e., a positive matrix with trace one.

3.1.3 Hamiltonian and dynamical evolution

The dynamical evolution of a system with Hamiltonian H separated from its environment is given by

$$\rho \mapsto e^{-iHt} \rho e^{iHt}$$

for every density matrix ρ.

3.1.4 Time-invariant states

A mixed state ρ is time-invariant (stationary) if and only if $[\rho, H] = 0$.

3.1.5 Equilibrium states

The Gibbs-state ('equilibrium state') for temperature T is the state given by the density matrix

$$e^{(-H/kT)}/tr(e^{-H/kT}),$$

when H is the system's Hamiltonian. The Gibbs-state is time-invariant.

3.2 The Quasi-Order

3.2.1 Definition

We write

$$(\rho, \gamma) \geq (\tilde{\rho}, \tilde{\gamma})$$

if and only if there is a sequence of finite dimensional Hilbert spaces $\hat{\mathcal{H}}_n$ and a sequence of density matrices $\hat{\gamma}_n$ acting on $\hat{\mathcal{H}}_n$ such that there is sequence of unitary transformations u_n acting on the joint Hilbert space of resource system, environment and target system

$$\mathcal{H} \otimes \hat{\mathcal{H}}_n \otimes \tilde{\mathcal{H}}$$

with the property that u_n preserves the state $\gamma \otimes \hat{\gamma} \otimes \tilde{\gamma}$, i.e.

$$u_n(\gamma \otimes \hat{\gamma} \otimes \tilde{\gamma})u_n^\dagger = \gamma \otimes \hat{\gamma} \otimes \tilde{\gamma} \tag{1}$$

such[9] that

$$\lim_{n\to\infty} tr_{12}(u_n(\rho \otimes \hat{\gamma} \otimes \tilde{\gamma})u_n) = \tilde{\rho},$$

where tr_{12} denotes the partial trace over the two leftmost Hilbert spaces.

3.2.2 Explicit characterization

If

$$(\rho, \gamma) \geq (\tilde{\rho}, \tilde{\gamma}) \tag{2}$$

then there is a completely positive trace preserving map (for a definition and meaning of those maps see [4]) G satisfying the covariance property

$$G([H, .]) = [\tilde{H}, G(.)]$$

such that

$$G\rho = \tilde{\rho} \quad \text{and} \quad G\gamma = \tilde{\gamma}.$$

Furthermore it can be shown [3] that for $[\rho, \gamma] = 0$ or $[\tilde{\rho}, \tilde{\gamma}] = 0$ the existence of such a map G implies (2).

[9] Note that the condition 1 is equivalent to the condition that u_n preserves the total free Hamiltonian $H \otimes 1 \otimes 1 + 1 \otimes \hat{H} \otimes 1 + 1 \otimes 1 \otimes \tilde{H}$, where $H, \hat{H}, \tilde{H}$ are the Hamiltonians of resources system, environment and target system, respectively. Remember that the Hamiltonians (up to irrelevant additive constants) are implicitly given by the equilibrium states if the reference temperature T is known.

3.2.3 Conservation of speed

Let H be the Hamiltoninan of a system with density matrix ρ. Then we define the *speed* of ρ as

$$S_H(\rho) := \|[H,\rho]\|_{tr},$$

where $\|.\|_{tr}$ denotes the trace norm [6] of a matrix. if u is an energy preserving unitary operator on the system's Hilbert space i.e., $uHu^\dagger = H$, then $S_H(\rho) = S_H(u\rho u^\dagger)$. Then one has:

$$(\rho,\gamma) \geq (\tilde{\rho},\tilde{\gamma}) \quad \text{implies} \quad S_H(\rho) \geq S_{\tilde{H}}(\tilde{\rho}).$$

Proof: In the definition of the quasi-order we took a sequence of environments as ancilla systems. By continuity arguments it is sufficient to prove the statement for one single environment and a unitary energy conserving operator u. Let $\hat{\gamma}$ be the environment's state. Assume that

$$tr_{12}(u(\rho \otimes \hat{\gamma} \otimes \tilde{\gamma})u^\dagger) = \tilde{\rho}.$$

Let $H, \hat{H}, \tilde{H}$ be the Hamiltonians of resource system, environment and target system, respectively. For short, write

$$F := H \otimes 1 \otimes 1 + 1 \otimes \hat{H} \otimes 1 + 1 \otimes 1 \otimes \tilde{H}.$$

Then we obtain:

$$\begin{aligned}
& \|[H,\rho]\|_{tr} = \|[F,\rho\otimes\hat{\gamma}\otimes\tilde{\gamma}]\|_{tr} = \|[F,u(\rho\otimes\hat{\gamma}\otimes\tilde{\gamma})u^\dagger]\|_{tr} \\
= & \sup_{\|a\|\leq 1} tr(a[F,u(\rho\otimes\hat{\gamma}\otimes\tilde{\gamma})]) \geq \sup_{\|b\|\leq 1} tr\Big((1\otimes 1\otimes b)[F,u(\rho\otimes\hat{\gamma}\otimes\tilde{\gamma})u^\dagger]\Big) \\
= & \sup_{\|b\|\leq 1} tr\Big([1\otimes 1\otimes b,F]u(\rho\otimes\hat{\gamma}\otimes\tilde{\gamma})u^\dagger]\Big) = \sup_{\|b\|\leq 1} tr\Big([b,\tilde{H}]\tilde{\rho}\Big) \\
= & \sup_{\|b\|\leq 1} tr\Big(b[\tilde{H},\tilde{\rho}]\Big) = \|[\tilde{H},\tilde{\rho}]\|_{tr},
\end{aligned}$$

where we have used $\|\sigma\|_{tr} = \sup_{\|a\|\leq 1} tr(a\sigma)$ (see [6]) if $\|a\| := \sup_x \|ax\|/\|x\|$ denotes the operator norm of a matrix and σ is an arbitrary matrix.

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Interfaces and Errors

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Abstract

In computer science many strategies have been developed to avoid nearly all types of faulty behaviour in computing systems. Fault tolerant operating systems are part of present computer technologies and the improvement of reliable hardware components is still going on. The quality of modern software engineering is defined in terms of usability, performance and reliability. The computer acts as a tool for solving sophisticated, well defined (numerical) problems.

On the other hand, one should recognize already popular trends to reimplement sources of errors into the deterministic machines, e.g. in the field of genetic algorithms and genetic coding. In the corresponding applications randomness and enforced errors widen the functionality of the computing system.

Once the error has reconquered the code level of the machines, this paper aims to define the subsequent questions: to which extend do we need errors also in the human-computer interaction (HCI), in advanced computer interfaces? What are the creative skills of errors, malfunctions and noise in current and future interface techniques?

For a first sketchy approach to the subject we highlight three completely different aspects of interaction and errors. Firstly, the well known concept of "trial and error" is briefly summarized with respect to the different levels of learning in computer science. Secondly, we flush the basics of our bugging theory. Whereas genetic coding uses random numbers for the mutation of the code population and well defined fitness functions (selection), in the bugging theory both the mutation and the selection is driven by human-computer interaction. The running program is dynamically disturbed and rearranged according to the user interaction. The third aspect of the paper deals with the basics of quantum interactions. In quantum mechanics and quantum field theories errors in terms of perturbations and arbitrary quantum fluctuations are naturally involved in all basic interactions. Moreover, the concept of quantum interaction defines a non-local interface technique that might be adopted in future human-computer interactions.

1 Introduction

In the theory and history of computing as well as in computer science the interface plays more and more the most important role. Whenever we treat the computer not only as a symbolic machine, e.g. as a machine that solves differential equations by numerical methods or that performs calculations, but if we take the computer as a machine that communicates, in the sense of a cultural and mass phenomenon, the interface plays a much more important role than the hardware or the logic of current computers.

One of the co-founders of the industrial company AutoDesk, Inc., namely John Walker, did suggest to write the history of computers not in terms of logic, nor in terms of hardware, but in terms of a multiplicity of interfaces [1], [2]. He suggests that the development of the computer is not a linear progress or a genealogy of hardware, lets say by the five hardware generations that usually classify the computer: computers build with relays, vacuum tubes, transistors, integrated circuits and VLSI-circuits... The appearance of the computer in a cultural field would be much more a non-linear history and a question of heterogenity in interfaces. Five distinctions in interface technology are made by John Walker: knobs and dials, batch-processing, time-sharing and graphical menues as interfaces. In other words: the history of computing as a cultural and media history can be written as a matrix of interfaces, which are neither logic nor materialistic.

The science of the 'human-computer interface' has been pursued from very different perspectives. An early point of view of the man-machine interface was that of two entities, the user and the computer. The interface is the medium between the two. "The interface is the stuff that goes between the faces (i.e., senses) of the human and the machine". From this point of view the interface is everything that happens between the user and the machine. The user and the computer are treated as counterparts. The interface problem is in this case reduced to a search for suitable communication styles between two given autonomous systems. The main question then is: 'To which degree will one side adapt itself to the other?' While in the early years of computing the user was the slave of the machine, who had to learn it's cryptic command languages, we now want the machines to mimic us. We try to adapt the machines and to teach the interfaces human communication skills. Interface design has to support the user and to afford the functionality of the system.

A newer and different image of the whole man-machine interface subject is that of "acting through the machine with something else, which is not the machine". "The fact that the person is trying to do something means its really human-work interaction with the computer as an intermediary. So I think for me the focus isn't on interacting with the computer, but interacting through the computer" [3]. The user with his goals and some sort of objective content are now the two counterparts. In this image the computer is no longer the given static opposite, but it becomes the interface itself. The computing system as a whole has to be taken as a flexible medium that can be formed and has to be designed appropriate. The whole existing computer science and its commercial products are seen as an invention of scientists and engineers. They are historical products without unchangeable fix-points and which should be kept in a move.

In the classical interface theory (the computers we use daily) interfaces grew out of the paradigm of industrial problems. Interfaces have been designed with different criteria that have nothing to do with the problem of symbolic calculation. The discipline that is concerned with the design, evaluation and implementation of interactive computing systems for human use is called 'Human-computer interaction' (HCI). The challenges of HCI are to improve the safety, utility (functionality), effectiveness, efficiency, and usability of systems. Usability, i.e. making systems easy to learn and easy to use, is the key concept in this list of goals. The starting-point for all considerations of interface questions is the intention to organize some work, or get some insight, or search for information. We first of all do not want to deal with computers. The problem is to build up an analogy to the industrial and ergonomic design of a working place. Although the idea to take the whole computer as a malleable interface is very powerful, some characteristic features of the resulting systems are still very poor. The weak goals of HCI lead to:

- mass products and exchangeability of users
- standardization of interaction and communication
- systems that make the user getting what he expects, nothing more
- sciences that do not connect the theory of interfaces to the theory of computation

We try to design one interface for everybody. That is in terms of culture and in terms of the first industrialization: the computer is a monoculture and the computer is used as a tool that is used to produce products. The resulting tools are mass products that expect some sort of average user for it's optimal functioning. This leads to a standardization of interaction and communication styles. Since the whole system is user centered, the computer gets a rather passive part. The user has a goal in mind and the system just has to guide the user safely and quickly to settle his work. The key areas of research to improve the human-machine interfaces are therefore multi-modality and multi-coding aspects. But these areas are not connected to the theory of computation.

In sciences the error is normally seen as something negative and should be avoided. Many strategies to avoid errors in calculations have been developed in the past, e.g. better materials and design concepts which allow the improvement of quality, or fault tolerant systems, where even in the case of errors the expected overall performance is maintained. A different strategy is to recognize errors as something that cannot be avoided. If we once accept that certain events are inevitable, we can concentrate on the reaction. An insurance model for example is a system that accepts the unforeseeable event and tries to make sure that some sort of compensation for the bad effect is guaranteed. The compensation does neither avoid nor undo the error. It just launches a second event that is positive in nature and therefore capable to smooth the consequences of the first negative event. In computer science we also begin to accept that people and machines both do err. Under this assumption interfaces have to provide reactions that help the user managing the situation [3], [4].

But if errors are anyhow unavoidable and people and machines do err all the time, then science and technology should not only take this well-known fact into account and provide appropriate reactions. If errors belong to the nature of computation we could go one step further and ask how we can reflect the fact of errors within the basic structure of our theories and machines ? Numerous researchers have recently stressed the critical but positive role of breakdowns especially in design and art activities. Errors in art and design are considered as something positive or even necessary to achieve certain results and behaviour. Genetic Algorithms and Computational Evolution are technical examples for complex solution strategies that are built on a positive evaluation of errors.

2 The Error in Computer Science

As a first approximation, an error can be seen as the unexpected that forces us to change our plans and actions. The unexpected is the difference between our assumptions or standards (models, theories, believes, assessments, protocols and standard specifications) and our actual observations. Terms like randomness, confusion or breakdown are different forms of describing unexpected events. A first thesis on errors could go: errors are not objective, they always depend on an observer or a community of observers and their interpretations and general rules. The border between what should be seen as an error and what not is blurry and changing in time. What for one is still tolerable or even fine might for somebody else be totally unacceptable. Situations which I judged as flawless yesterday, might today being perceived as intolerable faults. In many cases of course we do not have problems to draw the distinction whether an event is an error or not. It is the background shared by a community that creates a general accepted error. If the community is intact we normally are in agreement whether something is afflicted by an error or not. In the context of computing systems different types of errors can be distinguished.

2.1 Malfunction of Hardware and Software

'Malfunction' means that something does not fulfill its intended or formally described behaviour. The incorrect functioning of computing systems can originate from two different types of sources: physical breakdowns or logical faults. While software errors are always programming, i.e. logical faults; hardware errors can arise from design faults or material breakdowns, i.e. ongoing physical and chemical processes. Material faults are usually time dependent, e.g. spontaneous breakdowns of parts of a system that up to this point worked perfectly. The speed of these unavoidable processes depends on different sources like environmental and working conditions, material structure, component design and physical composition of the system. This occurrence of misbehaviour is to a certain degree statistically describable by probability laws for the live time of an object. Design errors depend completely on the conceptions and ideas of the system developers. They can slip into a system at different phases during the development of hardware or software modules. They can arise during the conception of the system, which means the specification of the system is already defective. But they can also be built in during the programming phase. Implementation errors mark the difference between the intention of the developers and the translation into a piece of software. Design errors can even be caused by some sort of meta-errors if certain parts of the development process are supported by another computing system. An incorrect compiler is for example able to produce incorrect machine code from correct higher level programs. In this case the error was made one step earlier during the design phase of the compiler.

2.2 Coding and Calculation Errors

Computers are normally seen as systems for storing, transmitting and processing data. Coding includes all methods to efficiently represent the data. If we want to bring anything into a digital computing system we have to decide about appropriate coding of the according phenomena. If we for example want to deal with real world objects we permanently have to make choices about their representations. Since digital computers can only deal with discrete quantities, the coding method is crucial for the accuracy of the results. Three different types of errors are connected to the coding process: quantification errors, sampling errors, and calculation errors. Quantification and sampling errors are produced by the coding of continuous signals for digital machines, e.g by digital representation of images, sounds, space, color or real numbers. The sampling rate determines the number of sample points, while the quantification is responsible for the number of bits per sample point. Calculation errors are a consequence of digitization. They occur because the word length of digital computers is restricted. If we for example multiply two numbers with eight digits the result is a number with sixteen digits. When we have two numbers with sixteen digits the result is a number with thirty-two digits. But it does not matter how many digits the machine uses to represent numbers. Sooner or later the maximum will be reached by repeated multiplication. And the situation is even worse for division, since the result can normally not be expressed with a finite number of digits, e.g. the result of 1 divided by 3 is a periodical number. Any digital computer is afflicted with this rounding problem caused by repeated arithmetical operations.

2.3 Uncontrollable Fluctuation / Noise

Computer systems can be devided in two classes: digital and analog machines. Today the analog principle has totally vanished from the market as well as from science. The critical question of analog machines was: how big is the uncontrollable fluctuation of the mechanism in relation to the significant signal? There is no analog machine, which really can calculate the product of two numbers. What we get is the product plus a small but unknown size, which represents the so called noise. This random value is the characteristic of the involved physical process. The ubiquity of uncontrollable fluctuations in any physical mechanism is the main reason why digital computing gained victory over analog computing. In digital computing on the other hand one also has to deal with errors, namely the above mentioned coding and calculation errors. So the difference between analog and digital errors is not of qualitative but of quantitative nature.

2.4 Operation Errors

While malfunction, coding and noise are characteristics of the machines that can be observed by the engineer, an operation error means misbehaviour of the user. An operation error can be a wrong sequence of interactions caused by carelessness or because the user is not familiar with the system. An operation error can also be a misjudgement when an experienced user is confronted with a complex situation that is asking to much of him. If the number of alternatives is small, trial and error is a good strategy of solving such problems by trying various ways and inspecting the results. But trial and error is also an important strategy for adaptation and development of systems, which will be discussed in the next section.

2.5 Trial and Error

Adaptability to new surroundings and new situations are important features of any intelligent, creative or autonomous system. Learning, as a change in performance can be seen as a function of errors. Improvement of performance usually means a reduction of errors. When you try to get rid of an error, you can choose different strategies. First you will try to solve a problem by applying only small variation in behaviour. You will cling to any strategy as long as possible and only modify some parameters within the scope of your current way of behaviour. Only if the situation becomes completely hopeless you will be willing to change an attitude and strategy or give up the whole theory. In computational learning processes errors can also have consequences for the system on different scales. The cybernetic description of learning processes (Bateson) distinguishes between several levels of learning: zero learning, 1*st* order learning, 2*nd* order learning, etc... [5] Zero Learning means, only hard wired or soldered links between stimulus and response are implemented. 'Trial and Error' is explicitly excluded. The system always gives the same response whenever it is confronted with the same question. We even speak of zero learning, when the user marks the error and says what has to be changed (e.g. delta rule in neuronal nets). If a system gives a different and better answer when it is asked again and if this improvement is caused by a external teacher, we are still in the scope of zero learning. Zero learning in adaptive systems means the user structures everything, he is even responsible for correcting errors.

Only at the next level of learning the system itself uses trial and error to improve its performance. $1st$ order learning is the usual form of learning and is also known as learning in structured environments (genetic algorithms, neuronal nets with Hebb rule). Here the context of the system and the characteristic algorithms remain unchanged. The distinction between the system and its environment exists only for a global observer. So the system does not recognize when it has to change its own identity. It does not know anything about its boundary and about its own function. $1st$ order learning in adaptive systems means the user chooses the learning algorithms and the system applies the algorithms to the data that is automatically gathered during the usage of the system.

$2nd$ order learning - sometimes called learning of learning - modifies not only data (operands), but also the rules of learning (operators). It changes to whole identity of the system and the context, in which the system lives and behaves. The system is able to draw a distinction between itself, the environment and the user, who also draws distinctions between itself and the environment. The levels of learning can be thought further by repeating the basic principle. $N + 1th$ order learning is the change of the process in nth order learning. One of the great challenges for research in adaptive systems is the invention of algorithms that realize second order trial and error strategies (in difference to ordinary trial and error, e.g. adaptation of data in $1st$ order learning processes).

Trial and error can be seen as the mutual influence and correcting power in the shared drift and development of system and user. In this sense trial and error strategies are important for the following questions: How can systems extend their own functionality ? How can we model context switches in a dialog between the system and a user ? How can a system change its own identity ? How can a system learn to inform the user about its own state and knowledge ?

3 Interaction and Errors in Media Studies

Classical media theories such as the Toronto School of Media Theory coined once the term "the media is the message". This slogan was already stated in the 20s and 30s of the last century and was called "fitting the message to the line". It meant to transform the message into a representation that is able to be communicated over a physical communication link. Here the message is the slave of the channel it is to be transmitted over. But if the physics of communication channels are related to the messages they transmit, we can at least in electronical media create meaning by changing the physical properties and states of the communication channel. This implies the question how errors could be useful in changing the message computer.

3.1 Malfunction in Cultural Theory

Faults and malfunctions in the theory of knowledge are very prominent. French intellectuals like Georges Canguilhem in 'The Normal and the Pathological' and Michel Foucault in 'Madness and Society' or 'The Order of Things' did show how pure reason even in its institutionalized form is based on madness, because it excludes madness. We only can say what is normal, because we set what is not normal. The german philosopher Martin Heidegger did stress this point in his explication of the 'Zuhandenheit' and 'Vorhandenheit' of things in Being and Time:

"But we discover the unusability not by looking and ascertaining properties, but rather by paying attention to the associations in which we use it. When we discover its unusability, the thing becomes conspicuous ... The modes of conspicuousness, obtrusiveness, and obstinancy have the function of bringing to the fore the character of objective presence in what is at hand. What is at hand is not thereby observed and stared at simply as something objectively present. The character of objective presence making itself known is still bound to the handiness of useful things ... The references themselves are not observed, rather they are 'there' in our heedful adjustment to them. But in a *disturbance of reference* -in being usable for...- the reference becomes explicit. It does not yet become explicit as an ontological structure, but ontically for our circumspection which gets annoyed by the damaged tool. This circumspect noticing of the reference to the particular what-for makes the what-for visible and with it the context of the work, the whole 'workshop' as that in which taking care of things has always already been dwelling. The context of useful things appears not as a totality never seen before, but as a totality that has continually been seen beforehand in our circumspection. But with this totality world makes itself known" [6].

The argument can be put very simply and easily into a optical metaphor: if we wear glasses, and if we -in a reduction of complexity- call these glasses a medium, we are usually not aware of wearing glasses. Only if these glasses fail or get broken, we suddenly become aware of the media environment that we live in. This process immediately turns into a reflection of the media we use to live in the -in terms of Heidegger- 'world' [6]. Terry Winograd and Fernando Flores for the computer science community did apply Heideggers analysis of the 'Vorhandenheit' and 'Zuhandenheit' to computer societies. In the case of using a hammer, the hammer only appears as a tool, if it malfunctions [6], [3]. The question of physical breakdowns are used by Winograd/Flores to question the design of computers. But Winograd and Flores did use breakdowns only to design new systems or better systems. Computer industry is already used to it: hackers are used to find traps and security holes in the system and have the function to make the system much more save. The error is in that case a stability function, not a creative function out of which new meaning is generated.

3.2 Noise in the Channel of Communication

In creative environments, like creative software, interactive installations and media art, the interface should follow different needs: the observer or the artist should determine the outcome of the "product"; lets better say the state of the software individually. Subjectivity in most so-called interactive installations is not really possible, if tools are used to manipulate data through standard and mass interfaces. Under interactive art one could understand a state of the creative process that is an answer of the system to each single observer, might it be an artist or a spectator. This answer must be distinguishable to each other person interacting with software, and not only following determined paths. In other words: if a subject uses a so-called "media-art-environment", the most challenging task would be that the code recognizes the subject as different from other observers.

Well, creative processes, returning to the question of the interface, are about to get individuality or personality. The unexpected, the new or unprobable communication situation are important issues to reach that goal. One approach to build new creative environments is reflecting again the error. It is an old trick that the error during the process of creation affects the tool or the outcome, and is turned into creation. This is quite natural, because if a tool is misused, the imagination of the personal user or artist or observer meets the medium during a process of reflection and with this process form and content is interpreted by the subject individually. Misusing tools enriches the circulating products. Let us call that in a general sense "art". Art is an individual interpretation made possible with the artists imagination that observes a transformed relation between content and form. An error can play an important role in the reflection of the artists work, the error can give the user of software or the artist a chance to reflect the "physical reality" of the medium she or he is working in.

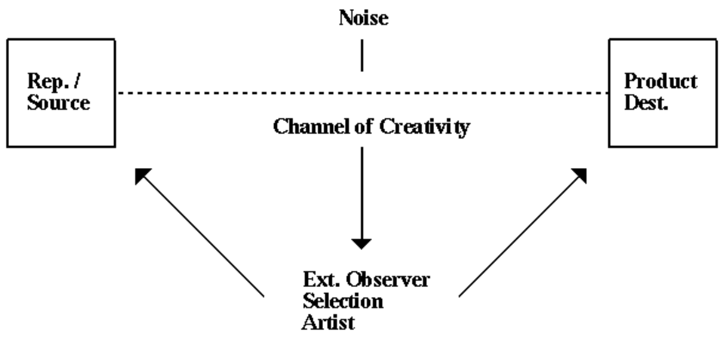

Figure 1: *Max Bense: Scheme of Creativity.*

Max Bense as a computer scientist in 1969 did make a scheme of positive reactions to errors (see figure 1). Signals Sig are turned into signs and meaning Z through a material function $Fmat$ of the communication channel $Fmat(x, y, z, \ldots, t)$ and are open to the interpretation of the observer as a relation R between the transformable signs M, the object O and the interpretation I. The process of aesthetical 'semiose' is therefore:

$$Sig \rightarrow Z \equiv Fmat(x, y, z, \ldots, t) \rightarrow R(M, O, I)$$

Here the error is induced through the physical communication channel, interpreted by the observer through a passive process in selecting the noise as a creative and aesthetical expression. But in the scheme of Bense the observer just selects messages. It would be a challenge now to let the user, artist or observer induce errors to the communication channel itself. This can be done in computer science with a theory of bugging in free and open software environments.

3.3 Theory of Bugging: Errors induced through the Observer

In a more general view the french philosopher and media theorist Michel Serres developed a theory of the parasite [7]. In his book 'The Parasite' source, destination and noise can rotate in their position (see figure 2).

Only under the assumption of static technical communication the scheme of Max Bense is theoretically useful, so to say in non-dynamical communication environments. In the case of the observer changing the physical state of the communication channel, e.g. programming, the observer creates a message himself. Serres general scheme of the parasite can therefore be expanded in a creative bugging scheme, if we assume that the observer, artist or user induces an error into the medium (see figure 3).

In creative environments there is need for a *theory of bugging* and the practice of *virulent or parasitological coding*. We should distinguish between what we can do with current interfaces

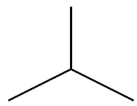

Figure 2: *Michel Serres: Parasite Theory.*

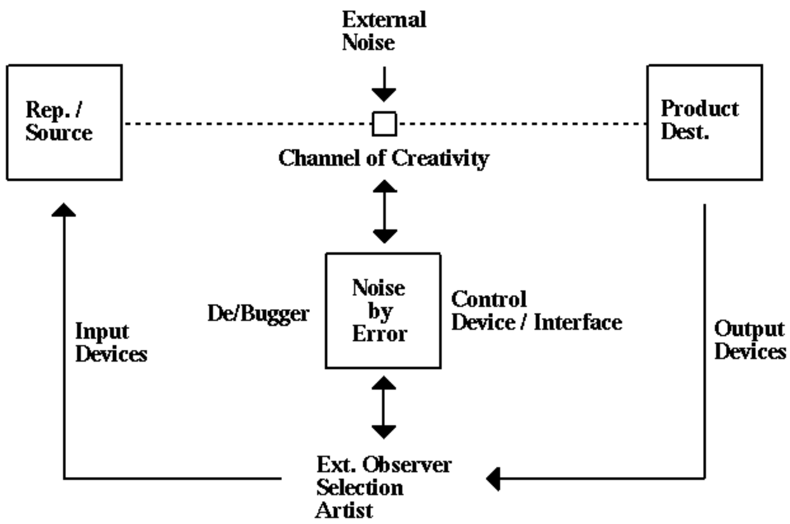

Figure 3: *Bugging Theory.*

(editors, integrated development tools, debuggers) and with advanced interfaces. In practice and with current interfaces a bugging theory would include several steps for the observer:

1. Get the code of a tool which is used to produce art in open source.
2. Re-Compile it with symbolic expressions.
3. Let it run in the Debugger.
4. Re-Code the Program during run-time by injecting virulent errors or recompile it by injecting virulent codes.
5. Save the errors for reproduction and exhibition.

By changing, mixing addresses, confusing control variables and/or structures, we are about to decontrol the trajectory of interaction with software. There are existing a lot of errors that are pleasant to look at. Numerical errors in digital image synthesis, errors in computer solid geometry. Out of these syntactical changes new visual forms or signs can be created individually.

Of course, an error based interaction with tools through integrated development environments opens up the question how in advanced interfaces the software could be designed to handle possible errors of the user. It should extend a simple editor to change programmed code. Here, in comparison to genetical algorithms, the interface would have the task to mediate not only the selection procedure to the user, but also the mutation procedure. The observer would not be just a slave of random genetical evolution, but be more a genetical engineer in a kind of code laboratory that mutates and resynthesize the code dynamically. This could imply the question to design new dynamical compiler that learn the errors of the user and display the code itself as a complex and dynamical interface which is open to the user for creative and erratic manipulation.

By inducing errors in addresses, algorithms, we are showing possibilities of the physical properties of the communication channel. Signals Sig are turned into signs and meaning Z through the exchange of erratic codes C_e. The material function $Fmat$ of the communication channel $Fmat(x, y, z, \ldots, t)$ is just important for the erratic observer O_e, if the process of semiose pleases to him. The interpretation of the observer is then not only passive, but also an active relation R that changes the message to be transmitted:

$$Sig \xleftrightarrow{C_e} Z \equiv Fmat(x, y, z, \ldots, t) \xleftrightarrow{O_e} R(M, O, I)$$

In turn: we do not debug like the industry, but bug. We do not find the physical fault in the system, but show the possible faults of the system. By showing the syntactial structures in computers, we see nothing else, but the physical reality of computing: possible functions of the machine. In other words: the medium, not the intended and anticipated messages by the software industry. Changing the codes and illustrating the different visual effects of this process by recoding is nothing less than showing the medium of the computer as a communication channel. It is the interface, not the materiality of the media, that is in question. The artist here would construct or inject errors as if she or he would be a virus in a parasitological environment. If we do not want to use the computer and the software as tools that are like the glasses hidden from an awareness and reflection we could simply show other physical states or being by crashing them. This can be done by bugging open software in current and advanced development environments. Through showing the media by inducing virulent error codes -that is recoding open software- we are in between saving its message and explore the computer -again- as a medium.

4 Interaction and Errors in Quantum Physics

In the currently available models of human-computer interaction (HCI) the influences of errors are expelled from the interaction theory. But in the previous chapters of this paper we have discussed the reimplementation of errors into HCI, following the strategy of "trial and error" (section 2) and the bugging theory (section 3). Whenever the user interacts with the computing system, he or she might disturb the computation and changes the state of the machine on data **and** the code level. However, such an interaction model has a prominent counterpart in the world of physics: quantum interactions in quantum mechanics and quantum field theories. Since all computing systems and interface techniques are - at lowest level - designed out of physical constitutents (in rising order: electrons, neutrons, protons, atoms, molecules, cristalls, etc.), we should also consult quantum physics for more general definition of interaction.

The models of physical interactions in the microscopic world **include** errors in a very elementary way. Here the influences of perturbations and arbitrary fluctuations - the sources of errors in physics - are important and well established features in quantum mechanics and quantum field theory [8, 9]. In this part of the paper we will introduce interactions as perturbations by explaining the Stern-Gerlach experiment in some detail.

Quantum theories are non-local theories. Therefore the models of quantum interactions can be interpreted as a global interface technique for the physical system. This aspect is of particular interest for computer science, because currently no HCI theory provide interfaces with non-local functionality. If we could design non-local interfaces even in classical (non-quantum) computing systems, a variety of new computer applications would emerge. As in quantum physics, global interfacing in computer science should also start with interactions as perturbations.

4.1 Quantum Interaction and Perturbation

The Stern-Gerlach experiment intuitively illustrates why we need a new understanding of interaction at small distances and it motivates the global dependence of physical observables in terms of commutation relations. Interacting with the quantum world always disturbs unpredictably the quantum system under consideration, in the Stern-Gerlach experiment: a beam of spin 1/2 electrons. The original, undisturbed quantum state of the system, which can be a superposition of single states, is not completely accessible by measurements or observations. Moreover, measurements and observations destroy information within the system, since - in general - only one particular state of the superposition "survives" the interaction.

On the first view, these "active" interactions in quantum mechanics seem to be restricting with respect to classical interactions and to human-computer interaction. Nevertheless, perturbations and fluctuations are unavoidable but useful in all parts of quantum physics. For example: perturbation theory in quantum field theory counts the errors systematically. Starting with the basic (classical) interaction we use higher order Feynman diagrams [10] to classify the contributions coming from the vacuum structure of the theory. In Quantumelectrodynamics (QED), the strange theory of light [10], one can calculate the power expansion for the disturbed interaction of an electron with an external magnetic field. Here the resulting theoretical prediction for the anomalous magnetic moment of the electron fits perfectly to the experimental data. Indeed, the predictions of perturbation theory in QED are extremely precise and can be checked in the experiments up to very high accuracy ("The best theory we have!", [11]). In other words: the errors in quantum interactions shift the theoretical values for physical observables towards the experimental numbers. Without the perturbations no matching between theory and experiment can be achieved.

Within the strong interaction[1] in the standard model of elementary particle physics quantum fluctuations are responsible for advanced (dynamical) processes, not present in classical physics, e.g.: the quark confinement [12, 13, 14], the spin of the proton or the mass generation of the $\eta\prime$ particle [15, 16]. Here "active" quantum fluctuations and perturbations, closely related to the complex vacuum state of the quantum field theory, create a flux tube in the static quark antiquark potential [12, 13, 14] or contribute to the proton spin in terms of disconnected diagrams [16]. These particular quantum effects demonstrate creative skills of errors in quantum interactions.

4.2 The Stern-Gerlach Experiment

The Stern-Gerlach experiment illustrates in a dramatic manner the completely new features of interaction in quantum mechanics. The experiment was originally conceived by O. Stern in 1921 and carried out by W. Gerlach et al. in 1922. A modern and detailed introduction to the subject and additional references can be found in [8]. The original experiment was done with silver (Ag) atoms. The source for the atom beam was a hot oven. Through a small hole a moderate number of atoms escaped from the oven. For the sake of simplicity we turn directly

[1] Quantumchromodynamics (QCD) is the non-abelian gauge theory of the strong interaction. QCD describes the dynamics of the quarks, the constitutents of protons and neutrons.

to ideal experimental settings. In the ideal experiment we have a beam of simple electrons with spin 1/2 escaped from the oven and bundled in a collimating slit (see figure 4). The spin of the electron, $\vec{S} = (S_x, S_y, S_z)$, is an additional discrete degree of freedom[2]: the component S_i of $\vec{S}$ can point in two directions: $S_i = +1/2$ and $S_i = -1/2$. Next, the electron beam is subjected to an inhomogeneous magnetic field in z-direction (see figure 4).

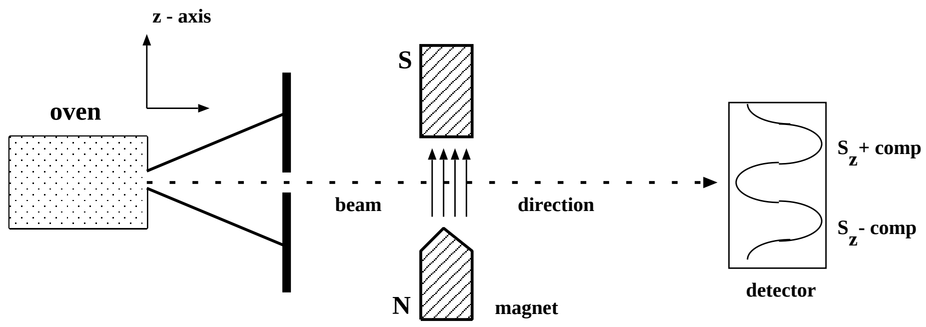

Figure 4: *The Stern-Gerlach experiment.*

Due to the magnetic interaction

$$F_z = \frac{\partial}{\partial z}(\vec{\mu}\vec{B}) \simeq \mu_z \frac{\partial B_z}{\partial z}, \tag{1}$$

the electrons in the beams with $S_z = +1/2$ (spin up, $\mu_z < 0$) experience an upward force whereas electrons with $S_z = -1/2$ (spin down, $\mu_z > 0$) feel an downward force. Hence, the beam splits into two parts corresponding to $S_z = +1/2$ and $S_z = -1/2$ (see detector in figure 4). Our Stern-Gerlach apparatus thus measures the z-component of $\vec{S}$ and we call this machine SG_z. By rotating the direction of the inhomogeneous magnetic field we design the machines SG_x and SG_y for measuring S_x and S_y, respectively.

We now consider the combination of Stern-Gerlach machines, the sequential Stern-Gerlach experiment (figure 5). First, the beam is subjected to SG_z and we get two distinct beams with S_z+ and S_z- (see figure 5 (a)). We block the S_z- beam and take the S_z+ beam as the input of the second Stern-Gerlach machine SG_z. Obviously, this time we do not see the S_z- component since we have blocked this component in the previous apparatus. In the next experiment we start again with the SG_z apparatus and we block the spin down component S_z-. The S_z+ beam enters the second apparatus that is of type SG_x and measures the x component of $\vec{S}$ (see figure 5 (b)). It is not surprising that we see both components S_x+ and S_x- because the electron spin $\vec{S}$ has initially a random orientation when escaping.

In the last experiment we use three Stern-Gerlach machines and we step into the strange world of quantum physics. We start again with SG_z and we block the resulting S_z- beam. The S_z+ component enters the second machine, SG_x, and we block the S_x- beam. Next, we use the S_x+ component as input for the third machine, another SG_z apparatus (see figure 5 (c)). Since we have blocked the S_z- component in the first apparatus, of course we would expect only the S_z+ beam. But, surprisingly, we observe the S_z+ beam **and** the S_z- beam. The S_z- component, originally surpressed by the first SG_z apparatus, has reappeared!

The findings from sequential Stern-Gerlach experiments have no equivalent in classical physics. The interpretation of the results is as follows: measuring the S_x component of the elec-

[2]Of course, the discreetness of physical observables was the first step towards quantum physics. Here I want to focus on the commutation relations in quantum mechanics.

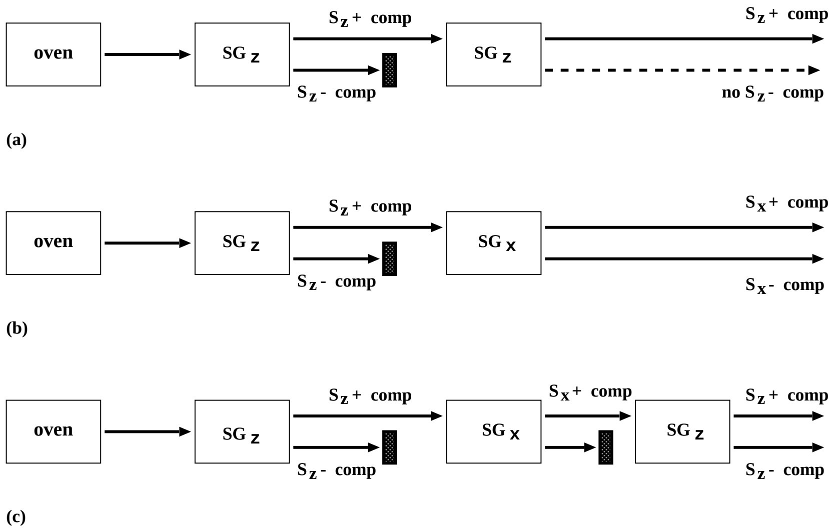

Figure 5: *Sequential Stern-Gerlach experiment*

tron spin destroys the information previously found for the S_z component. The measurement of S_x invokes a perturbation of the quantum state and the informations on the S_z component are lost. The three components of $\vec{S}$ can not be estimated at the same time. In the languange of quantum mechanics we say that the components S_x, S_y and S_z do not commute:

$$[S_i, S_j] = S_i S_j - S_j S_i = i\epsilon_{ijk}\hbar S_k \neq 0. \tag{2}$$

The same is true for other "classical" observables, e.g. the location $\vec{x}$ and the momentum $\vec{p}$ of the particle. In this particular case we are faced with the uncertainty relation of Heisenberg: we can not measure $\vec{x}$ and $\vec{p}$ at the time t up to all precisions. Or, in other words, measuring $\vec{x}$ destroys informations on $\vec{p}$ and vice versa.

In classical physics all dynamics are determined by the equations of motion. The classical variables, for example $\vec{S}$, $\vec{x}$ or $\vec{p}$ are connected only via the equations of motion. In quantum physics we have an additional constraint for physical variables: the commutation relations. Interacting with one component of $\vec{S}$ has some impact on the other components beyond the range of the equation of motion, in quantum mechanics: the Schrödinger equation or the Heisenberg equation. Via the commutation relation for $\vec{S}$ (eq. 2) an interaction with S_z "disturbs" the components S_x and S_y. In this sense quantum interactions are global perturbations. From quantum mechanics we can learn that interacting with quantum systems evokes errors and the state of the system is changed unpredictably. The interaction reduces the amount of information in the system and it destroys former knowledge of the state vector. These features of non-local quantum interactions have no equivalent in current human-computer interaction. All interface techniques change the state of the computing system in a deterministic manner. No information about the code or the data is of necessity destroyed or even damaged. All "classical" interfaces act locally on one particular variable of the computer.

The developing process in human-computer interaction has not overcome the "classical" limit like quantum mechanics did for classical mechanics. Since quantum interactions, including perturbations and fluctuations, are well established in our physical models of the (microscopic) world, one should allow the question, whether a restriction to "classical" local human-computer interaction does limit the abilities of computing resources from the beginning on. The physical models of nature are - at least - one step ahead.

In this section we have not touched the wide research area of quantum information [17, 18, 19, 20]. The fast growing community for quantum computing, quantum teleportation or quantum cryptography indicates a huge interest in new computing abilities beyond the classical machines. However, present quantum computers get use of the parallel computing resources within quantum systems and speed up "classical" computations, e.g. the factorization of large numbers. A clear understanding of the challenging non-local interface techniques (human quantum computer interaction (HQCI)) in quantum computing is still lacking.

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The Third Wholeness as an Endo-observer

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Abstract

The perspective of an endo-observer is defined as a partial wholeness and expressed as a partial quantifier within set theory. We use the formal concept analysis with respect to wholeness in a diagonal argument, whereby the partial quantifier can be formalized as an expression containing intent and extend. A dynamical interaction between an endo-observer and his surrounding (or the rule that he refers to) is replaced by the interaction between intent and extent in terms of the concept lattice theory. The partial quantifier plays a role for the interface between formal intent and extent. As a result, it is shown that the dynamical change of a concept lattice can constitute the interface between a distributive and a non-distributive orthomodular lattice. It represents the interfacing behavior between macroscopic phenomena described in a Boolean lattice and microscopic ones described in a non-distributive orthomodular lattice.

1 Introduction

Imagine that a cabbage is sold for one dollar. If you get a cabbage by paying one dollar, do you just accept the price as a rule between producer (or merchant) and consumer? You may pay attention to other prices demanded elsewhere – in case you really search for cabbages elsewhere. Depending on the context, you eventually will make a decision. Whenever you make a decision you refer to your own wholeness although this wholeness is not a baggage that envelops everything. That is why it is possible to encounter the situation that you got a cabbage yesterday at a certain price but you will not get one today for the same price. The perspective of a person buying a cabbage is the same as that of an endo-observer [1, 2] or an internal observer [3, 4, 5]. These perspectives originally have been discussed in physics by Rössler [1] and Matsuno [3].

Measurement is also a process of making a decision. It is always connected to the process of referring to the context. However, it is very hard to find the process of referring to the context in a dynamical system as a model of a particular real system. Trajectories are determined a priori, and a system just proceeds along a trajectory once the initial condition is chosen. It is very hard to find detection, vacillation and reference to the context. In other words, the measurement process itself is not explicitly implemented in a dynamical system. The question arises how one can formalize detection, vacillation and a choice along the trajectory [6].

In a dynamical system, the process of seeing the space is expressed as a product map such as $f : A \times B \to C$, and the process of choosing a trajectory (which is the choice of time) is expressed as the transpose of f, such as $g : B \to C^A$. There is a one-to-one correspondence between these two maps, whereby such a pair of transformations between space and time is usually called adjunction [7]. Because of the one-to-one correspondence, chosen time and space are consistent with each other and, moreover, a dynamical system as a model is self-consistent. However, the latter implies that a system cannot undergo an evolution, per se.

The ability of self-modification or evolvability is strongly connected with the process of referring to the context [8, 9]. If a system refers to the wholeness enveloping everything, it leads to a contradiction. If a system refers to an object outside – and it can refer to everything as a result – then nothing happens. Therefore, the above question of how a system evolves entails the further question: What is the process referring to the wholeness, or how can the perspective of an endo-observer be formalized ? An interface between the wholeness and a part of it has recently been proposed in terms of dynamical systems [10].

In order to get an answer to the above question, we first analyse the *concept of wholeness*. We examine how to use the concept of wholeness in mathematics, especially in a diagonal argument within set theory. Thereafter, we extend our analysis to the *concept of concepts*. Concepts of concepts have been introduced recently within *concept lattice theory* as a tool to analyse complex phenomena [11, 12]. We here replace the relationship between inside and outside by a relation between *intent* and *extent* of a concept and utilize a dynamical concept as a model for an endo-observer (see also [13]). Furthermore, we introduce the process of referring to the context, i.e., the perspective of an endo-observer. This process mediates the interaction between intent and extent. We propose to call this "the third wholeness". We furthermore show that a concept lattice can be dynamically changed from a *distributive* to a *non-distributive orthomodular lattice*, and vice versa. The non-distributive orthomodular lattice itself can contain the perspective of an endo-observer in the narrow sense [14]. From this point of view, the significance of the third wholeness lies in its parellel interaction [15] that cannot be interpreted by means of serial processing.

2 Process Between Empicical Subject and Theoretical Object

2.1 Wholeness in the Performance of Addition

As a first step we focus on the interface between a subject and an object in terms of a process of following a rule. Thereby, the rule is illustrated by the rule of addition. Whenever we count objects, we believe to follow the rule of addition which is mathematically defined as a successor $s : N \to N$, where $s(n) = n + 1$ and N is the set of natural numbers. Since our calculation is just empirical, there is no way to prove that our addition coincides with the rule of a successor. According to Kripke [16], there always exists an inexperienced number with respect to my own experience of addition. We designate this number as 51 and assume another rule of counting defined by $t : N \to N, t(51) = 1$ and $t(n) = n + 1 (n \neq 51)$. Since 51 has not been used in terms of my own experience of addition so far, I cannot determine whether I follow rule s or rule t, respectively. The convention to say that a specific rule has been used can be justified for pragmatic reasons although its verification is not feasible.

The following question remains: How do I actually follow a rule? Or in other words: How do I follow a specific rule in the pragmatic sense? For a first approach, consider the following two extreme cases:

1. I subsequently reconfirm the truth of a successor through my own action of addition.
2. I count the numbers in an arbitrary way just as I like it.

Presumably, in both extreme cases a successor is used. This, however, has to be checked in the following.

There is a crucial difference between an empirical world surrounding a subject (myself) and the formal universe defined by a successor. In an empirical world there exists a clear temporal distinction between before and after a calculation. In our example, we are first confronted with the task of adding, say $1 + 1$, and with the corresponding result $1 + 1 = 2$ afterwards. This distinction between before and after obtaining the result does not exist in the formal universe. Notwithstanding my own addition, in a formal universe there are all possible results of addition already included. Likewise, to reconfirm the rule of a successor (case 1) does not allow to distinguish between before and after obtaining the result. If case (1) above holds, my own calculation would be redundant because the result were known in advance. Actually, I know that my own addition *is* meaningful.

If the statement of case (2) holds, I can calculate $45 + 1 = 408$, for example. I know that such a calculation is not an addition as long as I do not introduce a rule of a successor. A calculation separated from a rule of a successor does not make sense.

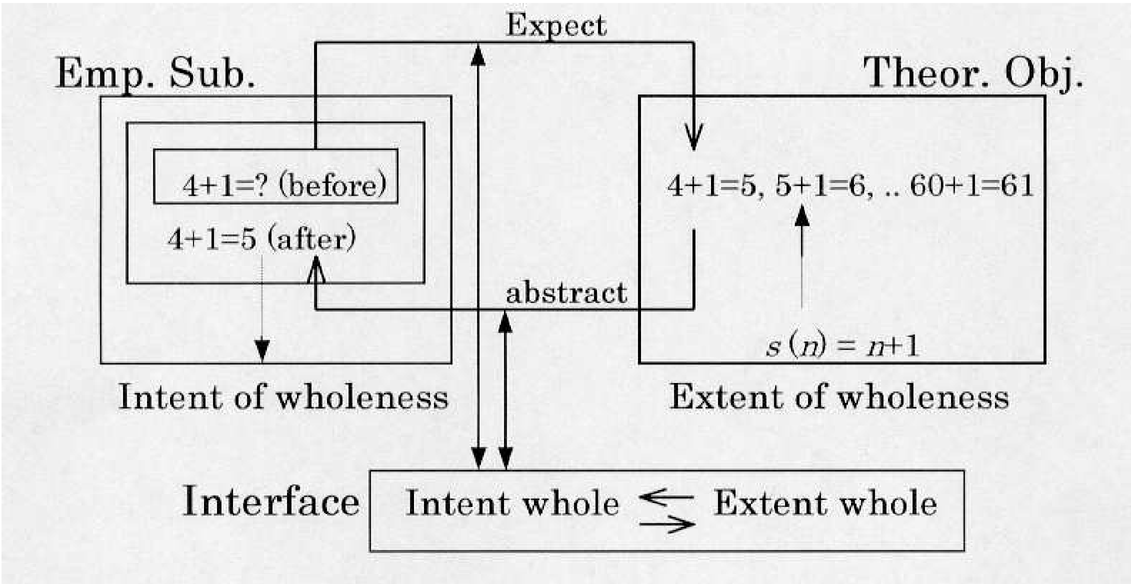

Figure 1: *Schematic diagram for the performance of an addition expressed as the interaction between a subject's performance of counting and the subject's usage of a rule of a successor. Because an individual subject's performance is not a specific state in the space prescribed by a rule, a subject has to connect perpetually the intent of wholeness (defined by the limit of his own performance) with the extent of wholeness (which is the rule of the successor). As a result, a subject can either maintain to follow a particular rule or change to another rule.*

Thus, it turns out that my calculation of addition neither is just a reconfirmation of a rule of a successor nor just acting independently from a successor. Such a situation is shown in Fig. 1. A subject expects that his own action is consistent with a particular rule and abstracts the content of that rule. However, the schematic diagram of Fig. 1 contains a mixture of different logical categories, the intent and the extent. It leads to a contact between both intent and extent. On the one hand, the concept of wholeness in a subject's actual world is assumed to be the border found by the iterated individual agitations of identifying the partial knowledge.

The arrow from the partial knowledge to the border that constitutes the wholeness implies that the wholeness is defined as a concept whose contents are partial knowledge. We call these contents the intent of the concept of wholeness. On the other hand, a concept of wholeness in the formal universe is defined by an a priori-concept. Once the formal rule (e.g., a successor) is given, all possible calculations are given by the rule in its own right which implies conceptual wholeness. A concrete individual calculation is performed by substituting the concrete numbers to be added to the rule. That is why the wholeness in the formal universe is the extent of the concept of wholeness with respect to our empirical world.

My own performance of an addition is constituted by both, the rule of a successor and my own act. There are reciprocal interactions between them. The performance of an individual addition, say $5+1=?$, is expressed in the following way:

$$\underset{(A)}{5+1=?} \;\rightarrow\; \underset{(B)}{(\rightarrow \cdot\cdot \rightarrow \text{int-wh})} \;\rightarrow\; \underset{(C)}{(\text{ext-wh} \Leftrightarrow s(x)=x+1)} \;\rightarrow\; \underset{(D)}{x=5} \;\rightarrow\; \underset{(E)}{5+1=6}$$

In step (A) we face the problem of adding $5+1=?$. In the second step (B), a transformation from the unknown to the known is applied which leads to the intent of wholeness (denoted by int-wh) through iterations. Because the intent of wholeness can be replaced by the extent of wholeness, a subject can use a particular rule, the successor (C). Then, by substituting the number 5 into the rule (D), the subject eventually obtains the result 6 (E). We conclude, that an individual performance of an addition is the result of a replacement of the intent by the extent of wholeness (steps B and C). How can such a replacement of intent by extent of wholeness be described?

2.2 Consistency and Concept Analysis

All general concepts are defined by pairs of intent and extent. If the concept of wholeness can by defined by the same manner, it is easy to replace intent by extent. Thus, the question is whether wholeness can be regarded as a concept defined by both intent and extent. In general, for a given concept X, Y is said to be an intent of X, if it is true to state that X is Y. Thus, the intent Y of X is an attribute. A set of intents is also called an intent. Similarly, Z is called an extent of X, if it is true to state that Z is X. The extent Z of X is an object. A set of extents is also called extent. For example, if the concept X is defined by "insect", the extent of the insects is expressed as {ant, beetle, butterfly, ...}. It is possible to say that ants are insects, beetles are insects, and so on. An intent of insects is given by {endowed with six legs, endowed with compound eyes, ...}, because we can trully state that insects are endowed with six legs, and so on. In other words, intent is the content of a concept and extent is the domain of application of the concept.

A concept is defined to be consistent if each element of the extent satiesfies all elements of the intent and if each element of the intents satiesfies all elements of the extent. The extent then is consistent with the intent. Recall the concept of insects. An ant has six legs, an ant has compound eys, and so on. Similarly, an ant has six legs, a beetle has six legs, and so on. In the same manner, each concept can be checked whether it is consistent. Completeness of a concept is defined by non-redundancy. Completeness implies that there is no pair of concepts such that both concepts have the same intent (or extent, respectively). If concepts are analytical, the universe consisting of objects and their attributes can be subdivided into non-redundant concepts. In the latter case, the universe is also called to be analytical.

Consider the ideal case where an observer sees the whole universe that consists of objects and their attributes. If each concept is consistent, then the observer can grasp the universe by means of irredundant concepts. In this particular situation consistency implies analysis, and vice versa. We generally assume the formal conceptual universe to be both consistent and analytical, because the relation between objects and attributes can be considered to be complete.

Now we extend the concept analysis to the concept of wholeness. According to the definition of intent and extent, intent is located inside a concept. Whereas, the extent must be located outside the concept since it indicates the domain of application of that concept. When one is confronted with an extent of a concept, one has to approach the concept from the outside and to deal the concept as an individual substance. Therefore, if wholeness is defined as a concept, i.e. via the definition of both intent and extent, then it can be approached either from inside or from outside. Is this connected with Russel's paradox? To get an answer to this question, we have to examine the concept of wholeness in a more precise mathematical way.

3 Too Strong and Too Weak Wholeness as Exo-observer

3.1 Too Strong Wholeness Acknowledging the Formal Space

We first examine Russel's paradox based on the equivalence between intent and extent of the concept of a set. In set theory the intent of a set is expressed as a statement that involves the symbol representing an element of the set such as $A(x)$, for example. The extent of a set is expressed as $x \in y$, for example. It follows, that a set y is defined as

$$\exists y \forall x \left(A(x) \Leftrightarrow x \in y \right), \tag{1}$$

by the equivalence relation between intent and extent. The intent can be defined by $x \notin y$. Since x is arbitrary, it can be substitued by y. This leads to $(y \notin y \Leftrightarrow y \in y)$, which obviously is a contradiction. To avoid this contradiction, the definition of a set has to be modified to $\forall a \exists y \forall x \left(A(x) \wedge x \in a \Leftrightarrow x \in y \right)$. Since now the intent is restriced to $x \in a$, the definition of $A(x)$ no longer leads to Russel's paradox. The described restricition means that the mixture of elements and sets is prohibited. In other words, the abstract sense of wholeness can no longer be contacted from the outside. Therefore, with respect to a concept of a set intent and extent are consistent with each other. Rather, the concept of the wholeness of a set is now defined only by an intent that consists of all symbols and expressions given by definition (1). Due to Russel's paradox, the wholeness is regarded as a transcendental concept. The concept of wholeness is located at the border of a universe. Therefore, we can regard it as the most objective observer, called an exo-observer [1].

The quantifier $\forall$ yields the status of an exo-observer. For example, $\forall x \in S$ represents $x = 0, 1$ with respect to $S = \{0, 1\}$, or $x = 0, 1, 2, 3$ with respect to $S = \{0, 1, 2, 3\}$. Notwithstanding the content of a set, the reference of this quantifier is determined a priori. Imagine that the symbol S represents a baggage. One has to continue to remove elements untill the baggage is empty which indeed is the meaning of the quantifier $\forall$. Everything in the universe can be acknowledged by this transcendental concept of the wholeness. This kind of wholeness lets the universe invariant. We call this wholeness the *first wholeness* and point out that it is too strong.

3.2 Too Weak Wholeness in the Diagonal Argument

Even in mathematics, there is another kind of wholeness that denies the universe. It is found in the diagonal argument that is used for a proof of Russel's paradox, too. Consider the proof to be applied to the cardinality of natural and real numbers. An infinite set of real numbers is expressed as an open interval, $(0.0, 1.0)$. Assume that all elements of the interval can be counted. Then a counted real number at the k^{th} turn is expressed as a binary sequence, $a_{k0}a_{k1}a_{k2}\ldots a_{kk}\ldots$. The assumption of countability represents the one-to-one relation between real and natural numbers. Due to this assumption, the diagonal elements, $a_{00}a_{11}a_{22}\ldots a_{kk}\ldots$, are taken to build a new binary sequence, $f(a_{00})f(a_{11})f(a_{22})\ldots f(a_{kk})\ldots$, where $f:\{0,1\}\to\{0,1\}$ is defined by $f(0)=1$ and $f(1)=0$. Since a new binary sequence is also a real number, it has to be counted. Assume that it is counted at the n^{th} turn. Then it is expressed as $a_{n0}a_{n1}a_{n2}\ldots a_{nn}\ldots$. By construction, the same number is given by $f(a_{00})f(a_{11})f(a_{22})\ldots f(a_{nn})\ldots$ which leads to the contradiction $f(a_{nn})=a_{nn}$.

We now apply the diagonal argument tho the concept of wholeness with respect to its intent and extent. The diagonal argument uses an uncountable entity regarded as the wholeness. In our assumption, the wholeness is prescribed in form of an intent, because an infinite binary sequence and/or the one-to-one correspondence between natural and real numbers is expressed as counting bits $a_{k1}, a_{k2}, \ldots$, and so on. The iteration of counting bits (parts) can lead to the wholeness of a binary sequence and the interation of counting binary sequences, $(a_{00}a_{01}a_{02}\ldots a_{0k}\ldots), (a_{10}a_{11}a_{12}\ldots a_{1k}\ldots)$, and so on, can constitute the wholeness of a one-to-one correspondence between real and natural numbers. Then, the wholeness (of infinity) can be expressed as a concept that consists of uncountable parts. That is why we regard the wholeness, as it appears in the assumption, as an intent of wholeness expressed as "affirmation of parts".

Due to the assumption, diagonal elements are chosen and modified to new binary sequences. The diagonal elements can contain the status of wholeness, whereby the wholeness as a plural collectivity is transformed into the wholeness as a single global totality. The wholeness as a single global thing has not the same status as a part contained in the intent of wholeness, unless the diagonal elements are modified by $f:\{0,1\}\to\{0,1\}$. Note, that every part of the wholeness defined by the intent is counted expressed by the sequence $a_{n0}a_{n1}a_{n2}\ldots a_{nn}\ldots$, i.e., it lies in a row. Only the expression $a_{n0}a_{n1}a_{n2}\ldots a_{nn}\ldots$ as a part of the wholeness has the status of a thing that can be contacted from the outside. Since only the extent of a concept can be contacted from the outside it has to be expressed as a sequence of row elements $a_{n0}a_{n1}a_{n2}\ldots a_{nn}\ldots$, too. A sequence of diagonal elements, $a_{00}a_{11}a_{22}\ldots a_{kk}\ldots$, per se, has not the status of a thing, because it consists of the same elements as a binary sequence already counted. However, after the application of the transformation $f:\{0,1\}\to\{0,1\}$ to the diagonal elements, a binary sequence different from any other so far counted can be constructed. The new sequence $f(a_{00})f(a_{11})f(a_{22})\ldots f(a_{nn})\ldots$ now has the status of a thing that can be contacted from the outside. Therefore, this new sequence is regarded as an extent of wholeness. On the one hand, the purpose of applying the transformation f to the diagonal elements is to construct a new sequence that is distinct from each previous sequence. On the other hand, the application of f inevitably leads to a representation of wholeness as an extent. One can say, that the new sequence, $f(a_{00})f(a_{11})f(a_{22})\ldots f(a_{nn})\ldots$, as an extent of wholeness emerges from the "negation of parts".

Thus, we found two kinds of wholeness through the application of the diagonal argument. One is the intent of wholeness expressed as an "affirmation of parts", and the other is the extent of wholeness expressed as the "negation of parts". As we mentioned above, a concept is well-defined if consistency and analyis is statisfied. The wholeness in the diagonal argument has inconsistent intent and extent, because the intent affirms but the extent denies the same parts. We are lead to the impression that the diagonal argument is of self-contradictory or antinomian nature. Does this lead to a logical fallacy?

The answer is "No". The diagonal argument satiesfies analysis. Since the concept of wholeness is the largest concept and therefore identical with the universe, there cannot exist another concept to be compared with the concept of wholeness. The concept of wholeness is a unique concept and, therefore, the universe necessarily consists of irredundant concepts only. This implies analysis.

The concept of wholeness in the diagonal argument is analytical, though being inconsistent. It therefore can be used in mathematics. However, as a result of the inconsistency between intent (the affirmation of parts) and extent (the negation of parts) wholeness in the diagonal argument can deny the universe. Thus, compared to the first wholeness, this kind of wholeness is too weak – it destroys the formal system.

3.3 Consistency *or* Analysis

There are two kinds of concepts of wholeness, as shown in the previous sections. The first one accepts the universe and the second one denies it. Both concepts are not appropriate to be used for the construction of the demanded interface between intent and extent in a computational process – the first one is too strong and the second one is too weak. As you may anticipate, our goal in the following is to construct a "third wholeness" that is neither too strong nor too weak. To this end, we extend the definition of extent and intent in a natural way by introducing an indicator called "this" which in turn can be regarded as a concept. This new concept of "this" is a particular concept that satiesfies only consistency.

To get an intuitive idea, imagine the following situation. There is a pen in front of you and me. I ask you "please, pass me this one". You kindly pass me the pen. Clearly, the word "this" leads to a performative action between you and me. I intended to get a pen by using the word "this" and you interpreted "this" as a pen. Let me recapitulate, that the intent Y of a concept X is defined through the statement X *is* Y. For the situation in hand, the content of the concept of "this" is a pen, or in other words, the intent "pen" of the concept is expressed as the speaker's intention. The listener, in turn, detects what is indicated by "this" and examines the domain of application of "this". Eventually he determines whether the pen is "this" or not. We conclude, the extent of "this" is expressed as the listener's interpretation – the pen in our example.

Consistency in the concept "this" is satiesfied in an extreme manner, so to speak, since intent and extent are identical – a pen is a pen. However, the concept of "this" is not analytical, per se, since both intent and extent change according a particular situation. If in a similar situation as in the example above a notebook is in front of you and me, both intent and extent of "this" are represented by the notebook.

	Ideal concepts	The second wholeness	"this"
Consistency	○	×	○
Analysis	○	○	×

Table 1: List of concepts naturally used. Compared to ideal formal concepts, the concept of the wholeness used in the diagonal argument has no consistency but analysis. The concept of an indicator, "this", has only consistency.

As shown in Table 1, there are two extreme concepts. One is the concept of wholeness in the diagonal argument and the other is the concept of "this". In the former one, only analysis holds, and in the latter one, only consistency holds. Recall, that the first wholeness turned out not to be a concept at all. There exist various kinds of concepts in a real universe. Both consistency and analysis may not be satiesfied by most natural concepts. Natural concepts are mostly dynamical and not invariant. Objects, attributes and their relations are dynamically changed. Note, that the intent and the extent of a concept are mutually connected by the notion of wholeness or a particular quantifier, $\forall$. In the following, we replace such a quantifier by the third wholeness which is indeed different from the first and the second wholeness as described in the previous sections.

4 The Third Wholeness in Formal Concepts

4.1 A Formal Concept in an Ideal Universe

In section 2.1, the computational process of an observer or an actor has been discussed. The crucial point of such a computation is given by the interaction between intent and extent of wholeness. The interface, to be constructed in what follows, is called the third wholeness. The task is, to construct it neither too strong (or trancendental) as the first wholeness nor too weak as the second wholeness in the diagonal argument.

Each ideal concept consists of an intent and an extent in a consistent and analytical way (cf. section 2.2). Intent and extent are connected via the first wholeness. The interaction between the subject's action (intent) and a particular rule (extent) in a computational process including an actor (or observer) is now replaced by the intent and the extent of a formal concept. Different from the first wholeness, however, we now define the third wholeness that interfaces intent and extent. To this end, the basic idea of formal concept theory [11, 12] is reviewed first.

A formal context is defined by $K = (G, M, I)$, where G is a set of objects, M is a set of attributes, and I is a relation such as $I \subseteq G \times M$. A formal context, K, implies the ideal universe. From a formal context, a formal concept can be derived by introducing an extent-intent-pair (A, B), with $A \subseteq G$ and $B \subseteq M$ and the definition $A' = B, B' = A$, where

$$\begin{aligned} A' &= \{m \in M | gIm, \forall g \in A\} \\ B' &= \{g \in G | gIm, \forall m \in B\}. \end{aligned} \tag{2}$$

Among concepts, a partial order is defined by

$$(A_1, B_1) \leq (A_2, B_2) :\Leftrightarrow A_1 \subseteq A_2 \quad \text{and} \quad B_2 \subseteq B_1. \tag{3}$$

A concept lattice is defined by a set of concepts together with the partial order of definition (3). In general, a lattice is a partial ordered set, S, that is closed with respect to the supremum $(x \cup y)$ and the infimum $(x \cap y)$ for all two-element-sets, $\{x, y\}$, with $x, y \in S$. Because of definition 2, all concept lattices are complete [12] and the following statements can be proven: For $A, A_1, A_2 \subseteq G(\text{or} A, A_1, A_2 \subseteq M)$,

$$\begin{aligned} &A_1 \subseteq A_2 \Rightarrow A_2' \subseteq A_1 \\ &A \subseteq A'' \\ &A' = A'''. \end{aligned} \tag{4}$$

From statements 4, A' can be regarded as a closure of A. This means that two operations $' : P(G) \to P(M)$ and $' : P(M) \to P(G)$ lead to a Galois connection, where $P(X)$ represents a power set of the set X. It can also be proven, that $A \subseteq B' \Leftrightarrow B \subseteq A'$, i.e., a one-to-one correspondence is given. In terms of category theory, $' : P(G) \to P(M)$ is left-adjoint to $' : P(M) \to P(G)$ (the functors are in adjunction) [7].

Note, that there are many adjunctions in mathematics in terms of category theory. When one defines syntax and semantics in formal logic together with two transformations between them like $' : P(G) \to P(M)$ and $' : P(M) \to P(G)$, one can find adjunction. In other words, there is a one-to-one correspondence between syntax and semantics which is the intent of wholeness. If one treats the wholeness of a one-to-one correspondencs as the extent of wholeness, he has to use the diagonal argument. This, however, results in incompleteness in the sense of Gödel's theorem. By simply introducing a syntax-semantics loop, a formal system cannot be forced to show evolution. One has to introduce the third wholeness in adjunction.

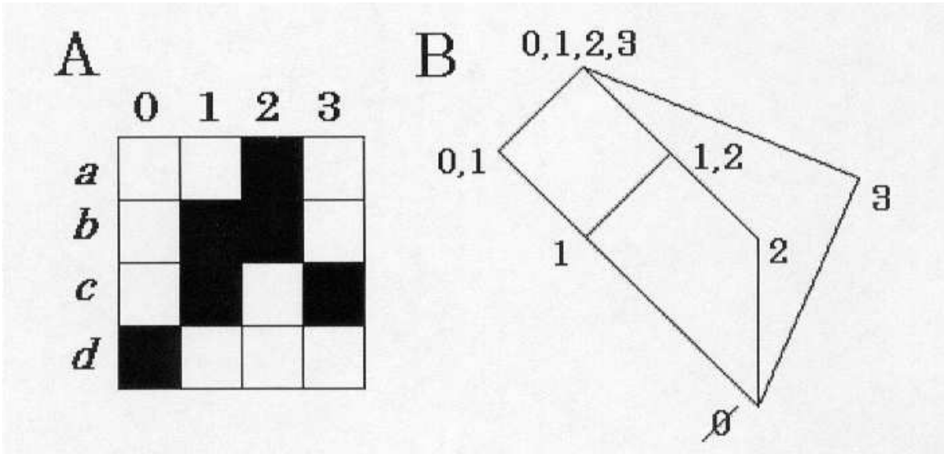

Figure 2: *A) a particular formal context is shown and B) the corresponding formal concept.*

A Hasse diagram of a concept lattice is drawn by choosing the maximal concept (A_2, B) for $(A_1, B) \leq (A_2, B)$ with $A_1' = A_2' = B$. This procedure of choosing maximal concepts leads to an irredundant concept lattice. In the concrete case of a context as shown in Fig. 2A, all concepts are obtained as

$$
\begin{array}{l}
\underline{(\{0,1,2,3\}),} \\
(\{0,1,2\},\emptyset), \quad (\{0,1,3\},\emptyset), \quad (\{0,2,3\},\emptyset), \quad (\{1,2,3\},\emptyset), \\
\underline{(\{0,1\},\{c\}),} \quad (\{0,2\},\emptyset), \quad (\{0,3\},\emptyset), \quad \underline{(\{1,2\},\{b\}),} \quad (\{1,3\},\emptyset), \\
(\{0\},\{c\}), \quad \underline{(\{1\},\{b,c\}),} \quad \underline{(\{2\},\{b,d\}),} \quad \underline{(\{3\},\{a\}),} \quad \underline{(\emptyset,\{a,b,c,d\}),}
\end{array}
$$

where the underlined concepts represent irredundant elements of the lattice. Consequently, a local formal concept lattice (or local lattice) that consists of irredundant elements only is expressed as shown in Fig. 2B in the form of a Hasse diagram. A concept lattice is denoted by $B(G, M, I)$.

The condition $A' = B$ and $B' = A$, implies consistency, as mentioned above. Futhermore, the partial order defined in Eqn. 3 leads to completeness of the lattice which in turn implies analytical concepts. As a result, formal concepts can be adequate models for ideal concepts. It remains to replace the quantifier $\forall$ in the definition of A' and B' in Eqn. 2 by the third wholeness.

4.2 The Third Wholeness Interfacing Intent and Extent

Recall the schematic diagram for the computational process that includes an observer as shown in Fig. 1. This scheme can be also applied to the learning process. Imagine, that you are learning a sequence of π by heart. After you have acquired the sequence you can use it as a particular

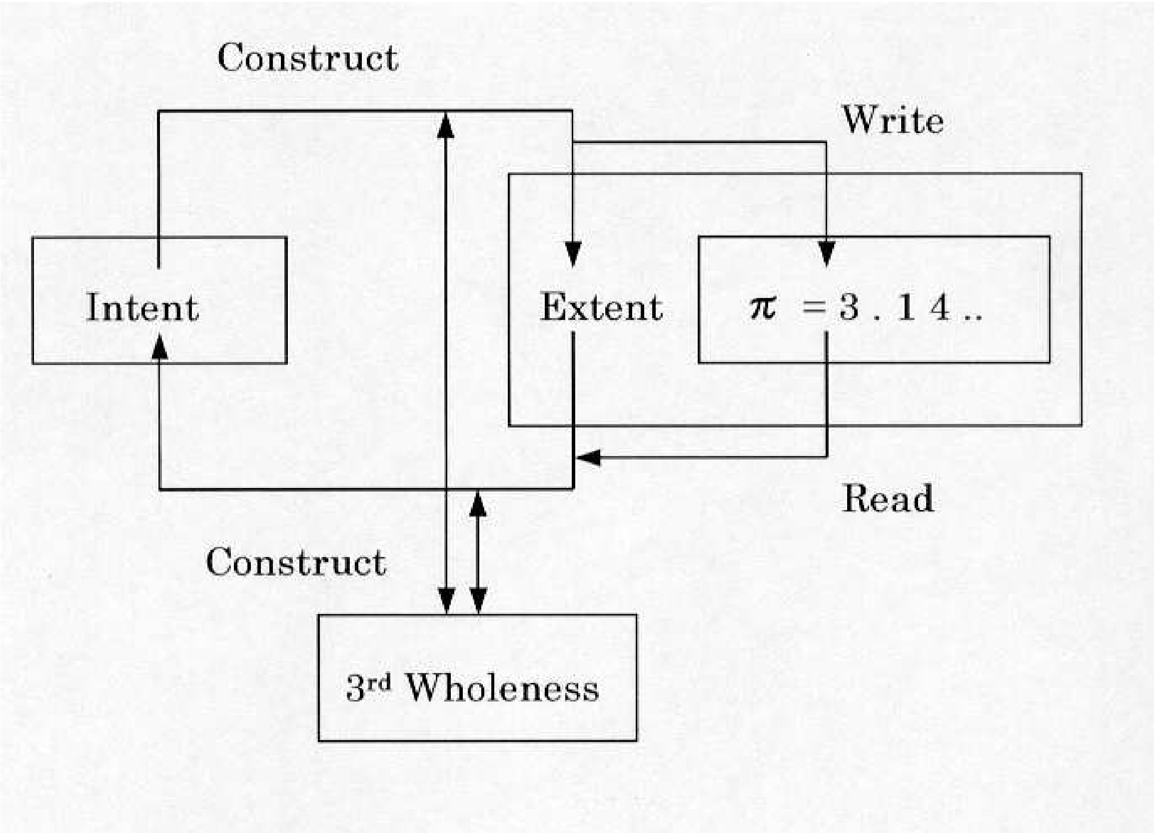

Figure 3: *Schematic diagram of learning successive numbers expressed as teh interaction between a subject as the operator and a buffer as the operand. The acquisition and the subsequent usage of the succession of numbers can no longer be separated.*

rule. As long as the process of acquisition cannot be separated from the succeeding process, it is unnecessary to distinguish between the learning and application processes. Concerning the application process of an observer, the alteration of a rule and the usage of that rule cannot be separated. The learning process is schematically depicted in Fig. 3. In order to express both the process before and after the acquisition an explicit domain, e.g. a buffer, as a rule is added to the diagram of Fig. 1. Extent can be written into the explicit domain or read out from it. The other parts of the scheme in Fig. 3 remain as depicted in Fig. 1. A rearrangement of Fig. 3 is shown in Fig. 4. The heuristic notion has now been replaced by the notion of formal concepts, whereby the operation between intent and extent as defined in Eqn. 2 has been modified by using the third wholeness. The scheme in Fig. 4 includes a time development of formal contexts and concepts. A time step is designated by t, and the formal context as well as the concept are denoted by $K(G_t, M_t, I_t)$ and $B(G_t, M_t, I_t)$, respectively.

Our next step is to define an operation, $F : P(G) \to P(M)$, that includes the idea of the third wholeness. To this end, for any $A \subseteq G$ we define FA by

$$FA = \{m \in M | gIm, \forall_p g \in A\}, \tag{5}$$

where a specific quantifier $\forall_p$ called a partial quatifier has been used. The partial quantifier, $\forall_p$, refers to the partial wholeness (the third wholeness) and is defined by

$$\{g \in A | \forall_p g \in A\} = A \cap ((A')^c)^+ . \tag{6}$$

The definition of A', hereby, is the same as given in Eqn. 2 and B^c is the complement of a set B satisfying $B \cap B^c = \emptyset$, $B \cup B^c = M$ and $B^{cc} = B$. The operation B^+ is defined by

$$B^+ = \{g \in G | gIm, \exists m \in B\}. \tag{7}$$

The partial wholeness is the concept yielded through a natural extension of the first wholeness since it describes the set (a part of the universe) indicated by the wholeness but – this is the new aspect – depends on an indicated set. We refer to the first wholeness as the transcendental baggage. Compared to the first wholeness, the partial wholeness involves the observer's stance expressed by the chosen subset $A \subseteq G$.

The partial wholeness can also be seen as the natural extension of the second wholeness since it weakly involves the contradiction of $A \wedge \neg A$ (or $A \cap A^c$), which is the definition of the second wholeness. Hereby A represents the whole set of parts. The difference is, that the third wholeness is based on both extent and intent of a concept. The formal intent is obtained from the extent. Then the complement is taken. Eventually, the operation B^+ involves the partial negation of the operation B'. The latter can be seen by taking the complement of $\{m \in M | gIm, \forall g \in A\}$ which gives $\{m \in M \ | g\not{I}m, \exists g \in A\}$. Hereby, $g\not{I}m$ means that g has no relation to m. Finally, this results in the unequalitity $A \cap ((A')^c)^+ \neq A \cap A^c = \emptyset$. These natural extensions of the first and the second wholeness justifies to call $\forall_p$ the third wholeness.

In order to construct a lattice one usually introduces an inclusion relation like $FA_1 \subseteq FA_2$ (i.e. $B_1 \subseteq B_2$). However, in the case under consideration this would meand that the consistency of a concept is lost. On the other hand, since the least as well as the greatest element is obtained, the lattice is complete which in turn implies that the concept is analytical.

Next we define $U : P(M) \to P(G)$ for any $B \subseteq M$. This operation is defined by means of the adjunctive operations, $f^+ : G \to P(G)$ and $f^- : P(M) \to G$, through

$$\begin{array}{ccc} & f^+ & \\ G & \longrightarrow & P(G) \\ R_1 & & R_2 \\ M & \longleftarrow & P(M). \\ & f^- & \end{array} \tag{8}$$

The relations $R_1 \subseteq G \times M$ and $R_2 \subseteq P(G) \times P(M)$ used in the definition of Eqn. 8 are defined by

$$\begin{array}{rcl} gR_1m : & \Leftrightarrow & gI_{t+1}n \quad \forall n \in \{g\}', m \in \{g\}', \\ AR_2B : & \Leftrightarrow & A' = B, \end{array} \tag{9}$$

for $g \in G, m \in M, A \in P(G)$ and $B \in P(M)$, where $P(X)$ represents a power set of X. The operation $f^+ : G \to P(G)$ is defined by

$$f^+(g) = \{g\}, \quad \forall g \in G \tag{10}$$

and $f^- : P(M) \to G$ is defined by

$$f^-(B) = m, \quad \forall B \in P(M), m \in B. \tag{11}$$

Due to the above definition, f^+ and f^- constitute an adjunctive pair. It is easy to prove that

$$\begin{array}{rcl} gR_1f^-(B) & \Leftrightarrow & gI_{t+1}n \quad \forall n \in B, m \in B \\ & \Leftrightarrow & B = \{n \in B | gI_{n+1}n\} \\ & \Leftrightarrow & \{g\}' = B \\ & \Leftrightarrow & f^+(g)R_2B. \end{array} \tag{12}$$

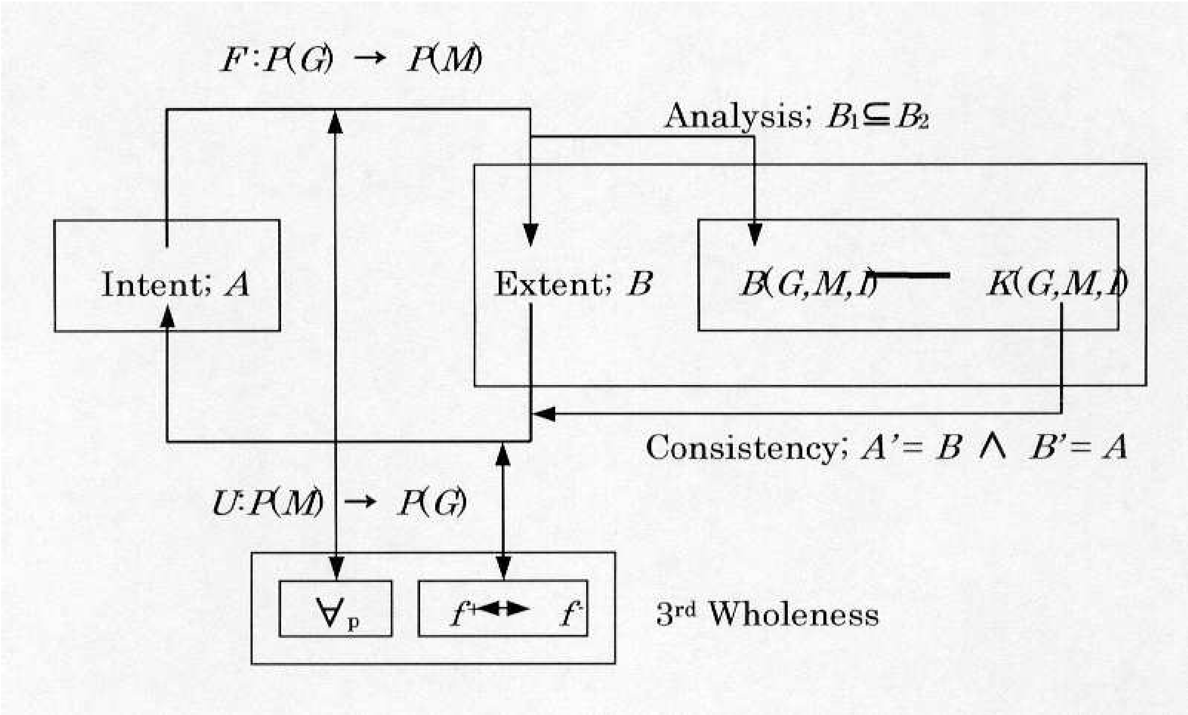

Figure 4: *Schematic diagram of the interaction between intent and extent in term of a formal concept. Since the interactin is intervened by the partial quantifier, both formal context and concept are dynamically changed.*

To satisfy the condition of Eqn. 8, the operation U is defined as follows. First, for the greatest element M, the empty set, $\emptyset$, is defined as extent which leads to the concept $(\emptyset, M)$. For $B_1 \subseteq B_2$ (i.e. $FA_1 \subseteq FA_2$) a new extent is created to satisfy $A_2 \supseteq A_1$. If $B_2 \subseteq B_1$ and $B_3 \subseteq B_1$ then define $A_2 = A_1 \cup \{\star 1\}$ and $A_3 = A_1 \cup \{\star 2\}$ with $\{\star 1\} \neq \{\star 2\}$. Otherwise, if $B_3 \subseteq B_1$ and $B_3 \subseteq B_2$ then define $A_3 = A_1 \cup A_2$.

The operation U as defined above can constitute a concept lattice that consists of $(UB_1, B_1) \leq (UB_2, B_2)$ with $UB_1 \subseteq UB_2$ and $B_1 \supseteq B_1$, where $B = FA$. This concept lattice is denoted by $B(G_{t+1}, M_{t+1}, I_{t+1})$. For any $g \in G_{t+1}$, one can obtain $\{g\}R_2B \Leftrightarrow UBR_2FA$. In other words, one can list all $m \in M$ with $gI_{t+1}m$ for each $g \in G$, according to $gR_1f^-(FA)$. As a result, we can transform from $K(G_t, M_t, I_t)$ to $K(G_{t+1}, M_{t+1}, I_{t+1})$ through the construction of the concept lattice that consists of (UB, FA) based on $FA_1 \subseteq FA_2$ and by obtaining $gI_{t+1}m$.

4.3 Dynamical change of Context and Concept Via the Third Wholeness

We now present an example for the dynamical change of formal contexts and concepts. The initial context, $K(G_t, M_t, I_t)$, is given as shown in Fig. 5A. For any $A \subseteq G_t$, the entities $A', (A')^c, ((A')^c)^+, \{\forall_p\}$ and FA are calculated as shown in Table 2. Since $(FA, \subseteq)$ is a partially ordered set, it yields the lattice depicted as a Hasse diagram in Fig. 5D. A set that consists of the elements, $a, b, c,$ and d, can have new attributes in M_{t+1}. By applying the operation U, each element of the Hasse diagram in Fig. 5D can be obtained as a concept that is defined by a pair of extent and intent, thus the notation $B(G_{t+1}, M_{t+1}, I_{t+1})$. From all

A	A'	$(A')^c$	$((A')^c)^+$	$\{\forall_p\}$	FA
$\{1,2,3,4,5\} = G$	$\emptyset$	M	G	A	$A' = \emptyset$
$\{1,2,3,4\}, \{1,2,3,5\}, \{1,2,4,5\},$ $\{1,3,4,5\}, \{2,3,4,5\}$	$\emptyset$	M	G	A	$A' = \emptyset$
$\{1,2,5\}$	$\{b\}$	$\{a,c,d\}$	G	A	$\{b\}$
$\{1,3,4\}$	$\{c\}$	$\{a,b,d\}$	$\{1,2,4,5\}$	$\{1,4\}$	$\{c\}$
$\{1,2,3\}, \{1,2,4\}, \{2,3,4\}, \{2,3,5\}$ $\{3,4,5\}, \{1,3,5\}, \{2,4,5\}, \{1,4,5\}$	$\emptyset$	M	G	A	$A' = \emptyset$
$\{3,4\}$	$\{c\}$	$\{a,b,d\}$	$\{1,2,4,5\}$	$\{1,4\}$	$\{c\}$
$\{1,5\}$	$\{a\}$	$\{b,c,d\}$	G	A	$\{a\}$
$\{1,2\}$	$\{b\}$	$\{a,c,d\}$	G	A	$\{b\}$
$\{2,4\}$	$\{d\}$	$\{a,b,c\}$	G	A	$\{d\}$
$\{1,3\}$	$\{c\}$	$\{a,b,d\}$	$\{1,2,4,5\}$	$\{1\}$	$\{a,b,c\}$
$\{1\}$	$\{a,b,c\}$	$\{d\}$	$\{2,4\}$	$\emptyset$	M
$\{2\}$	$\{b,d\}$	$\{a,c\}$	$\{1,3,4\}$	$\emptyset$	M
$\{3\}$	$\{c\}$	$\{a,b,d\}$	$\{1,2,4\}$	$\emptyset$	M
$\{4\}$	$\{c,d\}$	$\{a,b\}$	$\{1,2,5\}$	$\emptyset$	M
$\{5\}$	$\{a,b\}$	$\{c,d\}$	$\{1,2,3,4\}$	$\emptyset$	M
$\emptyset$	M	$\emptyset$	G	$\emptyset$	M

Table 2: List of A (formal extent), A' (the corresponding intent in the sense of a formal concept),$(A')^c((A')^c)^+$, $\{\forall_p\}$ (all elements of a set, A, represented by the partial quantifier) and FA (formal intent mediated by the partial quantifier). The formal context is given as shown in Fig. 6A.

concepts of $B(G_{t+1}, M_{t+1}, I_{t+1})$ a new context can be obtained denoted as $K(G_{t+1}, M_{t+1}, I_{t+1})$ (Fig. 5C). To summarize our results so far, via the third wholeness, $\forall_p$, a lattice based on $(FA, \subseteq)$ can be obtained which allows the procees of a dynamical change from $K(G_t, M_t, I_t)$ to $K(G_{t+1}, M_{t+1}, I_{t+1})$. A formal concept lattice corresponding to $B(G_{t+1}, M_{t+1}, I_{t+1})$ based on $(A', \subseteq)$ is shown in Fig. 5B.

Assume given a $K(G_t, M_t, I_t)$. It is easy to see that if A is a singleton set then $FA = M$ and $B(G_{t+1}, M_{t+1}, I_{t+1})$ is obtained as a different concept lattice from $B(G_t, M_t, I_t)$. To show this, we need the following proposition.

Proposition 1

Given $K(G_t, M_t, I_t)$. If $A \subseteq G$ is a singleton set such as $A = \{h\}$, then $FA = M$.

Proof

First, we show that $A \cap ((A')^c)^+ = \emptyset$. Suppose $h \in ((A')^c)^+$, then

$$\begin{aligned}
(A')^c)^+ &= \{g \in G | gIm, \exists m \in (A')^c\} \\
&= \{g \in G | gIm, \exists m \in \{m \in M | gIm, \forall g \in A\}^c\} \\
&= \{g \in G | gIm, \exists m \in \{m \in M | g \not\!I m, \exists g \in A\}\},
\end{aligned}$$

which leads to $gIm \wedge h \not\!I m$, for any $g \in ((A')^c)^+$. Due to the assumption, we can substitute

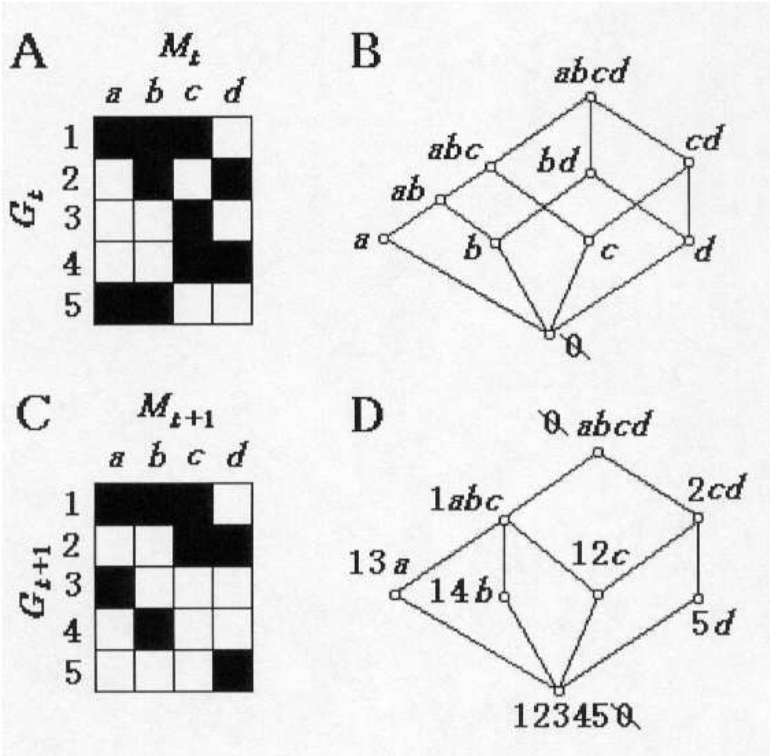

Figure 5: *A) An example for a dynamical context. B) A formal concept lattice,* $(A', \subseteq)$ *derived from the context shown in part A. C) The subsequent dynamical context obtained from the dynamical concept lattice shown in part D. D) The dynamical formal concept lattice,* $(FA, \subseteq)$ *that corresponds to the context shown in part A.*

g by h, which leads to a contradiction, $hIm \wedge h\not{I}m$. Therefore, $h \in ((A')^c)^+$ does not hold, which implies $A \cap ((A')^c)^+ = \emptyset$. As a result, $\{g \in A | \forall_p g \in A\} = A \cap ((A')^c)^+ = \emptyset$ and $FA = \{m \in M | gIm, \forall_p g \in A\} = \{m \in M | gIm, g \in \emptyset\} = M$. ■

If $B(G_{t+1}, M_{t+1}, I_{t+1})$ is a particular non-distributive complemented lattice, then $K(G_t, M_t, I_t)$ is expressed as a special context where each object has only one relation to an attribute. Such a context always leads to a 2^1-Boolean lattice via the partial quantifier. This fact is comprehended in the following proposition.

Proposition 2

Given $K(G_t, M_t, I_t)$ in which $\forall g \in G_t$ there uniquely exists an $m \in M_t$ with gI_tm, then $B(G_{t+1}, M_{t+1}, I_{t+1})$ is a concept lattice consisting of two elements, $(G_{t+1}, \emptyset)$ and $(\emptyset, M_{t+1})$.

Proof

For a proof, we have to treat three cases with respect to $A \subseteq G_t$.
(i) $A \subseteq G_t$, where A is neither a singleton nor an empty set. Since $\forall g \in G$ there uniquely exists an $m \in G$ with gI_tm, $A' = \emptyset$ and $(A')^c = M$. Then, $((A')^c)^+ = G$. Therefore, we obtain $\{g \in A | \forall_p g \in A\} = A \cap ((A')^c)^+ = A$. This means that in this case a partial quantifier is the same as the usual one. It leads to $FA = A' = \emptyset$.
(ii) $A = \{h\}$ a singleton set. From proposition 1 follows, $FA = M_{t+1}$.

(iii) $A = \emptyset, \emptyset' = M_t$ and $(\emptyset')^c = \emptyset$. Then $((\emptyset')^c)^+ = G_t$. We obtain $\{g \in A | \forall_p g \in A\} = \emptyset$ which leads to $FA = M_{t+1}$.
Finally, this leads to a lattice with $\emptyset \subseteq M_{t+1}$, and, by applying the operation U, we obtain two concepts, $(G_{t+1}, \emptyset)$ and $(\emptyset, M_{t+1})$. ■

By contrast, the contexts which satisfy the specific condition of the following proposition always lead to a non-distributive lattice as a consequence of the partial quantifier.

Proposition 3

If $K(G_t, M_t, I_t)$ with $|M_t| \geq 3$ is subject to the conditions
(i) $\forall g \in G_t(g \neq h)$, there uniquely exists $m \in M_t(gI_t m \quad \text{and} \quad gI_t n)$,
(ii) $\forall m \in M_t(m \neq n)$, there uniquely exists $g \in G_t(gI_t m \quad \text{and} \quad hI_t m)$,
(iii) $h \not{I}_t n$,

then the concept lattice, $B(G_{t+1}, M_{t+1}, I_{t+1})$, is a non-distributive complemented lattice.

Proof

First, we identify the elements of $B(G_{t+1}, M_{t+1}, I_{t+1})$ by treating three cases with respect to $A' \subseteq M_t$.

(i) $A' = \emptyset, (A')^c = M_t$ and $((A')^c)^+ = G_t$. We obtain $\{g \in A | \forall_p g \in A\} = A$ which implies $FA = A' = \emptyset$.
(ii) $A' = \{p\}$ a singleton set.
(ii-1) $A' \neq \{n\}, n \in (A')^c$, and $gI_t n, \forall g \in G$. Since A' is a singleton set, $(A')^c$ has at least another element denoted by $s \in (A')^c(s \neq n, p)$. It is now clear that $hI_t n$. We conclude that $\forall g \in G$ there exists $m \in (A')^c(gI_t m)$. This in turn means that $((A')^c)^+ = G_t$ and $FA = A' = \{p\}$.
(ii-2) $A' = \{n\}$. Since $(A')^c = M_t \backslash \{n\}$, it follows $((A')^c)^+ = G_t$. Therefrom we obtain $\{g \in A | \forall_p g \in A\} = A$. Finally we have $FA = A' = \{n\}$.
(iii) $A' \subseteq M_t$, where A is neither singleton nor empty.
(iii-1) $n \in A'$. Since A' is not singleton there exists another element $m \in A'$ with $m \neq n$. Note that A' has at most two elements. Due to the assumption, there uniquely exists $g \in M_t(gI_t m$ and $gI_t n)$, thus, $A = \{g\}$. Therefore, $(A')^c = M_t \backslash \{m, n\}, ((A')^c)^+ = G_t \backslash \{g\}$, and $A \cap ((A')^c)^+ = \emptyset$. Finally we have $FA = M_{t+1}$.
(iii-2) There is no n in A'. From $h \not{I} n$ we have $h \in A$. Since A' is not singleton, there are at least two elements, $m, r \in A'$ with $m, r \neq n$. Assume $g \in A$ with $(gI_t m$ and $gI_t r)$. Due to the assumption, the latter relation can be satiesfied only by $h \in A$. This leads to $A = \{h\}$. Therefore, $A' = M_t \backslash \{n\}, (A')^c = \{n\}, ((A')^c)^+ = G_t \backslash \{h\}$ and $A \cap ((A')^c)^+ = \{h\} \cap G_t \backslash \{h\} = \emptyset$. Finally, $FA = M_{t+1}$.
From (i)–(iii), it follows that a concept lattice, $B(G_{t+1}, M_{t+1}, I_{t+1})$, consists of $\emptyset \subseteq \{p_1\}, \{p_2\}, \ldots, \{p_w\} \subseteq M_{t+1}$ with respect to the intent, where the $\{p_i\}$ are singleton sets. This lattice contains a sublattice consisting of $\emptyset \subseteq \{p_1\}, \{p_2\}, \{p_3\} \subseteq M_{t+1}$, thus, it is non-distributive. For any element $\{p_i\}$ with $i = 1, 2, \ldots, w$, there exists a $\{p_s\}$ such that $\{p_i\} \cap \{p_s\} = \emptyset$ and $\{p_i\} \cup \{p_s\} = M_{t+1}$, which means that the lattice is complemented. ■

A sub-context of a formal context $K(G, M, I)$ can be defined by $H \subseteq G, N \subseteq M$ and $J = I \cap (M \times N)$, denoted as $K(H, N, J)$. In formal lattice theory [12], a sub-context is known to be compatible to $K(G, M, I)$, if and only if $\Pi_{H,N} : B(G, M, I) \to B(H, N, J)$ is a complete surjective homomorphism, where $\Pi_{H,N}(A,B) = (A \cap G, B \cap M)$ for $(A,B) \subseteq G \times M$. As far as the sub-context is compatible, there is a congruent relation so that $B(G,M,I)$ is isomorphic to $B(H,N,J)$. A sub-context, $K(G \backslash \{h\}, M \backslash \{n\}, I \cap (G \backslash \{h\}) \times (M \backslash \{n\}))$, as it emerges in proposition 3 is compatible to $K(G,M,I)$, if the concept is defined by $A' = B$ and $B' = A$. In other words, if, one the one hand, the context is transformed in the sense of an ideal universes and, on the other hand, if it is transformed via the partial wholeness, then contexts and concept lattices change perpetually along the time.

The computational process including an endo-observer can be regarded as an interaction between the computation of a particular Boolean expression and the development of semantics based on $B(G_t, M_t, I_t)$. For example, a Boolean expression can be defined by an elementary cellular automaton, i.e.

$$a_k(t+1) = F\left(a_{k-1}(t), a_k(t), a_{k+1}(t)\right), \tag{13}$$

where f is expressed as a lattice polynomial (i.e., it contains the operations $\cap, \cup$ and complement). Let the system size be N. Futhermore, it is defined that a binary sequence computed at the t^{th} step controls the number of compatible transformations of $K(G_t, M_t, I_t)$ by adding new elements $\{h\}$ to G_t and $\{n\}$ to M_t, respectively, in such a way that $\forall g \in G_t (g \neq h) g I_t n$, and $\forall m \in M_t (m \neq n) h I_t m$, and $h \not{I}_t n$. The concept lattice, $B(G_t, M_t, I_t)$, yields a value of the cellular automaton. Assume that a given lattice polynomial is fixed in the form of Eqn. 13. If the lattice is not a distributive one, then the complement is not uniquely determined and, therefore, the computation based on Eqn. 13 is not deterministic.

Figure 6 shows the dynamical change of the context, $K(G_t, M_t, I_t)$, based on the partial quantifier. In part B of Fig. 6 one sees the lattice, $B(G_t, M_t, I_t)$, that corresponds to the context located at the same coordinate. The thin arrows represent the temporal change from t to $t+1$ based on the partial quantifier. The thick arrows represent compatible transformations of the formal contexts. Note that the compatibility makes sense as long as the concepts are defined by $A' = B$ and $B' = A$. The compatibility loses its meaning if the concepts are defined by $FA = B$. For example, when we start with the lattice $B(G_0, M_0, I_0)$ located at the coordinate $(0,0)$ as depicted in Fig. 6B, the initial computation of Eqn. 13 obeys a Boolean lattice. It leads to the context $K(G_0, M_0, I_0)$ at the coordinate $(0,0)$ shown in Fig. 6A. The binary sequence in excess of the computation represents for four times a compatible transformation and $K(G_0, M_0, I_0)$ moves to the context at the $(1,3)$-coordinate. Through the influence of the partial quantifier, the lattice $B(G_1, M_1, I_1)$ can be obtained, located at the $(1,3)$-coordinate. Therefrom, $K(G_1, M_1, I_1)$ is obtained as the matrix shown in the lowest row. If the binary sequence computed at the 2^{nd} step does not represent a compatible transfromation of the context, then the obtained lattice $B(G_2, M_2, I_2)$ is determined as that one located at the $(2,2)$-coordinate. It leads to $K(G_2, M_2, I_2)$ located at the $(3,1)$-coordinate. Assume that the binary sequence computed at the 3^{rd} time-step also represents no compatible transformation. The context $K(G_2, M_2, I_2)$, then, is no longer transformed and the lattice $B(G_3, M_3, I_3)$ is obtained as the lattice located at the $(3,1)$-coordinate. This elementary Boolean lattice is the same as a lattice located at the coordinates $(1,1), (1,2), (1,3), \ldots, (1,n)$. It, therefore, leads to the context located at coordinate $(0,0)$. This means, that the Boolean context is recapitulated.

As mentioned above, both compatible transformations and the lattice transformations based on the partial quantifier can show a dynamical change of the "semantics" of computation. Each lattice shown in the first instance represents a distributive complemented Boolean lattice (Fig 6B). Each lattice shown in the second instance represents a modular lattice, and each one in the third instance represents an orthomodular lattice. A distributive lattice is defined by a lattice with distributive law that is expressed as $a \cap (b \cup c) = (a \cap b) \cup (a \cap c)$. Modular

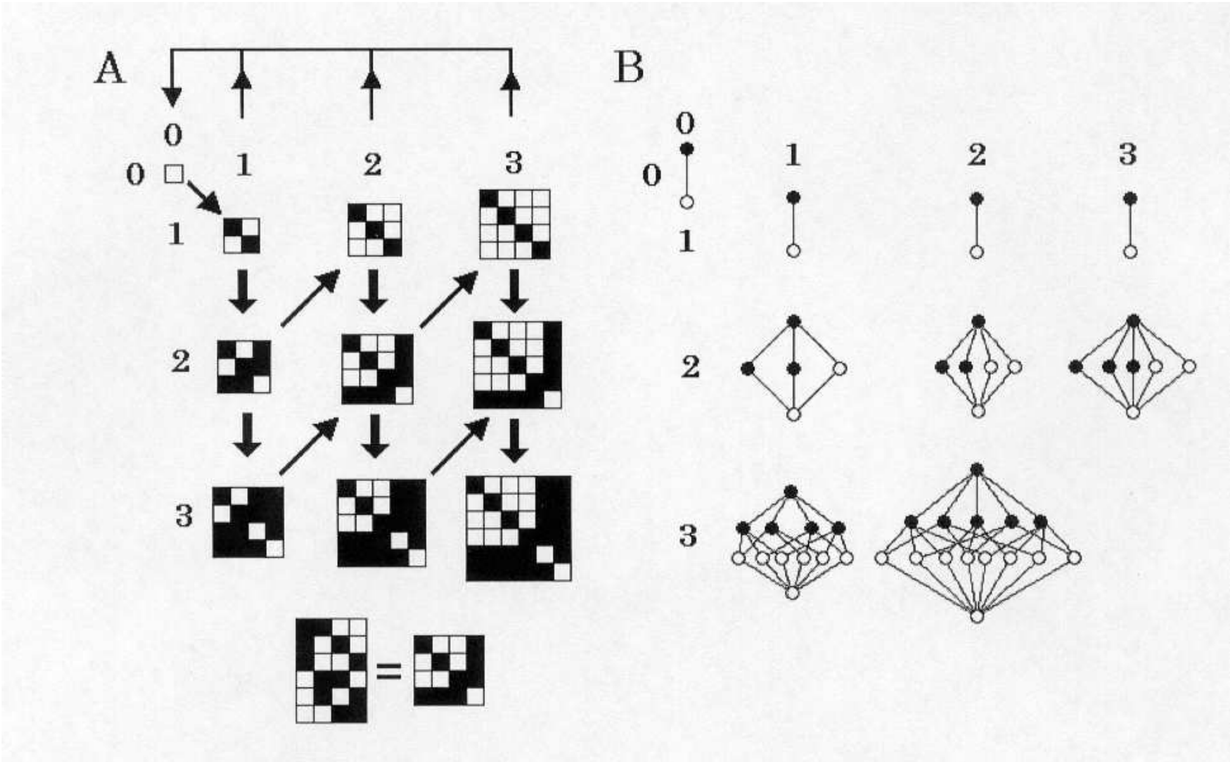

Figure 6: *A) Dynamical transition of a formal context, $K(G_t, M_t, I_t)$ obtained by the dynamical change of the concept lattice, $B(G_t, M_t, I_t)$, based on $(FA, \subseteq)$. The thine line represents the dynamical change of context and lattice as a caused by the interaction between intent and extent. The thick line represents a compatible transformation of contexts in the sense of $(FA, \subseteq)$. B) Dynamical concept lattice, $B(G_t, M_t, I_t)$, based on $(FA, \subseteq)$, that is obtained from the context at the same coordinate in A. The lattices in the upper row are complemented distributive lattices, lattices in the middle are non-distributive modular lattices and the lattices in the lower row are non-modular orthomodular lattices.*

lattices are defined by lattices obeying the modular law: if $a \leq c$ then $a \cap (b \cup c) = (a \cap b) \cup c$. The orthomodular law is expressed as $a \leq b$ then $a \cap (b \cup a') = a$, where a' represents the orthocomplement of a. The lattice-succession of distributive, modular, and orthomodular lattices refers to the occurrence of a decreasing size of sub-lattices in which the distributive law hold. A modular lattice obey the distributive law only if $a \leq c, a \cap (b \cup c) = (a \cap b) \cup (a \cap c)$ and then $(a \cap b) \cup c$ since $a \leq c \Leftrightarrow a \cup c = c$. An orthomodular lattice obeys the distributive law in a more restricted sub-lattice. From recalling the processes depicted in Fig. 6 it is clear that the dynamical transformations of lattices change the size of the sub-lattices in which the distributive law holds.

The distributive law allows the interpretability of a parallel processing to a serial one. If the computational processes are expressed as functions such as $f : A \to B$ and $g : A \to B$, a parallel processing can be expressed by using a product map which reads $f \times g : A \times A \to B \times B$. In contrast, a serial processing with a switch-mechanism can be expressed as $f + g : A + A \to B + B$ by using a direct sum. In addition, if the distributive law, $A \times (B + C) = (A \times B) + (A \times C)$, holds, then the parallel process can be replaced by the serial one: $X \times B \simeq X \times (I + I) = (X \times I) + (X \times I) = X + X$, where $B = \{0, 1\} \simeq I + I$ and I being a singleton set. Rephrased in the abstract language of category theory: join and meet in a lattice is the same as a direct sum and a product, respectively. Therefore, the distributive lattice implies a semantics in which any parallel processing can be replaced by a serial one, or, in other words, the law in a distributive lattice is always a causal one.

The succession from a distributive, modular, orthomodular, non-modular lattice implies the existence of an extent of interpretability between parallel and serial processing. In physics, macroscopic phenomena are descibed by classical mechanics which is based on a Boolean (i.e. distributive, complemented) lattice. Whereas quantum mechanics which describes microscopic phenomena is based on an non-modular, orthomodular lattice [14]. There is an essential difference between Boolean and non-modular, orthomodular lattices in terms of physics. The question arises, how these two perspectives can be connected. The existing dualism of classical and quantum mechanics results from the dualism of the existence of causal laws, where the distributive law holds, and non-causal laws, where the distributive law does not hold. It seems that a parallel processing can be comprehended only if it can be replaced by a serial processing. If a processing is parallel in principle, it can be regarded just as disorder. However, in the fields of complex systems research the complicated but regular united behaviors that result from in-principle parallel processings (interactions) are manifestations of progress. The notion of complex systems clarifies not negative but positive significance of parallel processing [15].

The positive significance of parallel processing cannot be comprehended only in non-distributive lattices. Non-commutability does not contain a positive significance untill the connection from non-commutability to a commutative law is found. Our model based on the partial quantifier can express the change of the concept lattice, $B(G_t, M_t, I_t)$, and contains the positive significance of a negative statement (the non-distributive law). As mentioned earlier, both the transformation of concept lattices and compatible transformations of formal contexts can lead to the perpetual exchange of distributive and non-distributive lattices. Such a dynamical expression is a positive one concerning the negative statement of the non-commutative law, which means that non-commutativity is not only found in quantum mechanics but also in observation processes in general [17].

5 Discussion and Conclusion

How does a self-evolving system work? This has been our initial question. It is generally believed that the interaction between syntax and semantics can lead to emergent behavior. On the one hand, paradoxes such as Gödel's theorem of incompleteness result from this interaction. On the other hand, this interaction is possible in simulations without logical contradictions. Therefore, it is believed that the simulated interaction avoids to fall into a contradiction and enables emergent behavior.

The simulated interaction between syntax and semantics works *wrapped up* by the first wholeness, i.e. a super-observer. The interaction itself cannot carry the concept of wholeness. Through the examination of the relationship between intent and extent of a concept, we manifest that the wholeness regarded as the limit of parts is confused with the wholeness of a super-observer, where substantially the former one is the intent and the latter is the extent of a concept of wholeness. Since the intent of wholeness is not consistent with its extent in the diagonal argument, this leads to a paradox, per se. This wholeness is called the second wholeness.

Dualism of the inside-outside-type can be compared with the dualism of syntax and semantics. An observer who is faced with an object inside his own perspective and makes a decision always refers to the outside. Our investigation has shown that when we refer to the outside (wholeness) neither the first nor the second wholness is adequate; we rather use the partial wholeness for a local observer. That is why the third wholeness is the perspective of the endo-observer.

The interaction between syntax and semantics is replaced by the interaction between individual calculations and a rule of computation. We found, that the third wholeness can mediate the interaction. Indeed, this interaction is replaced by the interaction between the formal intent and extent of a formal concept. In formal concept theory, intent and extent are mediated by the first wholeness, a quantifier. It leads to a static concept that never evolves. To overcome this problem, we introduced the third wholeness in form of a specific partial quantifier.

Thanks to the partial quantifier, the context or the relation between intent and extent of concepts is dynamically changed. In other words, we gave up the consistency between intent and extent to make an analytical universe (complete lattice) that consists of concepts, where consistency is compensated by a relation between objects and attributes. The iteration of this procedure enables the change of lattices and contexts.

The dynamical change of concepts has been examined with respect to a distributive law. We utilized the concept lattice as semantics by the computation of a particular lattice polynomial as transition rule. Even if a transition rule, expressed as a lattice polynomial, is fixed, the change of a lattice can entail an emergent state unexpected from a Boolean lattice. If a distributive law in a lattice holds, then the complement of an element of the lattice is always uniquely determined. Otherwise, the complement of such an element is not uniquely determined and the subsequent state can be proved to be both 1 and 0. That is why stochastic behavior is possible, if the computation is based on a non-distributive lattice, and vice versa. It, therefore, leads to a computation deviated from controlled computation.

Originally, orthomodular lattices have been studied under the consideration of the relation to quantum mechanics, whilst Boolean (complemented distributive) lattices have been compared to classical mechanics [18] [19]. Our study may evoke the dynamical interface between these disciplines and show that emergent properties result from the interaction between these two perspectives. Emergent properties can result from virtually parallel processing. Schooling behaviors of fish is regarded as a fascinating example [20]. Virtually parallel interactions cannot be interpreted as a serial processing, although one cannot know the significance of the parallel processing in a particular lattice. Hidden significances of parallel processing cannot be expressed in a distributive lattice where parallel processing is always replaced by a serial one. However, not only a distributive but also orthomodular lattices cannot carry the significance of virtually parallel interactions, because the significance of virtually parallel processing can no longer be positivly expressed in non-distributive lattices. If the connection between these two lattices can be expressed, the positive significance can be regarded as an ongoing negative process (non-distributive law) pushing positive processes (distributive law). Clearly, the partial quantifier, or the third wholeness, plays a role in dynamically changing lattices with or without distributive law. It might be also possible, that fishes can refer to their own context in the sense of the third wholness.

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Making Sense of Internal Logic: Theory and a Case Study

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Abstract

Motivated by the *interfaciology* proposed by Otto Rössler, we have attempted to construct a framework of internal logic of the mind and brain. We propose a functional equation as an abstract form representing mental processes. We consider a method by which such internal logic can be interpreted and understood by an (external) observer. For this purpose, we propose a theory for cognitive experiments. Applying this theory to simple deductive inference processes exhibited by animal subjects in an experimental setting, with the assumption that syllogism is expressed as a composite mapping corresponding to the product operation of two implications $A \to B$ and $B \to C$, an interpretation of the neural activity associated with the behavior in these experiments is obtained. This theory is consistent with the internal description hypothesized by Rob Rosen.

1 Introduction

In this paper we are concerned with the question of how an external observer can understand the internal logic of a subject. In order to study this question, we wish to develop a general theory that can be used to construct and implement an interface between the observer and subject that can allow for such an understanding [1].

As a first step in this search for an interface between the observer and the subject in cognitive experiments, we assume the presence of neuronal correlates of cognition, especially with regard to the correlation between neural activity and its implication at the behavioral level, with the hope that a certain type of cognitive experiment on humans or animals leads us to identify such an interface. We have constructed a theory of a supposed internal process of inference. In this theory, the *discrimination* based on some equivalence class is introduced. By using this concept, the correspondence between the space of attributes of external stimuli and neuronal activity is derived and interpreted as the interface in question [2]. In this paper, we briefly outline this theory, which is consistent with the internal description hypothesized by Rob Rosen [3] in his relational biology.

In our model of the experiments, the environment is expressed in terms of some dynamical variable or variables. Here we denote these by X_t. Let us consider two extreme cases for internal dynamics of the brain (Fig. 1). In one case these dynamics consist of a copy of the external world. In this case, the internal dynamics are identical to the environmental dynamics, X_t. Thus the dynamics of the brain constituting the *description* are of *fixed-point* nature. The other extreme case is that in which the internal dynamics describe the external world in the form of a *constant function.* This represents a rigid description, independent of any dynamics of the environment. The former extreme here is the completely adaptive case, and the latter is the autistic case. Clearly actual brain dynamics must be somewhere between these two extremes. Such an intermediate dynamics could be chaotic at the description level. We propose a functional equation for the *description*, which we believe may represent a meta-dynamics of mental processes.

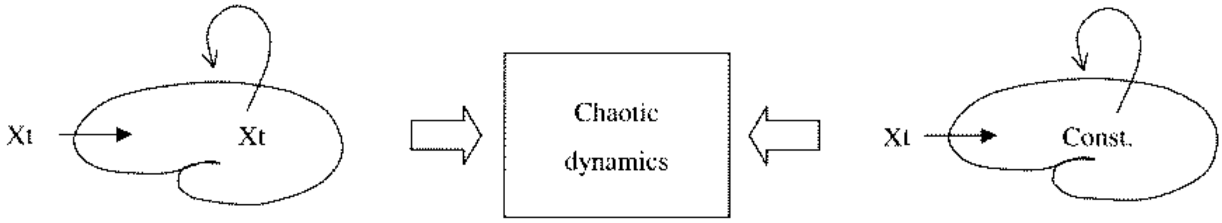

Figure 1: *The extreme cases of brain dynamics are depicted. One extreme is the case in which these dynamics constitute a copy of the external world. Conventional neural network studies are concerned with this case. The other extreme is the case of autism, in which the brain dynamics are fixed, irrespective of the external world. The actual situation must be somewhere between these two cases.*

2 A theory for cognitive experiments

In order to formulate an effective interface, we have searched a sufficiently simple yet meaningful cognitive experiment. As one candidate for such an experiment, we considered the type recently carried out by Sakagami and Niki [4] and Sakagami and Tsutsui [5].

They performed a set of experiments investigating multidimensional visual discrimination tasks with monkeys. In these experiments, they recorded the prefrontal cell activity while monkeys performed a *go/no go attention task*. The subjects were trained to make a *go* or *no go* response, depending on, for instance, the color, the direction of motion, or the shape of compound visual stimuli, namely moving patterns of different colors and shapes. Moreover, the subjects had to "understand" the meaning of the color of the fixation spot that is presented at the center of the screen at each trial. That is, for each trial, the subject is presented a pattern. Each pattern is in general characterized by the attributes of motion, color and shape, but for a given trial only one of these is "important". The important attribute is indicated by the color of the fixation spot. For instance, if this color is purple, then the important attribute is color (we call this situation the *color condition*), if it is blue this attribute is motion (the *motion condition*), and if it is red this attribute is shape (the *shape condition*). The subject is then required to act in some way, according to the state of the important attribute, namely the kind of condition. The basic formulation of the experiment can be understood from the following. At the beginning of a trial, the fixation spot is presented. With the important attribute thereby fixed, the subject is presented with a pattern. For each attribute, certain states correspond to the *go* response, and certain attributes correspond to *no go* response. For example, red means *go* and right-directed motion means *no go*. Thus if a red, right-moving pattern is presented, the correct response is *go* in the color condition but *no go* in the motion condition.

We formulated this experiment as a case study. Let us denote a set of conditions by $X = \{x_c, x_m, x_s\}$, where x_c represents the color condition, x_m the motion condition and x_s the shape condition. Let us denote a set of target stimuli by $\mathbf{Y} = Y_c \times Y_m \times Y_s$, where Y_c is the set of color attributes of the target stimuli, Y_m the set of motion attributes, and Y_s the set of shape attributes. Finally, a set of responses is denoted by $Z = \{z_g, z_{ng}\}$, where z_g is a *go* response and z_{ng} a *no go* response.

Then, a learned response to stimuli can be expressed by a mapping $f : X \times \mathbf{Y} \to Z$. It is reasonable to assume that this mapping can be described by the following *renewal mapping system*:

$$f(x, (y_c, y_m, y_s)) = \begin{cases} f_c(y_c) & (x = x_c) \\ f_m(y_m) & (x = x_m) \\ f_s(y_s) & (x = x_s), \end{cases} \tag{1}$$

where $f_c : Y_c \to Z$ is a response to a color attribute in the color condition, $f_m : Y_m \to Z$ a response to a motion attribute in the motion condition, and $f_s : Y_s \to Z$ a response to a shape attribute in the shape condition. This is a kind of description at the cognitive level. On the other hand, a physiological description is represented by a mapping of the form $F : X \times \mathbf{Y} \to$ *neural activity*. The mapping F represents the activity of neurons or neuron assemblies resulting from stimuli in the case that the correct response is given.

We define a *discrimination* as a decomposition of a set A derived from the equivalence relation induced by a mapping $f : A \to B$ for any sets A and B. Sakagami *et al.* found several types of neurons which respond conditionally or unconditionally to a certain specific attribute of stimuli. Applying these results, it is possible to compare the theoretical classification of the stimulus space $X \times \mathbf{Y}$ with the classification based on neuronal activity.

Let us now consider candidates for deductive inference which could occur during the performance of a cognitive task. There could exist two elicited higher-order functions of f (by the Curry method) , which we denote here as g and h. The map g is defined as a renewal mapping system $\mathbf{Y} \to Z$ depending on the conditions X, whereas the map h is defined as a renewal mapping system $X \to Z$ depending on the stimuli $\mathbf{Y}$. Since for each trial in the above experimental setup an important attribute is first recognized by the subject, the existence of g is more plausible than h.

Two possible decompositions of g correspond to two kinds of attention, *focal attention* and *divided attention*. Here, focal attention is attention to a particular attribute, and divided attention is attention to all attributes. One decomposition can be expressed as a composite mapping, $\mathbf{Y} \to Y \to Z$. In other words, a particular attribute of the stimulus is first selected, and then behavior is determined from this attribute. The second decomposition can be expressed as another composite mapping, $\mathbf{Y} \to \mathbf{Z} \to Z$. In other words, the processing of a stimulus to its behavioral implication is first carried out parallelly for each attribute, and then a particular behavior is selected. The causality in the process of the former decomposition is summarized as *selection process* $\Longrightarrow$ *transformation process*, and that of the latter is summarized as *transformation process* $\Longrightarrow$ *selection process*. Thus, the former decomposition represents the focal attention and the latter divided attention.

Taking into account the above considerations, we can determine the internal processes that occur at the level of each type of neuron. The details will be published elsewhere.

3 The internal description must be dynamic

Let us assume the environment to be dynamic and described by $X_{n+1} = F(X_n)$, where n is a discrete time step. In general, F can represent some nonlinear, chaotic dynamics. The brain inevitably possesses a *description* of F, which is here denoted by h_n. We assume that this description changes to follow another dynamical system $\tilde{F}$. Then we obtain the functional

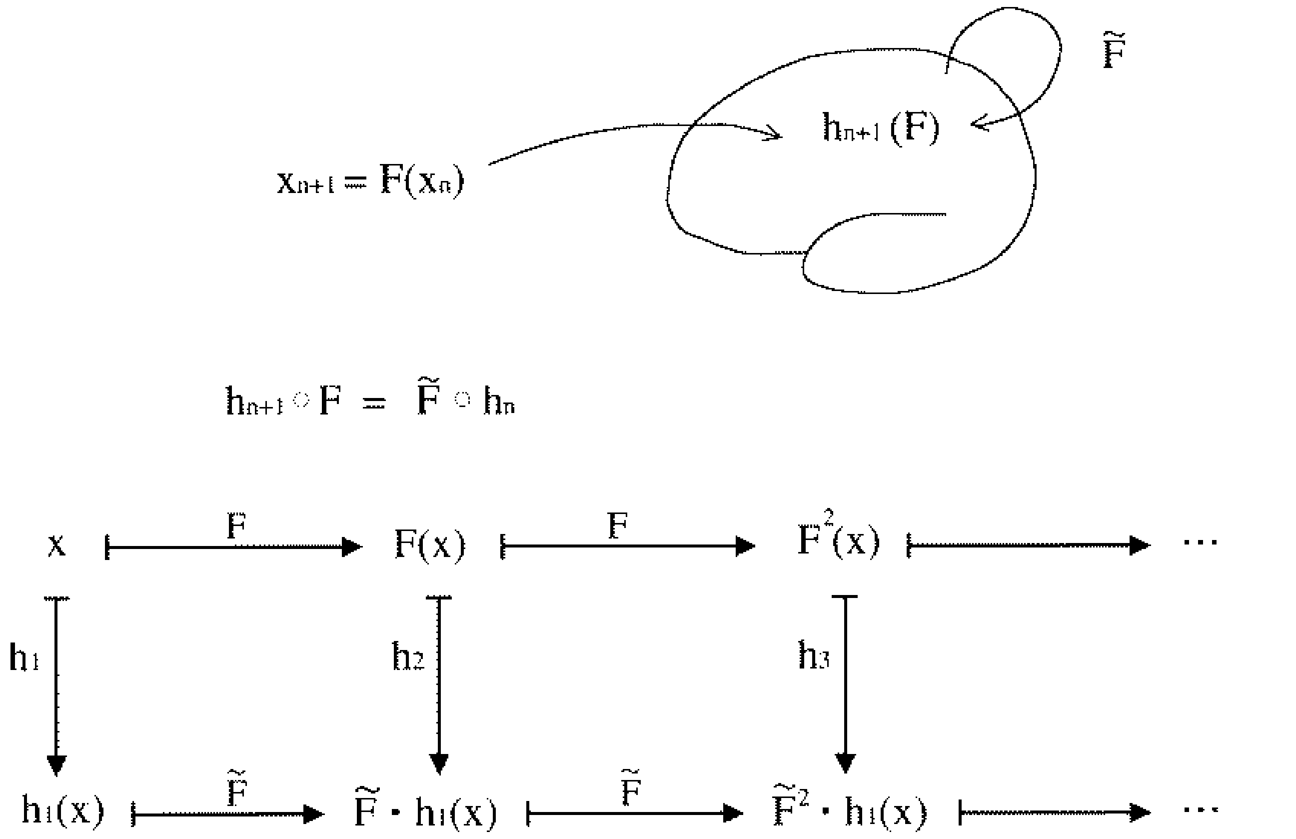

Figure 2: *The dynamics of the internal description are modeled by a functional transformation. A certain instability at the level of the description insures the development of the level of internal description, depending on the external dynamics.*

equation

$$h_{n+1} \circ F = \tilde{F} \circ h_n. \tag{2}$$

The dynamics of this description are schematically depicted in Fig. 2.

Let us consider the two special cases. In the case $\tilde{F} = F$, what is an invariant description? This condition implies that the same dynamical system can be used to model both the external world and its internal description. A trivial solution in this is

$$h^*(X) = X. \tag{3}$$

Here, the description provides a copy of the external world. This is the first extreme case discussed in the Introduction (see also Fig. 1).

The second special case we consider is that in which the dynamics of the description has a fixed point, that is, the case $\tilde{F}(X) = X$. Then we obtain

$$h_{n+1}(X_{n+1}) = h_n(X_n). \tag{4}$$

This implies the presence of a fixed point of the description, irrespective of the external world. This is the second extreme case discussed in the Introduction (see also Fig. 1).

The functional equation (2) for the internal description of the brain contains a great variety of solutions. When $F(X_n) = X_n$ and $\tilde{F} = h$, this functional equation takes on a form similar to that of the functional map of Kataoka-Kaneko [6].

In this paper we have treated the case of a learned state only, and thus the present theory does not provide a true dynamics of description. We are just at the starting point. In order to treat such a dynamics in the brain more realistically, we have to treat the learning process itself. In such a situation, the dynamics of the functional equation are expected to provide useful information.

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An Autocatalytic Reaction is the Prisoner's Dilemma Game When Viewed From the Eyes of Molecules

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Abstract

We propose that when we view chemical reactions from the eyes of molecules and consider reactions as games played among molecules, autocatalytic reactions emerge spontaneously from reaction networks.

Autocatalytic reactions (AR) are the simplest type of self-replication leading to the origin of life [4]. The probability for obtaining an autocatalytic enzyme by random combination is extremely low. It has been suggested that AR spontaneously emerge in sufficiently complex reaction networks [9]. We propose in the present paper that when we view chemical reactions from the eyes of molecules and consider reactions as games played among molecules, autocatalytic reactions emerge spontaneously from reaction networks.

Autocatalytic reactions (AR) are expressed in general by

$$mX + (n-1)Y \to nY \tag{1}$$

where Y is the autocatalytic molecule and X is the substrate. If molecule Y behaves as a template like RNA, the reaction is self-replicative. When this type of reaction is viewed from the eyes of molecules, it is a game between X and Y. Molecule Y plays against X when they collide with each other. In the reaction (1), when Y meets with X, Y increases from $(n-1)$ to n, that is to say, the gain of Y from the game against X, W_{YX} is $n/(n-1) > 1$. To the contrary, the payoff of X, W_{XY} is equal to 0 because X disappears or loses everything when X plays against Y. The catalytic molecule degrades in general. It follows that when Y plays against itself, the gain of Y, W_{YY}, is expected to be less than 1. The substrate X alone is inactive, and thus the payoff W_{XX} should be neutral or equal to 1. Then, the payoff matrix of the game of AR expressed by Eqn. (1) is given by

	X	Y
X	$W_{XX} = 1$	$W_{XY} = 0$
Y	$W_{YX} > 1$	$W_{YY} < 1$

The game is the Prisoner's Dilemma Game [11], because the matrix satisfies the condition that $W_{YX} > W_{XX} > W_{YY} > W_{XY}$, and $2W_{XX} > W_{YX} + W_{XY}$, if X is regarded as the player to cooperate and Y as one to defect.

Nowak and May studied the spatial game dynamics for the PD game [10]. They distributed players who always defect and those who always cooperate on a two-dimensional lattice. All players play games against their nearest eight neighbors. The strategy of each player at the next round is determined as that of player who obtained the best payoff among the nearest nine neighbors including itself. They found that the system exhibited very complex time-space patterns similar to those of class 4 cellular automata (CA) like the Life Game [6]. They considered the behavior as the origin of cooperation. In order to discuss the origin, however, we need to consider why and how players to defect or to cooperate emerged at the beginning.

The one-dimensional version of the spatial game dynamics for the PD game exhibits a phase transition. Each player is assumed to play against the nearest two neighbors and itself in this case. When $W_{YX}+2W_{YY}<2$, clusters of Y (defector) contract but isolated Y can coexist with X (cooperator). If $2<W_{YX}+2W_{YY}<3$, then clusters of Y survive and if $2<W_{YX}+2W_{YY}$ is greater than or equal to 3, Y grows steadily and dominates the space. Thus, the phase transition occurs when $W_{YX}+2W_{YY}=3$ between steadiness (class 2 of CA [12]) and divergence (class 1 of CA). The two-dimensional model studied by Nowak and May [10] shows a similar phase transition depending on W_{YX} and $W_{YY}(=0)$ between steadiness and chaos (class 3 of CA). For the sake of simplicity, we will use the one-dimensional model in the followings.

We suppose that molecules (players), either X or Y, are arranged on a one-dimensional lattice and that each molecule collides with two-neighboring molecules and itself. When molecules collide, they play games. The site will be occupied by the molecule which obtained the best payoff among the three molecules.

The dynamics of repeated games mentioned above can be expressed in general by local rules of CA with $k=2$ and $r=2$, where k is the number of states ($X=0$ and $Y=1$) and r is the radius of interaction. The local rules f are expressed as

$$\begin{aligned} a_i^{t+1} &= f(s_i^t), \\ s_i &= a_{i-2}+2a_{i-1}+4a_i+8a_{i+1}+16a_{i+2}, \end{aligned} \tag{2}$$

where a_i^t is the strategy (0 or 1) of player i at round t.

The number of rules in CA with $k=2$ and $r=2$ are 2^{32}. There are several constraints, when the rule represents game dynamics, such as $f(a_{i-2},0,0,0,a_{i+2})=0$ and $f(a_{i-2},1,1,1,a_{i+2})=1$. Assuming symmetry further, we still have $2^{10}=1024$ kinds of rules. The condition of rules when molecules are supposed to play the PD game is much more limited and is given in table 1. In order to explain the origin of AR in the primordial soup, we need to explain why the particular rules given in table 1 are selected among 1024 kinds of rules which express the reaction dynamics between two kinds of molecules.

s	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$f(s)$	0	0	1	0/1	1	1	0/1	0/1	1	1	1	1	0/1	1	1	1
s	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
$f(s)$	0	0	1	0/1	1	1	1	1	0/1	0/1	1	1	0/1	1	1	1

Table 1: Local rules of cellular automaton corresponding to the one-dimensional spatial game dynamics for the Prisoner's Dilemma game. Definitions of s and $f(s)$ are given by Eqn. (2) in text. When $s=3$ or 24, $f(s)=0$ if $W_{YX}+2W_{YY}<2$, and $f(s)=1$ if $W_{YX}+W_{YY}>2$. When $s=6,7,12,19,25$ or 28, $f(s)=0$ if $W_{YX}+2W_{YY}<3$ and $f(s)=1$ if $W_{YX}+2W_{YY}>3$.

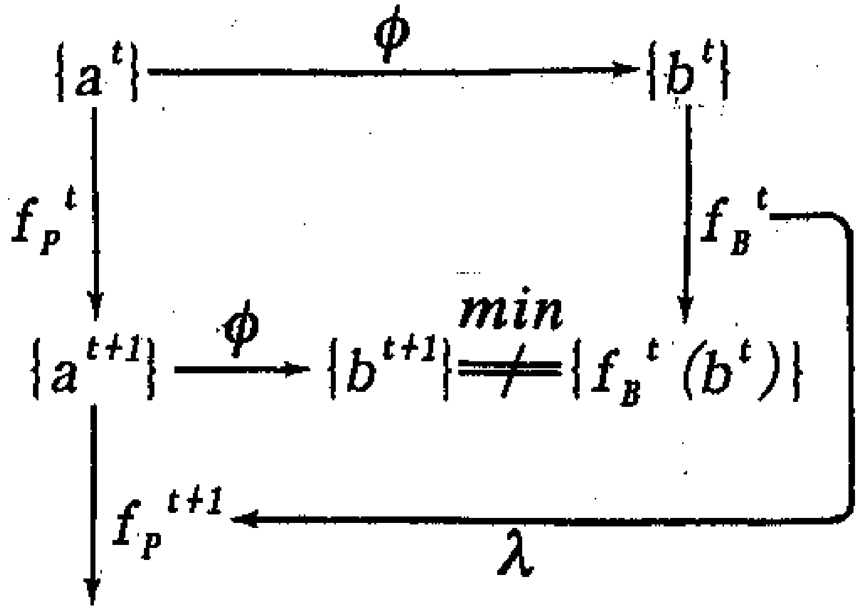

Figure 1: *The flow diagram of the bootstrapping system which perpetually equilibrates the local inconsistency resulting from two complementary logics; Boolean f_B and pseudo-Boolean f_P. See text for definition of ϕ and λ.*

When organic molecules in the primordial soup on the earth grow larger and more complex, a kind of uncertainty should arise. Conrad [2] distinguishes the inter-cellular computation and intra-cellular computation, and suggests that intrinsic uncertainty of information processing occurs through the interaction between them. A same kind of uncertainty should occur in the interaction between inter-molecular and intra-molecular processes. While reactions occur among small molecules, the state of molecule contains little uncertainty, and thus reactions can be described by some deterministic dynamics. As organic molecules in the primordial soup on the primitive earth grow larger and more complex, then the inter-molecular measurement of the state of large molecules is destined to accompany uncertainty, because the conformation of large molecules is always fluctuating and therefore the intra-molecular interaction is perpetually changing.

It is custom to neglect this kind of uncertainty on the basis of statistical thermodynamics, and the effect is taken into account within the estimation error of rate constants. We claim that the uncertainty cannot be neglected when the system is open and evolvable. The difference in the speed of response between the inter-molecular and intra-molecular computation (interaction) causes infinite regress in describing the state and interaction rules, and thus intrinsic uncertainty [7]. We will call this kind of intrinsic uncertainty as the effect of internal measurement.

Gunji and others proposed the bootstrapping system, shown in Figure 1, with two complementary logics, Boolean and pseudo-Boolean, in order to describe the effect of internal measurement [8]. We show in the following that a complex system containing large molecules with intrinsic uncertain state tends to self-organize so that AR may spontaneously emerge among many kinds of reactions.

Consider a primordial organic soup on the primitive earth. There existed simple molecules X such as monomers of amino acids and RNA, as well as large complex molecules Y with some arbitrary function. Y is not presupposed to be autocatalytic. The pseudo-Boolean logic is employed in the description with uncertain measurement (the left-hand side of Figure 1). In this description, the state of complex molecule Y cannot be fixed and thus an uncertain state 1/2 which is neither 0 nor 1 is assigned to Y. The state of simple molecule X is 0. After measurement or chemical reaction, states of both X and Y become certain a posteriori and therefore the Boolean logic is used to describe the system (the right-hand side of Figure 1) in which 0 and 1 are assigned to X and Y, respectively. We study how the bootstrapping system of CA, of which Boolean function is given by Eqn. (2), evolves when the effect of intrinsic uncertainty is taken into account.

While Boolean functions f_B for Eqn. (2) have 1024 different kinds, corresponding pseudo-Boolean functions f_P are much more diverse. For ease of computation, we assume that intra-molecular measurement of Y always accompanies uncertainty and therefore the uncertain state 1/2 only is used for Y in pseudo-Boolean functions. This greatly simplifies computation but does not affect the essential feature of results.

Let us imagine that one large molecule Y happens to appear in the primordial soup composed of simple molecule X. The corresponding initial state is a one-dimensional array occupied by 0 excepting the center site occupied by 1/2. The initial rule is a $0-rule$ with $f_P^0(s)=0$ for all s, implying that Y had no catalytic function at the beginning. The initial state $\{a^t\}$ with $t=0$ is transformed by f_P^t to the next state $\{a^{t+1}\}$, where $a \in \{0, 1/2\}$. We note that this process inevitably accompanies uncertainty in both rules and states. The state $\{a^t\}$ is uncertain a priori consisting of 0 or 1/2, but it turns out to be the certain state $\{b^t\}$ a posteriori consisting of either 0 or 1. This procedure is denoted in Figure 1 and is defined by $\{b^t\} = \{\phi(a^t)\}$, where $\phi(0) = 0$, and $\phi(1/2) = \phi(1) = 1$.

After the system evolved according to the pseudo-Boolean rule; $\{a^{t+1}\} = \{f_P(a^t)\}$, we induce a posteriori a Boolean rule f_B^t in such a way to satisfy,

$$f_B^t(\phi(a)) = \phi(f_P^t(a))) \tag{3}$$

The function f_B satisfying (3) is not necessarily to be unique and thus introduce arbitrariness in the evolution of the system. In the present system, vagueness resulting from the pseudo-Boolean logic is contracted by constraint (3), or inconsistency arising from incomplete measurement is perpetually minimized.

A bootstrapping procedure λ is employed in order to deduce the next-step function f_P^{t+1}. If the effect of internal measurement is nill, the system does not evolve and thus $f_P^{t+1} = f_P^t$. In this case, the whole process is consistent. In order to express the uncertain effect of internal measurement, we introduce probability p, and assume the following procedure. If b_k where k ranges from $i-2$ to $i+2$ do not contain 1, or those sites do not contain molecule Y, then the effect of measurement is nill and thus $f_P^{t+1} = f_P^t$. If b_k contain 1, f_P^{t+1} changes from f_P^t with probability p, being derived from f_B^t as

$$f_P^{t+1}(a) = (f_B^t(\phi(a)))^c, \tag{4}$$

Otherwise, $f_P^{t+1} = f_P^t$. Here, x^c is a complement of x, given by $(0)^c = 1/2$ and $(1)^c = 0$. It is clear that if $p = 0$ the system degenerates to a deterministic system and does not evolve.

Non-zero probability p represents the effect of uncertain measurement. The system is characterized by this dilation process (4) and by the contraction process (3), representing disequilibration resulting from uncertain internal measurement and the following minimization of disequilibrium, respectively. The bootstrapping procedure shown in Figure 1 is repeated. Local rules change perpetually, reflecting the uncertainty of the state of complex molecules Y. It is noted that the inconsistency introduced by Eqn. (4) is a kind of noise, when observed

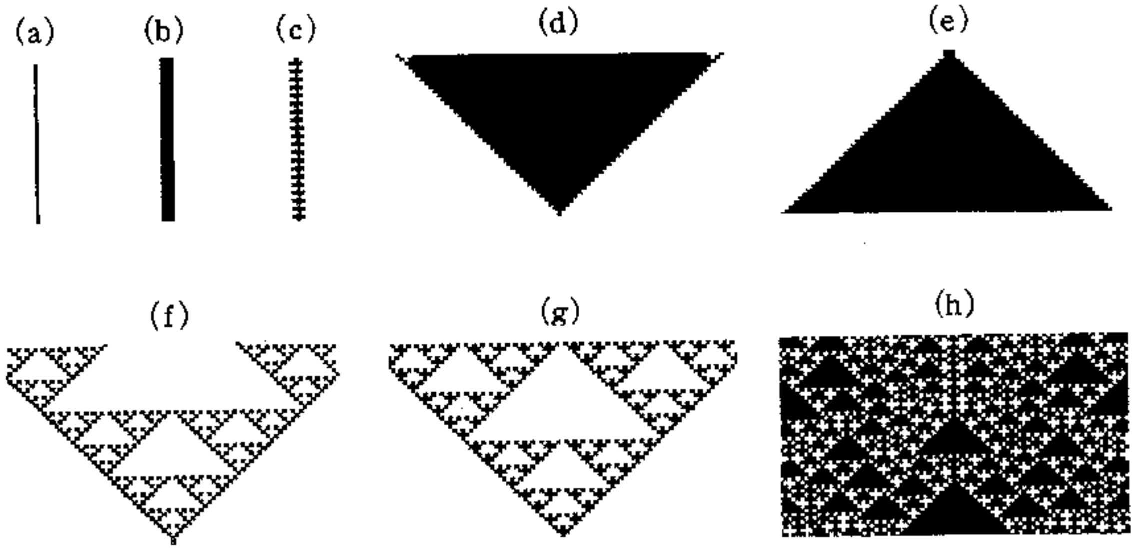

Figure 2: *Examples of typical transient patterns when p is relatively small. Black squares denote Y (=1 or 1/2) and white ones are X (=0). (a) isolated Y continues. (b) A cluster of Y of more than 2 is stable. (c) Y oscillates periodically. (d) Y grows continuously. (e) Y decreases gradually. (f) and (g) Self-similar patterns. (h) A composite pattern consisting of self-similar one and periodic one.*

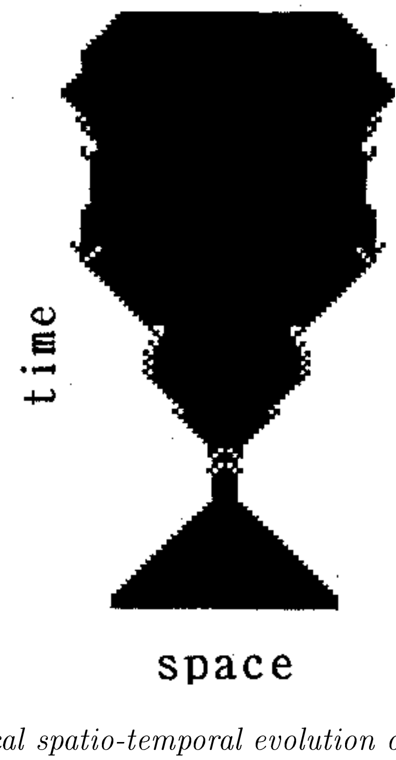

Figure 3: *A typical spatio-temporal evolution of Y when* $p = 0.1$.

from outside. This internal noise, however, is not random and is coherent through the perpetual disequilibration and equilibration process. This coherence is the cause why the system self-organizes and evolves.

Starting from the initial state with only one molecule of $Y(=1/2)$ in the center among $X(=0)$ in all other sites, the system evolves into two types of stable steady states. The stable states are either the state with all 0 or the one with all $1 (or 1/2)$. The former corresponds to a process that large molecules happened to be compound but got decomposed finally. The latter may correspond to an evolving process that the complex molecule Y reacted autocatalytically with X to produce more Y. The present system exhibits very long transient stages before it reaches the latter steady state of all 1. Examples of typical basic patterns appearing at the transient stage are shown in Figure 2.

When probability p is close to zero, being less than 0.01, patterns (a), (f) and (g) are seen exclusively. Those patterns become unstable when p is increased, and are rarely seen when p is about 0.1. When p is about 0.1, patterns $(b), (c), (d)$ and (e) are typical basic patterns. Most typically, the fraction of Y fluctuates as the dilating pattern (d) and the contracting pattern (e) interchange repeatedly as shown in Figure 3. Pattern (h) is an example of composite pattern consisting of self-similar patterns generated essentially by pattern (e) and periodic pattern (c).

We emphasize that the most typical patterns $(b), (c), (d)$ and (e) are generated also by the local rules of CA corresponding to the one-dimensional spatial game dynamics for the Prisoner's Dilemma game given in Table 1. Pattern (b) is generated when $W_{YX} + 2W_{YY} < 3$, pattern (c) when $W_{YX} + 2W_{YY} < 2$, pattern (d) when $W_{YX} + 2W_{YY} > 3$, and pattern (e) when $W_{YX} + 2W_{YY} < 2$.

It should be noted that we do not presuppose that the molecule Y is autocatalytic. Nevertheless, the system self-organizes without tuning or selection to have CA rules equivalent to the spatial game dynamics of the PD game. As has been explained at the beginning of the present paper, the autocatalytic reaction can be expressed as the PD game played between the autocatalytic molecule and the substrate molecule. We consider that the internal noise generated by the interaction between the inter-molecular process and the intra-molecular process acts as an apparent force as if it drives the mutation of Y to have autocatalytic function. It has been demonstrated in other studies [9, 5, 3, 1] that AR sets can be spontaneously formed in sufficiently complex networks. The present model also demonstrates that the emergence of AR sets is not by chance and that AR sets leading to the origin of life should emerge without natural selection when organic molecules grow complex enough on the primordial earth.

We have limited our discussion for the origin of AR comparing it to defection in the PD game. Our discussion can be applied also to the origin of cooperation or altruism, by changing the initial state to be all 1 instead of all 0 in the present model. The same system can be used to explain the origin of activator-inhibitor reaction-diffusion system in biological pattern formation. Our model aims a coherent description of the origin and evolution of pre-biotic and biotic processes.

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Thermodynamics as an Interface Agency Tailoring Quantum Mechanics for the Beginning of Biology

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Abstract

The first law of thermodynamics first noted by Julius Robert von Mayer in 1842 is unique in addressing the issue of energy transformation without explicating the material substrate implementing the transformation. It points up the presence of the interface agency accommodating the qualitative difference of energy between before and after the transformation while observing its quantitative conservation. Heat engine is a pronounced case of such an interface agency acting between different temperatures. Thermodynamics provides a software for the occurrence of a heat engine if there are available temperature differences. Quantum mechanics can basically furnish a material hardware for actualizing and maintaining such temperature differences. Temperature dynamics serving as an interface agency lets any material body being affected by changes in the ambient temperature respond to the changes as quickly as possible. Since temperature is a quantitative figure about the context of material bodies moving randomly, temperature dynamics is intrinsically selective in that no contextual constituents belong to two different contexts at the same time. Temperature dynamics thus tailors quantum mechanics so as to accommodate chemical evolution of prebiotic molecules to meet the beginning of biology.

Introduction

The first law of thermodynamics as understood as such is about the transformation of energy. The transformation requires at least two agencies. One is the supplier of the energy to be transformed, and the other is the consumer of the transformed. The transformation mechanism alone cannot do anything unless it is supplemented by both the supplier and the consumer of the substrate. More specifically, thermodynamics is about a software of interfaceology [30, 16]. Hardware can be available from quantum mechanics, and a product thereof can be biology [17].

Interface requires more than one agency, to be sure. It is consequential upon the negotiation between different agencies. What a single agency can do is to be only part of the interface, but not the whole interface. If only one agency were good enough for implementing the interface, everything else would be colonized by the very agency. The boundary of a colony is not the interface, but the deprivation of the interface. Colonization destroys the interface. At issue is how to describe the interface. This brings us back to the very basic issue of description in a dynamic situation.

We should first note the difference between description and explanation. Explanation is a meta-description requiring the first-hand description of the issue more than anything else.

Explanation does give us the answer, but not the question. In order to have the latter, we have to describe the question first. Description is prior to explanation.

One of the longstanding positions adopted for describing any object is that what is describable remains in stasis. If the descriptive object is variable right in the process of its description, no one could expect complete identification of the object since those changes yet to come would constantly urge us to update the description. One direct outcome from this descriptive stance is that if movement is describable, it must be in stasis. In fact, the deductive syllogism concluding any movement is in stasis was first discovered by Zeno of Elea almost 2500 years ago. Since then, no one has ever succeeded in refuting this simple syllogism, though everybody including even Zeno himself does recognize that movement in stasis does not apply to empirical reality. The descriptive stipulation requiring that what is describable remains in stasis is too stifling.

One remedy relieving this stifling stipulation has come from mechanics asking the equality between a movement and its record. The record of a movement is about an inductive judgement or observation taking place in the empirical domain. Although mechanics is faithful in observing Zeno's stipulation requiring that what is describable remains in stasis, it is further supplemented by an empirical judgement asking that what remains in stasis is in movement as exemplified in Galilean inertia. However, mechanical stipulation requiring movement in stasis while demanding stasis in movement, like Zeno's movement in stasis, cannot cope with genuine genesis of changes and variations occurring in the empirical domain [3, 11, 31]. Mechanics can address dynamics only to the extent to which whatever stasis, once figured out, could remain in the empirical domain as it is. Despite that, mechanics cannot be completed unless it is supplemented by instrumental measurement. Noting that measurement is also part of dynamic process, one may enrich or extend what mechanics has accomplished to the extent that one could not expect previously, as incorporating the notion of measurement. Measurement can thus serve as a means of supplementing and extending what mechanics accomplished so far while incorporating the process of measurement also in the descriptive domain.

Movement Not in Stasis or Temperature Dynamics

Our subject matter of describing the interface properly is tantamount to addressing the issue of movement not in stasis properly. Exactly at this point enters the issue of measurement. Mechanics does require instrumental measurement for specifying both the boundary conditions and the condition of stasis in movement. In particular, instrumental measurement employed for the sake of the decidability of mechanics is unique in distinguishing between measuring the boundary conditions on the one hand and the required condition of stasis for the occurrence of mechanics on the other. These two instrumental measurements differ. Although mechanics suffers if stasis in movement is not literally confirmed on the basis of instrumental measurement, movement in stasis can definitely be salvaged in its record as far as the completed movement available from its instrumental measurement is concerned. What is unique to any movement registered in the record is that the notion of movement in stasis does certainly hold there even if the mechanistic stipulation requiring the equality between the record of the movement and the movement itself does not hold in advance. Even the movement not in stasis can be registered as a movement in stasis since the record of the movement, once registered, remains in stasis. The record does not change of itself by definition. Instrumental measurement does provide a means of gaining access to the movement not in stasis as far as the finished record is concerned.

What is more, the material body in charge of performing instrumental measurement can be any material body having the capacity of experiencing the target material body once the stipulation of registering the record in a specific manner is lifted. Any interacting material bodies can measure each other internally [16, 17]. Internal measurement upholding the movement not in stasis is certainly subject to the anthropocentric instrumental measurement, thus yielding the movement in stasis exclusively within the record.

Internal measurement among material bodies whose record can be identified as appealing to instrumental measurement is nothing but movement not in stasis. One such example of movement not in stasis is seen in temperature dynamics. In fact, temperature is a quantitative figure about the context of material bodies moving randomly. Internal measurement associated with temperature is about the temperature of some material bodies to be detected by other material bodies at a different temperature in the neighborhood, as demonstrated in Fourier's law of heat transfer. Temperature already detected is definite in determining the context of the detecting material bodies moving randomly, while temperature yet to be detected remains indefinite in the makeup of the material bodies moving randomly on the detecting end. Temperature dynamics certainly demonstrates the contrast between movement not in stasis beforehand and movement in stasis afterward.

Temperature dynamics has a unique characteristic because of its contextual nature. No contextual participants can belong to two different contexts at the same time because different contexts are mutually exclusive. Being contextual is being selective. Consequently, temperature dynamics is intrinsically selective in that realizing one particular context means elimination of all of the other conceivable contexts. An example of the selective capacity latent in temperature dynamics is this. Any material body experiencing, that is to say, being affected by changes in its ambient temperature responds to the changes as quickly as possible. There is no equal opportunity for both the fast and the slow responses. Always, the faster response wins because no chances are left behind for the slower responses. A small hot body put in a huge cold environment decreases its temperature as quickly as possible because there is no room for further temperature decrease for the late comers. Meta-stable energy sources at the higher temperature locally come to be fed upon by another material bodies at the lower temperature locally serving as energy consumers [18, 20] As a matter of fact, energy consumption is a common denominator of whatever biological organisms [19].

Here enters Darwinian natural selection taking most advantage of temperature dynamics that is intrinsically selective. Darwinian natural selection within the framework of a molecular selection experiment has already been well established. Suppose there has been available the recorded data of the experiment. One can read from the record the population of the target molecule and estimate the replication rate. One can know which molecular species wins at least on the completed record. At the same time, one can also imagine the following situation behind the scene. Suppose our laboratory colleague has completed the setup of a molecular selection experiment and put everything in order. All switches are on. Everything runs smoothly. After knowing that, our colleague has left the laboratory bench for something else. Of course, the molecules in the equipment are doing what they are doing. But, they are not counting the population nor estimating the replication rate. They are doing something else. What is evident at this point is that at the least, they are experiencing or responding to changes in the ambient temperature. The rule there is the first comes, first served. The context yielding the quickest response comes to win on the basis that the winner takes all. That is certainly selective and generative. Then, our colleague has returned to the laboratory bench. He can read both the population of the target molecule and its replication rate from what his molecules have been doing in his absence. Everything can be summarized in terms of the replication rate. No mystery is left behind. Everything is clear. Temperature dynamics mediates between movement not in stasis beforehand and movement in stasis frozen in the completed record, while the population of the target molecule and the associated replication can be read from the movement in stasis in the record.

What is unique to biology in general and biological evolution in particular as a concrete instance of temperature dynamics is that it can generate a local organization with the lower temperature on its own, that is nothing other than an energy consumer or an organism in the biological sense. Appearance of the lower temperature locally facilitates the faster temperature drop at the meta-stable energy sources. Then, the material body at the lower temperature can be stabilized as an energy consumer while feeding upon the meta-stable energy sources at the higher temperature locally. This just demonstrates an operational essence of the beginning and functioning of biology as a concrete instance of temperature dynamics that is contextual and accordingly is about an interfaceology between different contexts at different temperatures.

Quantum Mechanics as a Contextual Dynamics

Temperature dynamics is certainly contextual, but the nature of the contexts available there is quite singular in admitting only those contextual constituents moving randomly with each other. Temperature addresses only those contexts comprising material bodies moving randomly. One more conspicuous instance of contextual dynamics is found in quantum mechanics. Each quantum there is taken to be an attribute of the context that is almost completely coherent internally as a polar opposite to the case of temperature dynamics. Quantum mechanics provides us with the hardware supplying each material body as a quantum, while temperature dynamics is about the software manipulating the context of those quanta which quantum mechanics has provided. At this point, it is duly noted that temperature dynamics as an attribute of thermodynamics is by no means a derivative of quantum mechanics through its statistics.

Contextual dynamics operating in nature is thus sandwiched between the two extremes. One is quantum mechanics providing an almost coherent context internally in the form of a quantum, and the other is temperature dynamics yielding an almost completely incoherent context internally in the form of those quanta moving randomly. The present perspective enables us to seek the capacity of contextual selection within temperature dynamics instead of quantum mechanics in itself. Temperature dynamics exerts the activity of contextual selection upon the context of quanta moving randomly. When the ambient temperature changes, the realizable context of quanta moving randomly that determines the temperature of the target quanta responds to the temperature changes as quickly as possible. The fastest temperature response influences the material makeup of the context of quanta moving randomly.

Only those quanta in accord with the fastest temperature response come to be contextually selected and realized. This can necessarily be accompanied by a quantum-mechanical updating of those quanta to be implemented on material grounds. Although quantum mechanics intrinsically provides material capacity of making the context of a material body almost completely coherent internally, it is temperature dynamics that is responsible for determining which context is actually applied to each quantum from its outside. Temperature dynamics has the capacity of tailoring quantum mechanics so as to constrain the realizable quanta only to those demonstrating the quickest response to changes in the ambient temperature. Temperature dynamics has the capacity of transforming the nature of a material quantum of quantum-mechanical origin, which is of course in accord with implementing the first law of thermodynamics.

One conspicuous example demonstrating thermodynamic tailoring of a material quantum of quantum-mechanical origin is seen in nucleosynthesis in supernovea explosions. Synthesis of a heavy atomic nucleus such as iron's has been considered to proceed during supervoea explosions in the big bang cosmology. The temperature of those nucleons thermally accelerated at the core of a supernova could have reached even up to several billion degrees centigrade. They could have formed heavy atomic nuclei such as iron's since the thermal energy available there could be large enough to overcome the threshold for their binding. Then, the material bodies thus synthesized would have been scattered into deep interstellar space in the latter of which the temperature would be extremely low. The thermodynamic fate of such a material body might have had at least the following two possibilities. One was to lower the temperature while maintaining the synthesized material body as it was, and the other was to lower the temperature as disintegrating it into the former constituent nucleons. Our empirical observation of iron's nuclei in the empirical domain now comes to suggest that the synthesized material bodies scattered into deep interstellar space during supernovea explosions could have decreased their temperatures much faster when they remained as being integrated. The former thermal energy driving the random kinetic movement of individual nucleons could thus have been transformed into the energy for binding these nucleons in the synthesized atomic nuclei. Similar observations can also be expected even in experimental environments [22].

Empirical and Experimental Data Bases

Chemical Evolution in the Cosmological Context

The origin and evolution of biological organizations on the Earth has undoubtedly been put under the cosmological context. The formation of our solar system has been a cosmic event that took place almost 4.6 billion years ago. Formation of small organic molecules that are indispensable for the makeup of biological organizations on the Earth could also have been cosmological. One of the likely candidates for cosmological syntheses of small organic molecules, which is conceivable from the framework of temperature dynamics, is the one taking place in interstellar dust grains. In particular, the dust grains having the refractory core mantles, when irradiated by ultraviolet radiation in diffuse interstellar clouds, could make possible to synthesize various small organic molecules (see, for instance, [2, 28]).

Diffuse clouds keep the water-rich dust grains at temperature in the range $20 - 100K$. When they are irradiated by ultraviolet radiation, the accompanying photolysis can warm up the ice grains to help form aliphatic $–CH_2–$ and $–CH_3$ groups. As a matter of fact, near-infrared observations reveal the solid-state features due to the presence of dust grains in diffuse interstellar clouds, as pointing out the strong infrared absorption band complex centered around at wavelength $3.4nm(2955cm^{-1})$. The optical depth spectrum of diffuse clouds observed from Galactic Center IRS 6E is found quite close to the spectrum of a laboratory residue produced by the ultraviolet irradiation upon an interstellar ice analog at $10K$, then followed by its warming up to $200K$ ([28] and references cited therein). Such a similarity has also been observed with the specimen prepared in the laboratory and then exposed to long-term solar ultraviolet radiation on the EURECA satellite. The products could be nucleobases, sugars, and amino acids when coming into contact with liquid water [10, 9]. Furthermore, the similarity of the near-infrared spectrum between the interstellar observations and the ones from a Murchison carbonaceous meteorite suggests a cosmological ubiquity of chemical synthesis of small organic molecules in interstellar ice grains in diffuse clouds. Our Earth is no exception in being subject to the influence from these interstellar ice grains.

Another important source for making small organic molecules must have been cosmic rays and the primitive atmosphere of the Earth irradiated by them. Even if the atmosphere was oxidized, cosmic rays might be a major effective energy source for abiotic formation of amino acids and other bioorganic compounds [15]. When it was tried to synthesize amino acid molecules from carbon monoxide, nitrogen and water as irradiating their gas mixture with high-energy particle beams of protons, helium nuclei or electrons, a considerable amount of the yields was identified. The G-value, that is the number of molecules produced per $100eV$ of irradiated energy, of glycine was about 0.02. The present G-value is far greater than that expected from electric discharges. In addition, the G-value did not vary very much depending upon the species of carbon sources in the gas mixture, while it considerably depended upon the species in the discharge experiments. This observation suggests to us that synthesizing small organic molecules including amino acids with recourse to cosmic rays as major energy sources must be cosmic events, and not necessarily be limited to the atmosphere of the Earth. Meteorites and cosmic dusts could have conveyed to the Earth a considerable amount of small organic molecules synthesized elsewhere.

Of course, there might have been possibilities of synthesizing amino acid molecules and nitrogen bases through lightning or electric discharge in the primitive atmosphere on the Earth if the atmosphere was reducing. Spark charges in the hydrosphere could have been another possibility for synthesizing small organic molecules on the Earth [24].

Contribution of cosmic rays, radiation and lightning have been registered as significant factors for making feasible the presence of small organic molecules on the primitive Earth. In order to proceed further towards the emergence of life on the Earth, however, we are required to face something more specific to our Earth. Cosmic ubiquity of small organic molecules alone is not good enough for coping with material evolution following the synthesis of those small molecules. In this regard, the contribution of cosmic rays, radiation and lightning is suggestive in sharing one thing in common. That is, the synthesis of small organic molecules could appear in the process of thermal randomization of the primary energy input whatever it may be. Material evolution requires energies to be thermally randomized [8]. Some energy sources other than those from cosmic rays, radiation and lightning must have been available for driving further material evolution on our Earth. The energy sources specific to the Earth must be quite unique in their inevitable dissipation leading eventually to thermal randomization. At this point, we can see two major sources, each of which is quite specific to our Earth in the framework of temperature dynamics. One is the solar energy impinging on the Earth's atmosphere, and the other is the geothermal energy erupted into the hydrosphere from the Earth's mantle.

The sunlight reaching the surface of the Earth would soon decrease its temperature from roughly $6000K$ to $300K$ determined by the equilibrium condition of the black body radiation in the latter. Thermal randomization of the solar energy in the Earth's atmosphere may quite easily be established soon after the solar photons repeat their collisions with material particles constituting the Earth's environment. The characteristic time for each average solar photon to reach its thermal equilibrium with the surrounding black body is quite small because the time is scaled by the flight time of the photon. Even if there were no special traps of the solar photons available in the Earth's environment, their thermal randomization would meet no difficulty. In contrast, thermal randomization of the geothermal energy in the ocean is quite different compared to the case of the solar energy in the atmosphere. The thermal relaxation of the geothermal energy in the ocean takes place mainly through the collisions of water molecules. The characteristic time for the heated water molecules to reach a thermal equilibrium with the surrounding cold seawater is significantly greater than the relaxation time for the solar photons to reach their thermal equilibrium with the Earth's environment. The process is mediated by molecular collisions instead of the flight of photons. The greater thermal relaxation time may provide thermal randomization of the geothermal energy in the ocean with the richer catalogue of the relaxation processes taking place there. The richer catalogue could have facilitated further evolutionary capability in the relaxation of the geological heat in the ocean.

The sunlight cannot serve as an energy source to drive the relaxation processes in the ocean, because it is mostly reflected upon the surface of the ocean and back into outer space.

Photosynthesis could have been installed on the Earth's surface only when there appeared a mechanism of trapping the energy from the solar photons. For this to be accomplished, the trapping of the solar photons has to outstrip the thermal randomization of the photons in the Earth's environment due to the black body radiation. We cannot rely upon the sunlight as the energy source driving further material evolution until such a fast trapping mechanism of the solar photons emerges. Exactly at this point, the geothermal energy erupted into the ocean becomes significant from the perspective of temperature dynamics. The geothermal environment in the ocean could have been far richer in trying or even tinkering with a lot of evolutionary opportunities. Once there could be synthesized a molecular aggregate or organization in the environment in a time interval shorter than the relaxation time of the hot water molecules, the organization could survive if its decay time is greater than the thermal relaxation time of the water molecules there. The geothermal environment on the primitive Earth could have been a main stage of further prebiotic evolution prior to the emergence of photosynthesis on the Earth's surface.

Chemical Evolution in the Primitive Ocean on Earth

Ever since the ocean was formed around 4.2 billion years ago, off-ridge submarine hot springs interfacing with the surrounding relatively cold seawater in the Hadean Ocean came to provide unique locales for further prebiotic synthesis. First of all, the vicinity of the hot springs would have offered protection from bolide-induced vaporization of seawater, cosmic rays, ultraviolet photons, lightning and tidal waves [32]. Circulation of hydrothermal solution around the hot vents could have provided a means of gleaning traces of small organic molecules residing in the crust, that could ultimately have derived from the carbonaceous chondrites, interplanetary dust particles and comets [5, 27, 23]. What is further unique to the circulation of seawater through the hot events is the constant geothermal gradient or disequilibrium driving various chemical syntheses. This is the issue of nonequilibrium thermodynamics [29].

Of course, comic rays, radiation and lightning can impart their energy to small molecules and drive synthetic reactions in the latter. The energy pathway from the high-energy sources to the end products is definitely in nonequilibrium in the thermodynamic sense. Impinging high-energy particles, whether protons, helium nuclei or electrons, are responsible for making a nonequilibrium situation that can drive synthetic reactions among the available small molecules. Once those high-energy particles are interrupted for whatever reasons, on the other hand, there would be no factors driving such synthetic reactions. Impinging high-energy particles determine the actual synthetic reactions during their inevitable thermal decay. The actual synthetic reactions are associated with realizing the fastest thermal decay or temperature response. In fact, the temperature relaxation process that is actualized is the possible fastest one among the alternatives since there is no chance for the late comers.

This perspective comes to suggest to us that the constant geothermal disequilibrium is really unique in that it would take a considerable amount of time for the hot seawater ejected from the vents to reach a thermal equilibrium with the surrounding cold water. This implies that a synthesized molecule in the hot seawater, if any, can survive in the surrounding cold water if it can hold its own structure while the water droplet including the synthesized product decreases its temperature as contacting the cold surrounding.

The constant geothermal disequilibrium due to the mixing of the hot water from the vents with the surrounding cold water provides a selective sieve for the synthesized chemical products when they enter the cold surrounding. Those products that cannot hold themselves during the quenching imputed to the cold surrounding do not have their chance of survival. The dissociation rate of a synthesized product inside or near the hot vent could increase with temperature. If it remains near the vent, the product would likely be dissociated rapidly. On the other hand, if the product is rapidly transferred into the cold surrounding, the dissociation rate of the product is considerably quenched there and its chance of survival in the latter would be greatly enhanced. The constant geothermal disequilibrium thus focuses upon the activity on the part of the lower temperature side in determining the actual temperature relaxation. This exhibits a marked contrast to the case of cosmic rays, radiation and lightning, in which the actual relaxation process is determined by the higher temperature side, that is, impinging high-energy particles.

Supply of high-energy particles is met by only those synthetic reactions that could realize the actual fastest temperature relaxation. In contrast, consumption of the geothermal energy from the hot vents by the surrounding cold water is met by the synthetic reactions that could hold the products in the transference. The constant geothermal disequilibrium is maintained independently of the selective sieve acting upon the synthesized products in the hot regions. It can be maintained even if there are no chemicals to be reacted. Independence of the occurrence of the geothermal disequilibrium from the synthetic reactions taking place there now furnishes the reaction products with the selective characteristic imputed to the disequilibrium itself. When there is a dominant relaxation process of an imposed character such as the constant geothermal disequilibrium, it serves as a selective reference against other minor processes of a synthetic character to arise from within. Only those that can live with the dominant relaxation process can survive. Ever since the ocean was formed, the constant geothermal disequilibrium has provided nearby chemical reactants with the opportunity for taking advantage of the disequilibrium itself for the sake of the synthetic reactions taking place. An essence of the operation of the constant geothermal disequilibrium will further be clarified from the thermodynamic perspective of temperature dynamics.

The geothermal environments in the Hadean Ocean could certainly have played a significant role in setting the subsequent stage for prebiotic evolution. This is however not simply a matter of historical contingency unique to our planet Earth. In order to make it possible to have more complex molecules from smaller and simpler ones during chemical evolution, energy sources are definitely required. Energy is required to move chemical reactants away from their thermal equilibrium, in the latter of which no evolution could be envisaged. At this point, there could arise two important issues. One is from where and how the energy sources could be recruited, and the other is about how the energy transaction would proceed in time while activating some of interesting chemical reactants. As for the first question, all of cosmic rays, radiation, lightning and geological heat can be authentic candidates for supplying energy to nearby chemical reactants. For the second question, on the other had, there could appear a sizable difference in specifying the energy transaction especially in how the used energy could be disposed. Among them, the geothermal environments are quite unique in rendering the constant geothermal gradient or disequilibrium to be the dumping site of the used energy. If the disposer of the used energy is the heat reservoir in thermal equilibrium as is most often the case with cosmic rays, radiation and lightning, the way the energy is utilized is limited. Only the fastest relaxation processes towards thermal equilibrium could be actualized.

The constant geothermal disequilibrium, on the other hand, provides subsisting chemical reactants with a selective criterion stipulating themselves to live with the disequilibrium. This is quite different from another selective criterion intrinsic to thermal equilibrium letting the energized species decay towards its equilibrium condition as fast as possible and live with the reservoir indefinitely. Most significant to the occurrence of the geothermal environments in the Hadean Ocean is the installation of a de novo selective criterion applied to reacting chemical species in the environments. The likelihood of the present perspective on the occurrence of a new selective criterion applied to prebiotic evolution can even be demonstrated and tested experimentally.

Chemical syntheses leading to the origin and evolution of biological organizations on the Earth do require a selective criterion other than that applied exclusively to thermal equilibrium. The likely candidate is submarine hydrothermal systems which have persisted in existing ever since the ocean was formed on the Earth [4, 6, 33, 7, 34] The hot spring ejected from the hydrothermal vents soon comes to face cold seawater in the surroundings, which serve as the heat sink. Chemical products synthesized in the hot vents undergo abrupt cooling once they are ejected into the cold environment. The surrounding heat sink constantly feeds on the hot water and consumes the heat energy therefrom. In this sense, the contextual dynamics actualizing the fastest temperature relaxation is definitely operative towards the products. Only the products exhibiting the fastest temperature drop could survive there. Reaction products synthesized in the hot vents followed by their rapid quenching in the surrounding cold seawater are both generative and selective. They are generative in facilitating synthetic reactions in the hot vents, and at the same time selective in materializing only those that can decrease their temperature at the possible fastest rate when ejected into the cold environment. Furthermore, continuous circulation of seawater around the hydrothermal vents could make the selective process cumulative as constantly transforming the preceding products into the succeeding reactants even if the cycle time of revisiting any one of hydrothermal vents in the Hadean Ocean would be tens of thousands of years or more. Temperature dynamics applied to continuous circulation of seawater around the hydrothermal vents in the ocean can sustain selective process on material grounds indefinitely even prior to that Darwinian molecular evolution gets started.

We have constructed a flow reactor simulating a submarine hydrothermal system just to examine the appropriateness of temperature dynamics tailoring quantum mechanics for synthesizing prebiological oligomers in the hydrothermal context [21]. Synthesis of oligoglycine from monomeric glycine up to octaglycine was in fact confirmed in the flow reactor [12]. Hydrothermal vents could also be active for dissociating amino acids into their constituent molecules through, for instance, decaroxylation, deamination or even dehydration because of their high temperatures [1]. However, the synthetic reaction could survive despite that if the residence time of the reaction products in the hot vents is limited compared to the total cycle time required for completing the rounding around the vents. Once continuous circulation of the fluid carrying reactants is guaranteed for some time, an autocatalytic growth of the products could naturally be expected. For the reactants that help producing the products of like kind can increase their yields exponentially in time. In fact, we observed an autocatalytic growth of oligoglycine in the flow reactor [14, 12, 13]. Such a growth of products in the flow reactor also applies to the synthesis of oligopeptides from more than two different kinds of amino acids [26] and to the synthesis of oligonucleotides from monomeric nucleotide AMP (adenosine monophospate) [25]. Even formic and acetic acids were synthesized from carbon dioxide and water when metal oxides were put inside the simulated hot vents [35].

Concluding Remarks

Chemical synthesis connecting prebiological to protobiological evolution can be seen as a concrete instance of temperature dynamics proceeding on our Earth. Temperature dynamics of a contextual character makes each quantum of quantum-mechanical origin to act as an agency measuring the context under which it is placed. Temperature is about the interface between a quantum as an almost completely coherent context internally and one more larger context comprising the smaller contexts of quantum-mechanical origin moving almost completely randomly. Consequently, temperature dynamics is an interfaceology between two-tiered contexts of different scales. The outer larger context determining the temperature of the collection of the smaller inner contexts is almost completely incoherent in the movement of the inner contexts, while each inner context is almost completely coherent internally. However, the two contexts of different scales are not mutually independent. The outer context determining the temperature of the inner contexts is constantly subject to the fastest response to changes in the ambient temperature. When the outer context is affected by changes in the temperature of the surroundings, the target outer context may be able to respond to the changes faster by modifying the inner contexts of quantum-mechanical origin as seen in nucleosynthesis in supernovea explosions. If this is the case, the inner contexts thus modified can be stabilized within the perturbed outer context.

Material transformation due to the occurrence of temperature differences can of course be perceived within the operation of the first law of thermodynamics in terms of thermodynamic entropy if the entropy is definable. When a material body contacts with two heat sources at different temperatures under its stationary condition, the heat flow entering from the source at the higher temperature comes to equilibrate with the heat flow leaving the body into the source at the lower temperature. Since the heat flow is equal to the temperature multiplied by the entropy difference at the contact between the two bodies, the stationary condition yields that the material body contacting with two heat sources at different temperatures can decrease its entropy. This decrease of entropy being in accord with the operation of the first law of thermodynamics is certainly legitimate, but limited in that entropy is no more than an extensive quantity derived from a given context. Entropy, once defined legitimately, cannot affect the context that has been responsible for defining itself. Entropy, though legitimate, is not competent enough to assume the role of influencing the two-tiered contexts. This is exactly the place where temperature dynamics enters as claiming its own legitimacy upon the ground that temperature can be definable at least operationally insofar as it is measurable.

Temperature dynamics as an interfaceology having the capacity of connecting quantum mechanics to biology is unique in appreciating the construction of whatever contexts in a bottom up manner. What is intrinsic to the interfaceology is the observation that any contextual constituent of material origin has the capacity of measuring or observing its outside from within. That is internal measurement [16, 17].

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The Spectrum of Singularities of a Fractal Basin Boundary

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Abstract

We present a one-dimensional dynamic system driven by a chaotic forcing. The existence of an attractor with a fractal basin boundary is shown. The basin boundary can be viewed as the invariant set of an iterated function system with a locally varying contraction ratio in one direction. We derive expressions for the spectrum of Hölder exponents of this basin boundary and explain why numerical analysis has to face severe problems. We recommend this function as a synthetic data set for algorithm validation.

1 Introduction

Nowhere differentiable functions of a single variable have been of interest for more than one centannium, beginning with Weierstrass's famous proposition [4, 19] and becoming the focus of research activities again following the advent of fractal geometry [13]. Applications of fractal and nowhere differentiable functions have been reported from many different disciplines, like stock market [14], turbulence [3], surface roughness [18] (see also [6, 5] and as the boundaries of chaotic attractors [12, 16, 15, 7, 1, 2, 17].

In this paper we concentrate on the model proposed by O.E. Roessler [17], consisting of a one-dimensional chaotically forced dynamical system, the boundary of whose basin of attraction is defined by a fractal function. A substantial amount of research into these systems was conducted with various scopes of generality (c.f. [10]). Our development may appear very special in front of this backdrop. However, its more intriguing properties are easily accessible both analytically and numerically and rather intuitive.

In the Section 2 conditions for the existence, continuity and differentiability of this fractal function are given. In Section 3 an analytic expression for the multifractal spectrum of sigularities is derived. Based on these results we suggest our model in Section 4 as a testing ground for the analysis of fractality; parameter regions where reliable numerical results are expected are given.

2 Analysis of a fractal basin boundary

Consider the map, c.f. [17]

$$x_{n+1} = F(x_n) + b\,t_{n+1} \tag{1}$$

$$t_{n+1} = G(t_n) \tag{2}$$

with $F : \mathbf{R} \to \mathbf{R}$ being a differentiable, monotonous function with a stable fixed point at 0 and an unstable fixed point at 1. Let $G : [0,1] \to [0,1]$ be a one-dimensional, piecewise continuous and differentiable, locally invertible chaotic mapping, e.g. the logistic map. In order that the n-th iteration of G, G^n, is bounded it is necessary to require $c = \max_t\{G(t)\} \leq 1$. We regard b as a small positive constant.

Throughout this paper we restrict ourselves to:

$$F(x) = x^\gamma, \qquad \gamma > 1 \quad . \tag{3}$$

It is possible to give an explicit expression for the set of initial conditions (x_0, t) for which $x_n(t)$ remains finite, i.e. smaller than unity, for all n. This set is bounded from above by a basin boundary $x(t)$. With $x^{(n)}(t)$ we denote the n-th approximation to this curve according to the following expression

$$\begin{aligned} x^{(n)}(t) &= F^{-1}(\ldots F^{-1}(F^{-1}(1 - bG^n(t)) - bG^{n-1}(t)) \ldots - bG(t)) \\ &= (\ldots((1 - bG^n(t))^{\frac{1}{\gamma}} - bG^{n-1}(t))^{\frac{1}{\gamma}} \ldots - bG(t))^{\frac{1}{\gamma}} \quad , \end{aligned} \tag{4}$$

and

$$x(t) = \lim_{n\to\infty} x^{(n)}(t) \quad , \tag{5}$$

where we require the arguments of the inverse function of F, F^{-1}, be positive. $G^n(t)$ denotes the n-th iteration of t with G. It remains to be shown for which combinations of γ, b and G this basin boundary exists and is well defined.

By expanding F^{-1} to first order in b we obtain

$$x^{(n)}(t) = 1 - b\sum_{i=1}^{n} \frac{G^i(t)}{\gamma^i} \quad . \tag{6}$$

Thus, in this case, the limit function $x(t)$ results from summing up the forward orbit of $G(t)$ weighted with a factor which assures uniform convergence. Contrary to eq.(4), this boundary exists for all values of b. Similar functions were proposed by [16, 2].

2.1 Existence of a Basin Boundary

Obviously, in the limit of small b the basin boundary exists since the influence of the forcing is outweighed by the 'attraction' of the fixed point $x = 0$ of F. However, the greater b, the weaker the 'attracting force' at full forcing amplitude. This can be expressed in terms of $F'(x) = \gamma x^{\gamma-1}$ which approaches unity.

PROPOSITION. *For* $1 < \gamma$ *and*

$$0 < b \leq b_{max} = \frac{1}{c}(1 - \frac{1}{\gamma})\gamma^{\frac{1}{1-\gamma}} \tag{7}$$

the $x^{(n)}(t)$ (eq.(4)) *are well defined for all* n *and the limit* $x(t)$ *exists.*

It is convenient to introduce the following auxiliary functions:

$$\begin{gathered} f_t^n(z) : [0,1] \to [0,1] \\ z \to (\ldots((z - b\,G^n(t))^{\frac{1}{\gamma}} - b\,G^{n-1}(t))^{\frac{1}{\gamma}} \ldots - b\,G(t))^{\frac{1}{\gamma}} \quad . \end{gathered} \tag{8}$$

Clearly,

$$x^{(n)}(t) = f_t^n(1) \tag{9}$$

and

$$f_t^{n+1}(z) = f_t^n\left((z - b\,G^{n+1}(t))^{\frac{1}{\gamma}}\right) \tag{10}$$

$$= \left(f_{G(t)}^n(z) - b\,G(t)\right)^{\frac{1}{\gamma}} \quad . \tag{11}$$

Since $f_t^n(z)$ is a composition of monotonous functions in z, it is an increasing function of z. With (9),(10) we find that $x^{(n)}(t)$ is strictly decreasing with n.

$$\begin{aligned} x^{n+1}(t) &= f_t^{n+1}(1) \\ &= f_t^n\left(1 - b\,G^{n+1}(t))^{\frac{1}{\gamma}}\right) \\ &< f_t^n(1) = x^{(n)}(t) \quad . \end{aligned}$$

To show the existence of a lower bound to $x^{(n)}(t)$ for all t we introduce another auxiliary function $g(z)$ so that $g^n(z) < f_t^n(z)$

$$g(z) : [bc, 1] \to [0,1], \qquad z \to (z - bc)^{\frac{1}{\gamma}} \quad . \tag{12}$$

A lower bound to f_t^n exists when g has a stable fixed point on $[bc, 1]$. For a given γ we expect the appearance of a tangent-bifurcation under variation of b, i.e. the stable and the unstable fixed point of $g(z)$ merge for a certain value of b. The necessary conditions for a bistable fixed point at the bifurcation are

$$(z - bc)^{\frac{1}{\gamma}} - z = 0 \qquad \text{and} \qquad \frac{d}{dz}\left((z - bc)^{\frac{1}{\gamma}} - z\right) = 0 \quad . \tag{13}$$

We find b_{max} as the parameter where the tangent-bifurcation occurs. The lower limit is given by $z_{min} = \gamma^{\frac{1}{1-\gamma}}$.

Although the existence of $x(t)$ is not guaranteed by virtue of a lower bound in case $b > b_{max}$, the basin boundary may exist nevertheless for all t. However, this is dependent on the dynamics of $G(t)$. For the system to escape from the basin of attraction, it is necessary that $b\,G^i(t) > b_{max}$ for a certain number n of successive iterations $i = m+1, m+2, \ldots, m+n$ of G. Thus, a necessary (and often sufficient) condition for the existence of $x(t)$ is that $b\,t_F < b_{max}$ if t_F is the largest fixed point of G.

2.2 Continuity

PROPOSITION. *The basin boundary $x(t)$ is continuous for $b < b_{max}$.*

We find uniform convergence of $x^{(n)}(t)$ to $x(t)$.

$$\begin{aligned} 0 &\leq x^{(n)}(t) - x(t) \\ &= f_t^n(1) - f_t^\infty(1) \\ &= f_t^n(1) - f_t^n(z) \end{aligned}$$

for some $z_{min} < z \leq 1$.

$$f_t^n(1) - f_t^n(z) \leq (1 - z)\left(\frac{\partial}{\partial z'} f_t^n(z')\right)_{z'=z}$$

$$
\begin{aligned}
&= (1-z)\frac{1}{\gamma^n}\prod_{i=0}^{n-1}\left(f^{n-i}_{G^i(t)}(z)\right)^{1-\gamma} \\
&\leq (1-z_{min})\left(\frac{z^{1-\gamma}}{\gamma}\right)^n \quad .
\end{aligned}
$$

Where we make use of the concavity and differentiability of $f^n_t(z)$ with respect to z. We find

$$
\left(\frac{z^{1-\gamma}}{\gamma}\right) < \left(\frac{z^{1-\gamma}_{min}}{\gamma}\right) = 1 \quad . \tag{14}
$$

It follows that if $x(t)$ exists, it is continuous.

2.3 Differentiability

Depending on the choice of G and γ, it is possible that $x(t)$ becomes a nowhere differentiable function. It is also possible to choose γ such that $x(t)$ is Lebesgue-almost everywhere differentiable. The situation becomes even more complex if b is allowed to approach b_{max}, when $x(t)$ can have no finite derivative on intervals and be almost everywhere differentiable on the complement.

For the further study of $x(t)$ we need to restrict ourselves to the simplest case. We choose G to be an asymmetric (skewed) tent map with peak at unity:

$$
G(t) = \begin{cases} t/\Delta & : \quad 0 \leq t \leq \Delta \\ (1-t)/(1-\Delta) & : \quad \Delta < t \leq 1 \end{cases} \tag{15}
$$

The largest fixed point t_F is then given by $t_F = \frac{1}{2-\Delta}$.

PROPOSITION. *For G as above and in the limit of $b \to 0$, the function $x(t)$ has, (1) a finite derivative at no point if each of the inequalities*

$$
\gamma\Delta \leq 1 \tag{16}
$$

$$
\gamma(1-\Delta) \leq 1 \tag{17}
$$

holds, and (2) is Lebesgue-almost everywhere differentiable if the converse of both conditions hold.

For the first statement, consider the limit for $\epsilon > 0$

$$
\begin{aligned}
\lim_{\epsilon\to 0}\sum_{i=1}^{\infty}\frac{G^i(t+\epsilon)-G^i(t)}{\gamma^i\,\epsilon} &= \lim_{\epsilon\to 0}\left[\sum_{i=1}^{[\log\epsilon/M]}\frac{1}{\gamma^i\,\Delta^{j_i}\,(1-\Delta)^{i-j_i}} + \sum_{i=[\log\epsilon/M]+1}^{\infty}\frac{G^i(t+\epsilon)-G^i(t)}{\gamma^i\,\epsilon}\right] \\
&\leq \lim_{\epsilon\to 0}\left[\frac{\log\epsilon}{M} + \sum_{i=[\log\epsilon/M]+1}^{\infty}\frac{G^i(t+\epsilon)-G^i(t)}{\gamma^i\,\epsilon}\right] \quad .
\end{aligned} \tag{18}
$$

Since $G^i(t)$ is a piecewise linear function, a constant $-\infty < M \leq \min\{\log\Delta, \log(1-\Delta)\}$ can be found such that $G^{[\log\epsilon/M]}(t)$ is linear on the interval $[t, t+\epsilon)$, where $[x]$ denotes the largest integer smaller than x. The numbers $j_i < i$ denote the number of times that the contraction ratio was Δ at the generation of $G^i(t)$.

The latter statement can be proved by invoking RADEMACHER'S Theorem, see [9], because $b/(\gamma\Delta - 1)(\gamma(1-\Delta) - 1)$ is a global Lipshitz constant. If $b > 0$, the first statement holds nevertheless true since the contraction ratio along the x direction becomes greater than $1/\gamma$. However, in the global Lipshitz constant γ needs to be replaced by $\gamma' = \gamma(\inf\{x(t)\})^{(\gamma-1)/\gamma}$, taking into accout that the cusps 'become more pointed' when the function value approaches the limit z_{min} (figure 1).

If only one of the conditions eq.(16,17) holds, the set on which $x(t)$ has infinite slope is given by the set on which the local Hölder exponent is equal to one. To obtain more information, in the following we give an approximation to the spectrum of singularities of $x(t)$.

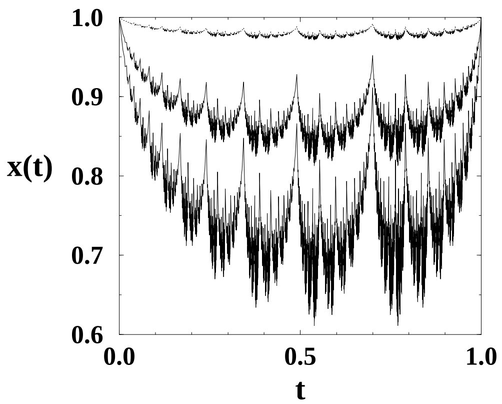

Figure 1: *For a number of constants b, the distortion of the limit curve becomes visible due to the non-linearity of the scaling in the vertical direction. Parameters are: $\gamma = 2^{1/3}, \Delta = 0.7$, and from the top $b = 0.01, 0.055, 0.1102$.*

3 The spectrum of singularities

The spectrum of singularities can be easily obtained in the limit of $b \to 0$ and G being a tent map. The function $x(t)$ is then well approximated by its Taylor expansion eq. 6. However, this object can also be viewed as the limit set of an Iterated Function System quite similar to the von-Koch curve [2].

3.1 The self-affine case

The self-similar structure of $x(t)$ is generated by the dynamics of the tent map. The invariant set of G

$$I^\infty = \lim_{n\to\infty} I^n = \{t \in [0,1] : G^n(t) = 0\} \tag{19}$$

becomes the support of the singularities of $x(t)$, see also figures (2,3). The limit set I^∞ is a Cantor set with Hausdorff dimension 1 and is self-similar with the two scaling ratios Δ and $(1-\Delta)$ in direction t. Furthermore, we observe that the vertical contraction ratio of the IFS in direction x is $1/\gamma$. The local Hoelder exponent α is given by

$$\alpha(t) = \lim_{\epsilon\to 0}\lim_{n\to\infty} \frac{\ln\left|x^{(n)}(t+\epsilon) - x^{(n)}(t)\right|}{\ln\epsilon} \quad . \tag{20}$$

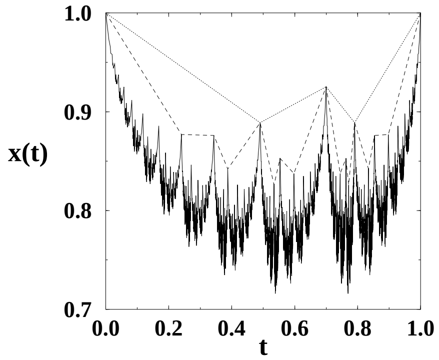

Figure 2: *$x(t)$ on the support of the singularities I^2, I^4, I^{13} for $\gamma = 1.3, b = 0.096$ and $\Delta = 0.7$. The self-similarity becomes evident also from the (dashed) plots, which connect the singularities of I^2 and I^4.*

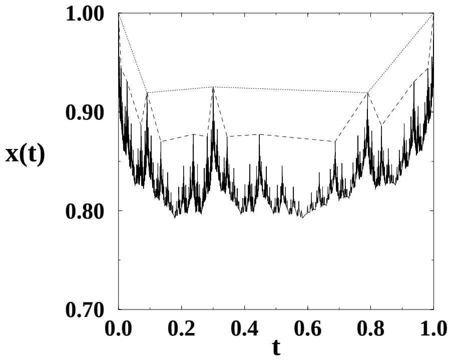

Figure 3: *$x(t)$ on I^2, I^4, I^{13} for $\gamma = 1.3, b = 0.096$ and $\Delta = 0.3$. The appearance of the graph changes significantly if the tent map G is skewed to the left.*

In the following, we choose as ϵ the difference between two adjacent points $t_i, t_{i+1} \in I^n$. [1] If we assume $\Delta < 1/2$ and $\gamma\Delta < 1$, we learn from eq.(18) that

$$\begin{aligned}
\lim_{n\to\infty} \left|x^{(n)}(t_{i+1}) - x^{(n)}(t_i)\right|^{1/n} &< \lim_{n\to\infty} \left(\frac{(\gamma\Delta)^{-n} - 1}{1-\gamma\Delta}\, \Delta^n\right)^{1/n} \\
&= \lim_{n\to\infty} \left(\gamma^{-n} \frac{(1-(\gamma\Delta)^n)}{1-\gamma\Delta}\right)^{1/n} \\
&= 1/\gamma \quad . \qquad (21)
\end{aligned}$$

Likewise, the opposite inequality can be shown by replacing Δ with $1 - \Delta$.

Following the thermodynamic formalism [8, 5, 10], we compute the structure function (or partition function)

$$1 = \lim_{n\to\infty} \left(\sum_{t_i \in I^n} \left|x^{(n)}(t_{i+1}) - x^{(n)}(t_i)\right|^q |t_{i+1} - t_i|^{-\tau(q)} \right)^{1/n} \qquad (22)$$

[1]The difference in functional value taken at these points is also called the oscillation of $x(t)$ on the interval $[t_i, t_{i+1})$.

$$= \frac{1}{\gamma^q} \lim_{n\to\infty} \left(\sum_{t_i \in I_n} |t_{i+1} - t_i|^{-\tau(q)} \right)^{1/n} \tag{23}$$

$$= \frac{1}{\gamma^q} \left(\Delta^{-\tau(q)} + (1-\Delta)^{-\tau(q)} \right) \quad , \tag{24}$$

where we make use of eq. (21). A parametrised solution of (24) is given by:

$$\tau(r) = \frac{\ln \frac{1-r}{r}}{\ln \Delta - \ln(1-\Delta)} \tag{25}$$

$$q(r) = \frac{1}{\ln \gamma} \frac{\ln(1-\Delta)\ln r - \ln \Delta \ln(1-r)}{\ln \Delta - \ln(1-\Delta)} \tag{26}$$

with $r \in [\Delta, 1)$ if $\Delta < 1/2$ and else $r \in (0, \Delta]$.

With the usual Legendre transformation we obtain

$$\alpha(r) = \frac{-\ln \gamma}{r \ln \Delta + (1-r)\ln(1-\Delta)} \tag{27}$$

$$f(r) = \frac{-1}{\ln \Delta - \ln(1-\Delta)} \left(\frac{\ln(1-\Delta)\ln r - \ln \Delta \ln(1-r)}{r \ln \Delta + (1-r)\ln(1-\Delta)} + \ln\left(\frac{1-r}{r}\right) \right) \quad . \tag{28}$$

We find the Hausdorff-dimension of the set on which $x(t)$ has no finite derivative as $f(\alpha = 1)$. In particular, note that $\alpha < 1$ iff $\gamma < \inf\{1/\Delta, 1/(1-\Delta)\}$.

3.2 The locally self-affine case

As we have seen, in the self-affine case the influence of the contraction with $1/\gamma$ results in a scaling of the graph of $\tau(q)$ by a factor $\ln \gamma$. If b is increased, the contraction ratio becomes a function of the value of $x(t)$ by

$$\gamma'(t) = \gamma x(t)^{(\gamma-1)/\gamma} \quad . \tag{29}$$

However, to conclude that γ should be replaced by $\langle \gamma'(t) \rangle$ falls short of the proper solution. This mean-field approximation delivers acceptable results if b is small, yet in case $b \to b_{max}$ it cannot account for the variation in the local vertical contraction ratio. To first order of b one can write

$$\gamma' = \gamma \left(1 - \frac{b}{2\gamma} \right) \quad , \tag{30}$$

and replace γ with γ' in equations 25 through 28. See figure 4 for an application of this approximation. Alternatively, it is possible to obtain the average γ' computationally.

4 The utility as a synthetic data set for algorithm validation

One of the most common algorithms used for the analysis of singular time series was inherited from research into hydrodynamic turbulence. Here, the 'structure function' is computed by

$$\langle |x(t+\delta) - x(t)|^q \rangle \propto \delta^{\tau(q)+1} \quad , \tag{31}$$

where $\langle . \rangle$ indicates an average over the entire sequence length.

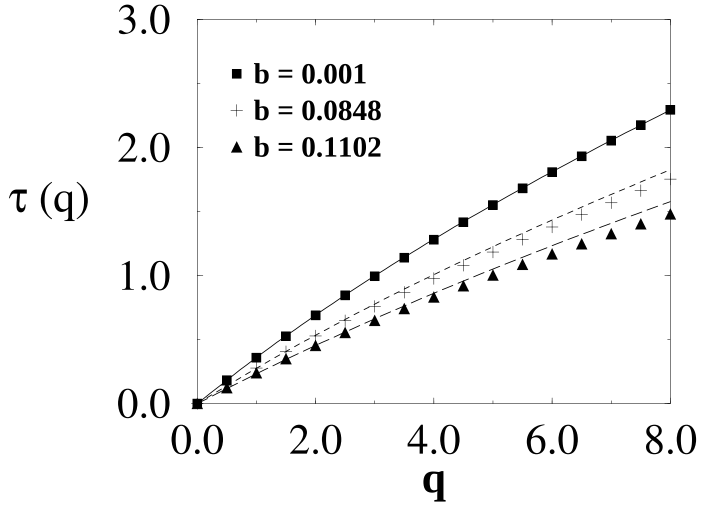

Figure 4: *The scaling functions $\tau(q)$ after Eq.(27), drawn as curves, and evaluated numerically, presented as symbols for some distinct q values, for $\gamma = 2^{1/3}$, $\Delta = 0.7$ and $b = 0.001, 0.0848, 0.1102$ from the top.*

It turns out that for $\Delta > 1/2$ and γ not too small and b not too big the numerical analysis is excellent. Examples are shown in figure (4). Quite the contrary is true as soon as $\Delta < 1/2$. Figures 2 and 3 show that the basin boundary appears markedly different. In particular, note that for $\Delta < 1/2$ the 'sharpest' peaks are the preimages of $t = 0$ and appear much more isolated than in case $\Delta > 1/2$, where they comprise the bulk of the curve. The failure of the structure function method comes down to a problem of resolution. The algorithm works well in the limit eq. (20), if it were carried out numerically, converges fast to the local Hölder exponent. For an algorithm which probes the curve at fixed size, the result becomes perturbed if many generations of singularities are thrown together.

The fact that the method excels for $\Delta > 1/2$ is mainly a result of the piecewise linearity of $G^i(t)$ so that the structure function closely resembles its analytic counterpart. This feature becomes worse if Δ is chosen closer to unity.

In the previous section we argued that a dilation of the graph of $\tau(q)$ along the q axis by a factor $\ln \gamma'$ is but an approximation, especially since it becomes apparent from the figures, that the symmetry of the spectra in Δ should be broken if b becomes larger. Although we cannot compute $\tau(q)$ analytically, we can give the asymptotic slope of $\tau(q)$ as

$$\lim_{q\to\infty} \tau'(q) = \ln(\gamma x_{\min}^{1-\gamma}) / \ln\left(\min\{\Delta, 1-\Delta\}\right) \tag{32}$$

and check so for the accuracy of the high order moments.

In conclusion, the fractal basin boundary puts any algorithms designed to analyze the Hölder spectrum of a signal to a severe proof. If γ is chosen close to unity, b close to its maximum and $\Delta < 1/2$, the singularities of smallest Hölder exponent become poorly resolved and very small - and the numerics tricky.

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Superluminality: An Implication of Special Relativity?

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Abstract

Li-Jun Wang recently described a superluminal wave crest in a gaseous medium with gain-assisted linear anomalous dispersion. The question of whether this result can be used to transmit information in a superluminal manner is presently open. An alternative approach using special relativity is proposed here. Einsteins dispersion gradient for the speed of light in a gravitational potential gradient, which via the equivalence principle follows from special relativity, can be used for the same purpose. The low-velocity people downstairs can send a superluminal signal by taking advantage of the higher light speed upstairs.

Introduction

One of the most curious postulates in the history of physics is the assumption of the constancy of the speed of light, no matter what the state of motion of the observer may be. It has become known under the name the Aarau vision of the young Einstein [2]. The constancy of the speed of light is the corner stone of relativity theory.

Recently, Nimtz [3] obtained empirical evidence in favor of a tunneling-induced speed of the crest of an electromagnetic (micro) wave of seven times the velocity of light (c). Very recently, Wang and colleagues [6], exploiting an anomalous linear dispersion in an almost-lasing Caesium gas, obtained an infinite speed ($310/c$, to be exact) for the middle portion of the gently rising front of a long smooth light pulse.

In both cases, the question of whether superluminal signalling can be obtained in principle and over large distances is still undecided. Cautioning arguments point to the fact that the rising foot of the light pulse only obeys "c plus" — that is, c augmented by the allowed classical and quantum-mechanical velocity spread (due to many partaking frequencies in the first case, and due to individual photons participating in the second). In the Wang experiment, the first appearance of the arriving light is invisible due to destructive interference and low photon density, combined. This invisible front ("dark foot") is followed by an apparently causality-violating jump ahead of the subsequent visible light front (slope and crest) by about one percent of the length of the pulse. The size of the jump is bound to increase with the length of the active medium but cannot be expected to overtake the foot itself. This interpretation restricts superluminal signalling to the speed of the foot. Since that speed becomes essentially luminal over large distances, the only way to exploit the effect over larger distances lies in linking many equal subelements together. This proposal presupposes that an (almost) instantaneous-acting amplification process can be provided. Whether or not quantum mechanics is opposed to this proposal is an open question.

On the other hand, the restriction to the speed of the dark foot is perhaps not the last word. Suppose it were possible to "hold back" the bulk of the pulse (especially those frequency components that make the jump possible) after the dark foot has already passed the cell. Then the drawback that the speed of the dark foot is essentially luminal over large distances would not matter. For the superluminal "catch-up process"would (through being manipulable) allow for negative signalling. The either suppressed or not signals would retain their strong superluminality because a withheld signal is a signal, too. However, this alternative is, admittedly, an unlikely option.

The described renewed interest in the problem of superluminal light propagation gives us an excuse, we feel, to point to a rather different scenario in which the occurrence of superluminal signal propagation is conceivable. It concerns a medium with dispersive light propagation that was originally discovered by Einstein in 1907 [1], namely, an acceleration field (for example, a gravitational field).

Gravitational Dispersion

Einstein saw that "downstairs"in a gravitational field, light effectively propagates more slowly from the point of view of the upper-level observer [1]. The effect is a corollary to the clock slow-down downstairs [1]. The Einstein disperson is confirmed by the "Shapiro phenomenon": Light passing close to ("grazing") the sun takes longer, so that the speed of light appears to be reduced downstairs in the field [5].

The basic situation is depicted in Fig. 1 The ratio between local clock rates is assumed to be two. One sees that the projection of a traveling light wave downstairs (bold line), up onto the upper level (dashed line), has subluminal properties. In the picture as drawn, the ratio is $\frac{1}{2}$ to one.

By implication, the velocity of light on the upper level, projected down onto the lower level, is not half as fast compared to the local speed of light downstairs, but twice as fast. This "apparent upper-level superluminality"can in principle be exploited by the inhabitants of the lower level.

A Prototype Situation

A concrete example is provided in Fig. 2 Light sent up from the origin, O, and then sent along the upper x axis to the right and then down again to point A on the lower level (bold line), arrives there after six lower-level time units ("seconds") — even though the lower-level distance between points O and A is eight lower-level space units ("light-seconds").

It goes without saying that by increasing the distance traveled on the upper level, the effective light speed can be made approach a superluminality factor of two in the case depicted. The conjecture is therefore possible that, for any acceleration-induced difference in clock rates no matter how small, a critical distance exists beyond which superluminal signal propagation can be achieved in a gravitational field or inside a constant-acceleration rocket, respectively.

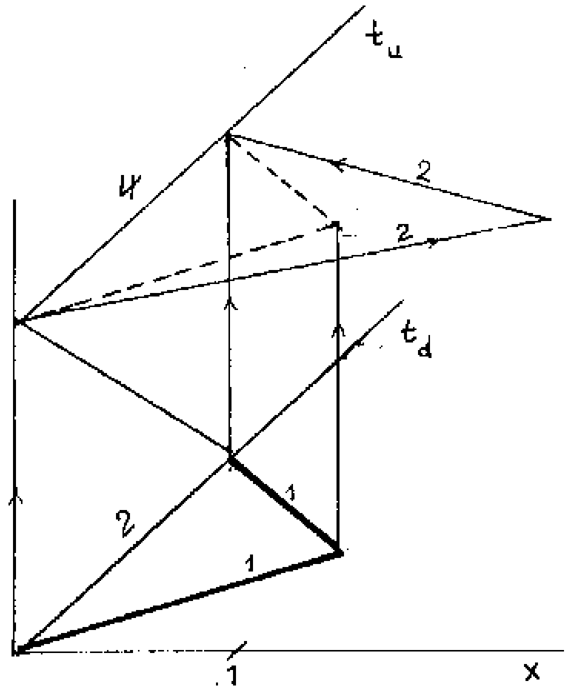

Figure 1: *Schematic picture of upper-level and lower-level light propagation in a gravitational field. x, t = space and time coordinates, respectively. t_u = upstairs time coordinate. Time downstairs is assumed to be slowed down by a factor of two for clarity.*

Discussion

A very simple idea was proposed. The dispersion of light in an acceleration field can be misused for superluminal purposes, from the point of view of the slowed-down lower level.

Two objections are possible. First, the effect is "trivial"since it is only valid in a region of space where the speed of light is reduced anyhow. Indeed, no one would have said, during the time of Foucault, that light propagating in the vacuum has a "superluminal speed" compared to light propagating in water. This comparison is, nevertheless, misleading since, unlike what holds true in water, *all* laws of physics are locally unchanged downstairs — including the speed of light — in a gravitational field. It is only to the upper people that the speed of light downstairs is slowed down as far as they can tell, not to the people living there themselves.

The second counterargument concerns the curvature of light rays, discovered by Einstein [1] in the same paper as an implication of the dispersion principle. For the case of drastic differences in the local clock rates, as assumed in Figs.*1 and 2, the curvature downstairs becomes marked compared to the vertical height difference. This curvature effect could conceivably spoil the result of Fig. 2.

However, this argument is invalid, too, for two reasons. First, the light paths can be "rectified" in a stepwise manner by simply implanting horizontal mirrors — like the stepping stones in a Japanese pond. Hereby the light path admittedly remains increased in its overall length by the curvature factor. This increase is less on the upper level, however, which brings in an additional advantage of switching to that level for the purpose of signal propagation. Second, we have the already mentioned fact that the total length (the horizontal portion in Fig. 2) can be increased arbitrarily. In this way it is assured that for a sufficiently elongated version of Fig. 2, the superluminal result shown in the Figure is re-obtained.

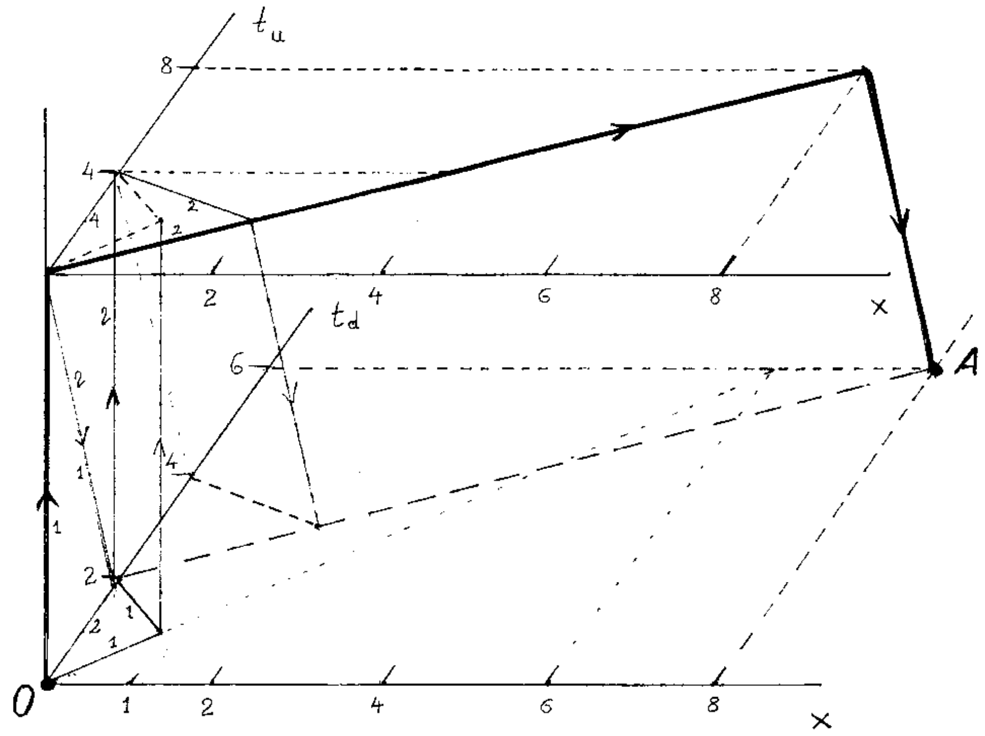

Figure 2: *Enlarged version of Fig. 1. There is a superluminal light path from O to A (bold line). Cf. text.*

This brings us to the question of the broader significance of the result. Does special relativity "really"imply the existence of superluminal signalling? The described mechanism is so simple that it perhaps qualifies as the first indubitable mechanism to ensure superluminal signal propagation if correct. The whole philosophy of special relativity is thereby put in jeopardy. Even though the rules of special relativity have been adhered to in every step in the above construction (in the special case of a wide-body constant-acceleration rocket which can be made obey the Rindler metric of special relativity [4]), the result contradicts special relativity. Therefore, either something is wrong in the above picture, or special relativity needs fixing in some little detail in order to rescue the speed limit of light.

Under such a condition, ordinarily taking recourse to experiment is suggested. Again, a quandary arises. We have no idea how a rocket-bound (or gravitational or rotation-type) experiment could be set up under currently accessible conditions that would produce a strong enough gradient in clock rates to allow a confirmation or refutation of the above theoretical result. The numerical threshold in acceleration or rotation speed below which the above result crumbles lies fairly high, although it has yet to be calculated exactly.

To conclude, an "anomaly" in the special theory of relativity, valid in the context of the equivalence principle, has been described. Either the mistake will be found soon or special relativity permits superluminal signalling.

Acknowledgements—Discussions with Dieter Fröhlich, Normann Kleiner, Heinrich Kuypers, Rüdiger Tschacher, Hans Diebner, George Galeczki and, in 1998, Günter Nimtz are gratefully acknowledged. For J.O.R.

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The Interface between Mortality and Immortality

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Abstract

Aging can be considered as protracted interface between life and death. What is the underlying biological mechanism of aging? An evolutionary argument for aging is that a progenitor has to pass away as soon as she or he has had reached reproductive age. The resulting "elephant curve" of a Gompertz-like type speaks in favor of a built-in death-program. The exponentially increasing endogenous death rate after twice the age of puberty seems to be confirmed by demographic data (cf. Azbel). An underlying physiological mechanism must therefore exist. The pineal concretions are a candidate for an accurate clock and the pineal hormone, melatonin, is possibly the "hand" of the time-of-life-clock. About 350 years ago, Ren Descartes considered the pineal gland as an interface between mind and body. Nerves working with little puffs of air – Descartes had discovered nerve conduction – keep the stones afloat in mid-air in the pineal, he thereby control the movements of the body through opening and closing the pores to the motor nerves (which he also believed to emerge from the pineal). If we suppose that the pineal stones have the function of an hour-glass with an associated chemical messenger which informs the cells of the organism, then we, too, play with the idea of an interface which, possibly, can be manipulated.

1 Introduction

Only the gods live for ever, but as for us man, our days are counted,

so it is said in the epic of Gilgamesh, supposed to be more than 5000 years old. The babylonian prince Gilgamesh experiences that his younger friend Enkidu who accompanied him on an expedition, suddenly died in his arms. Gilgamesh worried what a strange type of sleep had seized his friend. He decided to conquer death. On his search for immortality a wise man advised him that he first had to conquer sleep before he could reach out for immortality. Six days and seven nights was he told to stay awake. Gilgamesh was unable to pass this hard test. In this old epic the transitoriness of the body is pictured astonishingly vividly with the following sentence: the body will be eaten by worms like an old dress [42].

Humans are mortal, we age. What is aging? A scientific definition of aging is the following: aging is the increase of mortality with age. Konfuzius (551-479 BC) two and a half millennia ago, formulated more poetically: old age is the highest rank of maturity. Is aging the interface between mortality and immortality?

There are and there were philosophers and artists who remained active in old age and even showed a progressive development in their achievements. So the four Pietas built by Michelangelo (1475-1564) during his almost 90 years of life, are said to show an increase in the depth of expression. And when we here compare a fresco, titled "The Delphic Sibyl", painted by Michelangelo at the age of 35 (Fig. 1) with part of the fresco titled "The Last Judgement", completed at age 66 (Fig. 2), we, too, may recognize a deepening of the internal emotions of the protagonists. Let us take another example. Titian (1477-1576) painted when he was 38 years old a picture with the nice title: "Sacred and Profane Love"(Fig. 3), and at age 93, the "Shepherd and Nymph" (Fig. 4). Here we feel Konfuzius saying confirmed, old age is the highest degree of maturity in life.

Figure 1: *Michelangelo: The Delphic Sibyl, 1508–12, ceiling fresco Rome, Vatican, Sistine Chapel*

Figure 2: *Michelangelo: The Last Judgement (detail), 1536–41, fresco Rome, Vatican, Sistine Chapel*

Antiquity was mainly influenced by elderly philosophers and artists. Think of Socrates who reached 71 years, Democritus 85 years. Plato discussed philosophical problems at the age of 80. And Archimedes was so disturbed in a geometric problem at the age of 73. Seneca at 93 was regarded a wise man in ancient Rome. But ancient Rome showed also another side of the old age problem [17]. The social support for the sick elderly was a problem in those days. And those aged citizens who involuntarily did not return from the bridge over the river Tiber at night were left, as so-called "depontani", to their fate (in the river) [17].

Figure 3: *Titian: Sacred and Profane Love, about 1515, oil on canvas, Rome, Borghese Gallary*

2 Why do we age?

What is the function of aging, this protracted interface between life and death? Aristotle (384-322 BC), about 2350 years ago, said (in "De Longitudine et Brevitate Vitae") that it is not sure whether one universal factor is responsible or whether many factors are responsible for the fact that some plants and animals have long lifes and others short lifes. And he discussed that a healthy condition is not the decisive prerequisite for a long life span [2].

At the end of the 16th century, Francis Bacon (1561-1626), the famous English philosopher-scientist doubted the reports on immortal animals which had repeatedly appeared since antiquity because they were not convincing to his mind. But in his book "de vita et morte" (on life and death) Bacon wrote that a prolongation of life span is theoretically thinkable if it is possible to perfect the repair processes so that they function without mistakes [5]. This argument is an astonishingly modern one, a time-less argument. Bacon continued that the prolongation of human life span is the noblest goal of medicine. But, since he did not want to risk a disput with the church authorities, he added that the maximum life span is, of course, determined by the allmighty alone. But this would not mean that man should not do his best to reach that limit (cf. [21]). We can therefore name Francis Bacon the founder of scientific gerontology. (Whereas the french medical doctor Jean Martin Charcot (1825-1893) who described his experiences with the elderly in his diary is called the founder of clinical gerontology [17].) René Descartes (1596-1650), the 35-years younger contemporary of Francis Bacon, reasoned and advocated that science some day would find a recipe against aging [15]. Before the thirty year's war there existed an astonishingly advanced scientific thinking. Does there exist a positive cause for aging as a predictable interface phenomenon?

3 Life Expectancy Curves

Let us first look at some historical survival curves (Fig.5). 50 000 years ago, it is assumed life was so difficult for man that human beings had an exponentially declining probability of survival with age. Such a behavior of life expectancy curves is well-known from populations that do not age, as can be observed in some animal populations. For example, the charming birds called peewits, show this behavior: their survival probability decreases exponentially with age (Fig.6). Young nestlings were followed up for 12 years in a British study. This behavior can

Figure 4: *Titian: Sheperd and Nymph, about 1570, oil on canvas, Vienna, Kunsthistorisches Museum*

even be observed in inanimate things. There, too, exists a study – this time from the U.S.A. In a cafeteria water glasses were counted regularly, after seven and a half weeks half of the glasses were broken, after 32 weeks ninety per cent (cf. [21]).

In ancient Rome half of the citizens reached 45 years and 10 per cent grew to 60 and older. In comparison, in 1970 half of the people lived 70 years and 20 per cent 80 years and more. In the 18th century the median survivability was only 40 years and, therefore, differed not from the time of ancient Rome, as theologian Johann Peter Süßmilch found out (cf. [8]). Süßmilch, a clergyman, apparently loved statistics and invented and registered life expectancy tables for Prussia. And he wrote a book (in 1741) with the impressive title "The Divine Order in the Variations of the Human Gender proven from Birth, Death, and Reproduction" [46]. Süßmilch discovered a difference in the birth rate, namely for 100 girl-births there came 106 boy-births. He was heavily critized by the Swiss mathematician Nikolaus Bernouille and the French mathematician Abraham Moivre for his finding that the birth rate of boys was higher than the female one (cf. [8]). Süßmilch himself had moral qualms considering how the christian doctrin of monogamy could be sustained in face of the expected surplus of males. He solved this ethical problem through demographic research and found out that an increased mortality rate of boys during childhood and adolescence resulted in an even representation of the two genders at the age of marriage. From this demographic excursion, we now return to the mortality curves.

Comparison of the mortality curves of the last 90 years in the U.S.A., reveals that the first part of the curves becomes more and more straight and seemingly approaches an almost rectangular form (cf. [13]): Fig. 7. The biological life expectancy curves even have parallels in technical machines. For example, the survival curve of aircraft (Fig. 8) shown here for the cohort of DC 8 airplanes (from the dissertation of Artur Schmidt [41]) has a similar form. Apparently, good technical serveillance and repair have the same effect as hygiene and medicine had on the survival curves in humans.

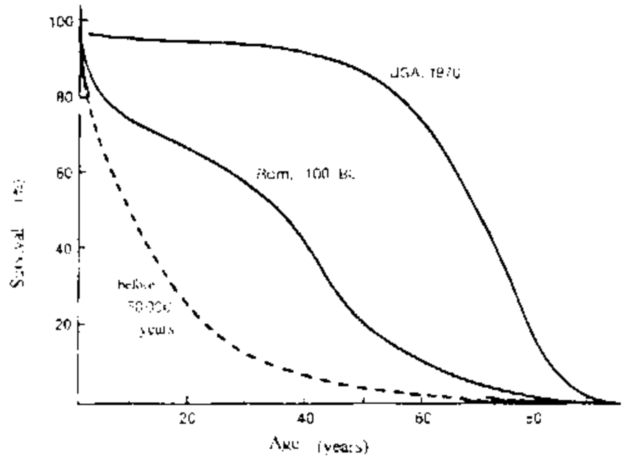

Figure 5: *Figure from Cutler, R., in Molecular Basis of Aging, Ed. A.K. Roy and B. Chatterjee, Orlando 1984. Cf. [21]. Cf. text.*

Figure 6: *Cf. [21]. Lack, Britisch Birds 36:214(1943) and M.J. Lamb, Biology of Aging, Glasgow/New York 1977, p.36. Cf. text.*

4 An Evolutionary Argument for Aging

More than one hundred years ago, Alfred Russel Wallace said that under natural conditions a competition between the young and the old arises. And nature would prefer species that die shortly after reproduction. ("..when one or more individuals have provided a sufficient number of successors they themselves, as consumers of nourishment in a constantly increasing degree, are an injury to those successors. Natural selection therefore weeds them out, and in many cases favors such races that die almost immediately after they have left successors" [49], cf. [33]). August Weissmann added that the old may even be dangerous for the young since they take away and occupy the place to live. ("Worn-out individual are not only valueless to the species, but they are even harmful, for they take the place of those which are sound" [49], cf. [45].)

If we try to generalize Wallace's argument, then it boils down to the following: In a restricted niche – as is almost always the case in biology – the young offspring and the old forebears

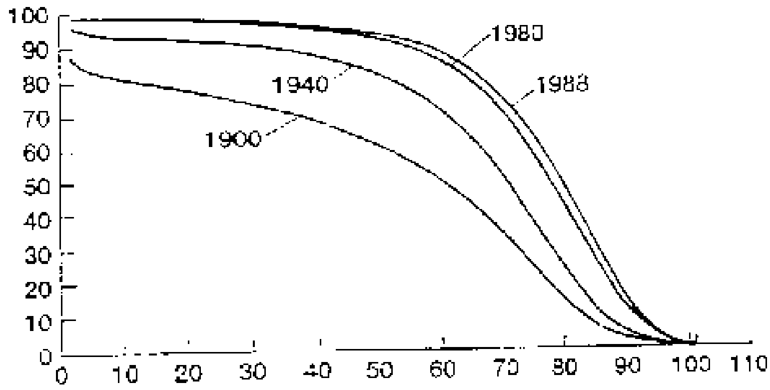

Figure 7: *Cf. text*

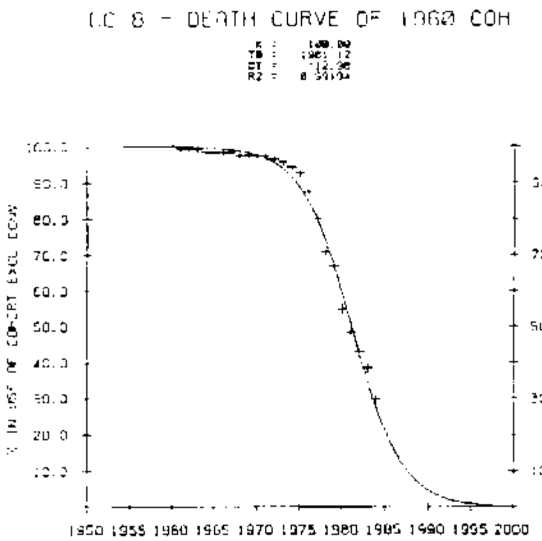

Figure 8: *Cf. [41]. Cf. text.*

necessarily become competitors. Is there a law by which nature could minimize this drawback for the best of the species?

If we assume that a progenitor has to pass away as soon as he or she is - on the average - replaced by one viable offspring of the same gender who has reached reproductive age, then one obtains the following death curve, the so-called elephant curve (Fig. 9). The corresponding equation is very complicated if written down explicitly, but it can be shown that it is closely related to the famous Gompertz equation. Benjamin Gompertz in 1825 wrote down a formula which very well describes the mortality rates of man and even of animal populations, after puberty [18]. Gompertz' equation relied on empirical data from several counties in England. We now have a very similar curve, but this time the mortality rate relies on the number of offspring. The elephant curve describes the endogenous death rate after puberty [34].

The Gompertz equation contains two death rates, one is age-independent and the other age-dependent. If one adds an age-independent death rate to the elefant curve, one obtains the following picture: Fig. 10. One sees a constant death rate at the bottom and an exponentially increasing death rate to the right. This latter portion of the curve is a straight line in a semi-logarithmic representation (as shown). These details were worth mentioning because there

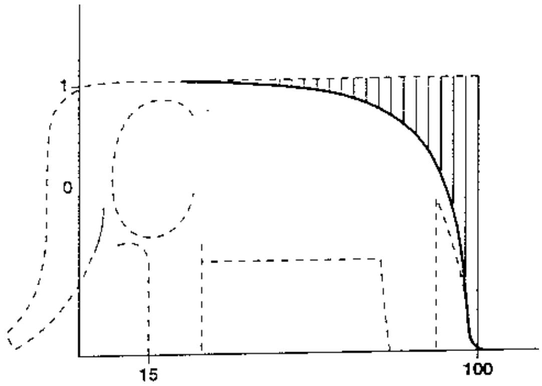

Figure 9: *Elephant curve.*

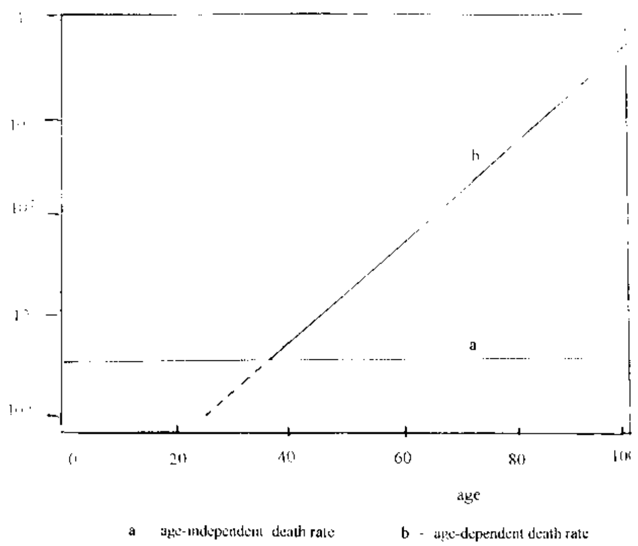

Figure 10: *Cf. text*

exists an empirical "curve" consisting of nothing but observed data in the best observed species known to man, the human species. Mark Azbel collected all available demographic data of two populations of human females and combined them in one empirical sample (Fig. 11). It contains only collected data without any curve fitting [4]. Only the postpubertal data can be compared with the theory (the letter V shaped dip in prepuberty and the higher infant mortality are of no concern here).

One sees that the Gompertz curve as well as the elephant curve are reproduced by nature with amazing accuracy. A biological underlying mechanism which on the level of the population acts with great accuracy must therefore exist. Even though the data are "only statistical" the regulation is highly precise. Therefore an accurate clock must exist in the average human organism. The identification of this clock is an unsolved problem to which we turn next.

The lawful increase of mortality rate with chronological age can be called "aging" (as mentioned). The endogenous increase of the probability to die, may be called "thanatos principle". (Stephan Meyer coined the term thanatos principle and Peter Kloeden is responsible for the mathematics.) The next question is, how this principle may be implemented in the physiological regulators of the body?

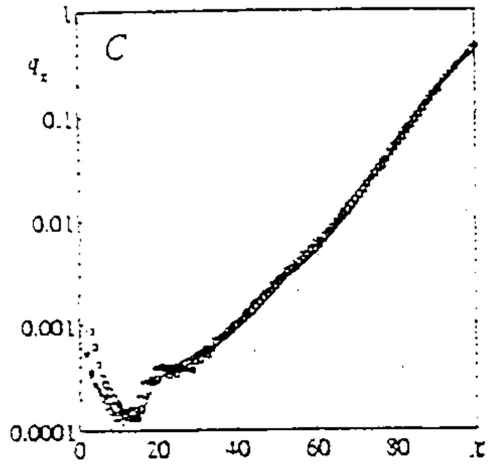

Figure 11: *Cf. [4]: Mortality rate of Japanese (1891–1980) females*

5 Regulation of the Thanatos Principle

If one is looking for a built-in mortality program as a function of time clocks come to mind. Intracellular clocks are known to exist since Leonard Hayflick and Paul Moorhead in 1961 proved that somatic cells have a limited life span in cell cultures. The number of possible divisions varies from cell to cell, and amounts to 50 divisions in human fibroblasts [21].

The molecular mechanism of the so-called Hayflick limit is almost completely understood [16]. The chromosomes contain on their ends caps, the so-called telomeres (cf. [9]). Telomeres are decisive for the doubling of the chromosomes. With each cell division the telomeres become shortened a bit like a train billet is ticketed with every train ride. When the telomeres are cut down to a certain critical length no further cell divisions are possible (as Elizabeth Blackburn and Carol Greider discovered in 1996 [19]). Already in 1971, Alexei Olovnikov discussed whether there exists a relationship between the telomeres and the age of the cell [27]. The paper was translated two years later, but then noticed by Calvin Harley who was so fascinated by the idea that there could be a connection between the length of the telomeres and the age of the cell that he devoted his research to this question. In 1990 (that is almost 20 years later) he demonstrated in collaboration with Carol Greider that the telomeres indeed shrink with age – in fibroblasts [20]. Intracellular clocks thus are present, 92 in every somatic cell of the human body [16]. Do there also exist centralized clocks?

One central clock responsible for the day-night rythm is known to exist: the suprachiasmatic nucleus (SCN). The daily “Zeitgeber” was after extensive studies by Curt Richter localized in the suprachiasmatic nucleus by Stephan and Zucker in 1972 [32, 43]. The SCN is a bipolar organ of the hypothalamus (midbrain) immediately adjacent to the crossing of the optical nerve. The SCN responds to light and to melatonin and regulates the 24-hour rythm in mammals. Is there in addition a slow “master clock” to be found in the organism, a clock that regulates the time of life?

6 The Pineal Gland

The pineal gland is a candidate for the master clock. The pineal gland was described anatomically more than 2000 years ago by Herophilus of Alexandria (around 300 BC). Herophilus ascribed an astonishing function to the pineal: The pineal controls the stream of memories, he said. In India the pineal gland is called Ajna chakra, third eye. The notion third eye is correct for the pineal gland has the function of a third eye in reptiles and birds. Some saurians had an extra opening in their skull. The pineal is responsible for seasonal behavior [1], for instance in birds of passage.

In 1958 Aaron Lerner discovered that the pineal gland synthesizes and secretes a hormone, which he called melatonin [25]. After investigating thousands of bovine pineals, Lerner by pure thinking arrived at the correct structure (cf. [31]). The biosynthesis of melatonin starts with the essential amino acid tryptophan and proceeds via serotonin to melatonin. The steep increase of melatonin in the evening is a signal for the nucleus suprachiasmaticus as mentioned and induces the wish to go to sleep. Melatonin is secreted only at night [1]. The highest levels of nightly melatonin are found in children of age 3 to 7. A sharp decline of melatonin in late childhood induces puberty (cf. [1, 31]). After puberty the melatonin secretion decreases almost linearly with age [22, 47].

The reported decline of melatonin secretion with increasing age stimulated Roman Rozencwaig et al., in 1987, to the hypothesis that the decrease of the nocturnal melatonin secretion may be a possible cause of aging (cf. [35]). In the same year astonishing experimental results were published by Walter Pierpaoli and George Maestroni: Mice receiving melatonin in their nightly drinking water lived about 25 per cent longer than the controls (cf. [29]). A few years later, Pierpaolis group successfully transplanted pineal glands from young mice to old mice and vice versa. The remarkable result was that old mice with young pineal gland transplants became active and lived 30 per cent longer than the sham-operated animals (1000 days versus 700 days). Young mice receiving pineal glands from old mice, in contrast, aged, developed cataracts and lived 30 per cent less (about 500 days) than the controls [29]. The life prolonging effect of melatonin was described not only in mice but also in rats in a smaller experiment by Nava Zisapel and his group. (Strangely, Roman Rozencwaig demonstrated that also microscopic multicellular organisms, rotifers, live twice as long when melatonin was poured into the water basin every evening at the same time [35].) Is the pineal gland the sought-for master clock in mammals and hence in humans?

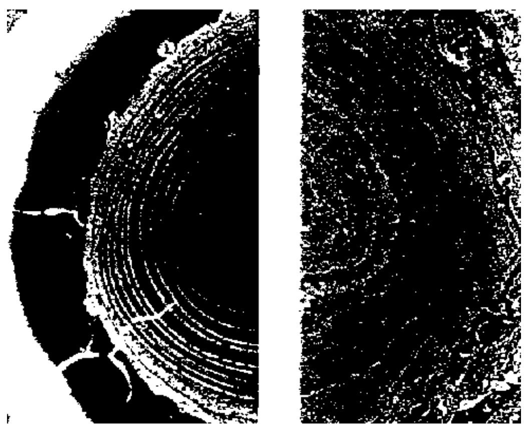

Figure 12: *Source: [50]. Cf. text*

7 Pineal Concretions

The pineal gland contains a peculiar structure – tiny stones. These so-called concretions or coacervates consist of a carbonate-containing hydroxy-apatite similar to the material found in the bone of teeth. Marcia Welsh, in 1985, published cross sections of the pineal stones (Fig. 12) which show a regular concentric deposition of this apatite material, and she compared this finding with the concentric precipitation of salts in gel, the so-called Liesegang phenomenon [50]. The concretions therefore resemble the scales of fish that sometimes allow to read-off their life history (cf. [30]). Is it possible that the pineal stones represent a physico-chemical clock, so that the pineal sand functions as an hour-glass, so to speak?

About 350 years ago, René Descartes, considered the pineal gland as an interface when he ascribed a special function to the pineal. He argued that the nerves working with little puffs of air – Descartes had discovered nerve conduction – keep the stones afloat in mid-air in the pineal, so to speak, with their momentarily positions blocking or opening the pores to the motor nerves which he also believed to emerge from the pineal. Due to the assumed lack of friction and the virtual masslessness of the stones (and, so one might add, the principle of energy-less chaos control) the mind could influence the movements of the stones and thereby the movement of the body without violating the laws of nature by opening and closing tiny motor openings [15]. The interface between mind and body was thus both invented and localized in the pineal gland by Descartes. So a sublime idea was put into an all-to-modest vessel, the pineal. Is the hypothesis that the stones measure the time of life not an even absurder hypothesis? It is a very daring concept. Nonetheless, there are some feable experimental hints, that the idea may be not entirely mistaken. Hermann Schmid in Providence, Rhode Island, investigated human pineal stones of different age and found differences. The ratio of calcium to phosphorus increased with age [40]. But, and this is a very big but, this research was performed on only three pineal glands.

If one supposes that the pineal stones are not moving and not the interface between the soul and the bodily movements but instead have the function of an hour-glass then the natural next question to ask is: How can this information reach the cells of the body.

8 The Hypothetical Signal of the Time-of-Life Clock

Which signal could be a messenger, a hand of the conjectured clock? Melatonin is liquid- and water soluble and can therefore, in principle, reach every cell of the body. It was already mentioned that the suprachiasmatic nucleus responds to melatonin [3]. The SCN contains special membrane receptors for melatonin. There also exist nuclear receptors for melatonin in most cells [11]. How melatonin, if it is the signal of the time-of-life clock, may inform the cells of the organism (and which subsequent intracellular reactions may be induced by it) is still a matter of speculation.

A single cell is a whole world which is only incompletely understood so far. It is known that cells contain so-called death angels on the one hand, and life saving squads on the other [26]. The ratio between protective and destructive materials (mostly proteins) can decide over life or death of the cell. The programmed cell death without inflammation was called apoptosis by John Kerr. Apoptosis is a crucial factor in the embryonic development – it is for example responsible that the fingers have no web anymore, as Kerr reported already 28 years ago [23]. Apoptosis is of significance in certain degenerative disorders and may also play a role in aging [48]. It is still unknown how shortened telomeres block cell division and trigger apoptosis. Recently, cells from cloned calves were reported to have longer telomeres than normal newborn calves, and those cells from cloned calves showed a higher Hayflick limit, that is, an increased number of divisions in cell culture [24]. This finding was greeted in the newspapers as a prospect for an increased life span in cloned individuals. The question whether the telomere length is the major determinant of life span is, however, not yet answered. Experiments in mice seem to show that the life span is not solely dependent on the telomere length [36]. Inbred mice with short telomeres due to a defective telomerase gene, so that the telomeres progressively shorten with every further generation, developed signs of senescence like gray hair, infirmity and an increased susceptibility to tumors much earlier than the control mice. The life span, however, was drastically shortened only in the sixth generation [36]. These findings seem to indicate that the cellular clocks – the telomeres – are mainly reponsible for the different life stages while the death-program itself is possibly not solely regulated by the telomere length, at least in mice. This makes it even more interesting to look whether melatonin has any effects on the telomeres or their mode of action. Is melatonin a modulating factor which keeps life span more or less unchanged even with moderately shortened telomeres?

Theoretically, it is conceivable that melatonin has an effect on the stop signal and thereby would prevent apoptosis. In this context it is noteworthy that melatonin has a protective effect against apoptosis in cell cultures [12, 28, 37, 39]. There exists a connection between apoptosis and the cytoskeleton [14, 44]. Melatonin has an influence on the cytoskeleton. Gloria Benitez-King and G. Ramirez recently demonstrated that melatonin reorganizes the cytoskeleton in unicellular organisms and so in plants and in vertebrates. The micro filaments (microtubuli and actin filaments inside the cell) are cyclicly decomposed and recomposed in the presence of low concentrations of melatonin, applied in a diurnal rythm [7]. This may be an ancient mechanism dating from the unicellular life style. Since melatonin acts on the cytoskeleton, the nightly rejuvenation of the organism through a thorough rebuilding of its stable elements may prevent apoptosis if functioning correctly. An antiaging effect would thereby be implicit. On the other hand, if one is honest, nothing definitively speaks so far in favor of melatonin being the hand of the time-of-life clock which may (or may not) exist in the pineal.

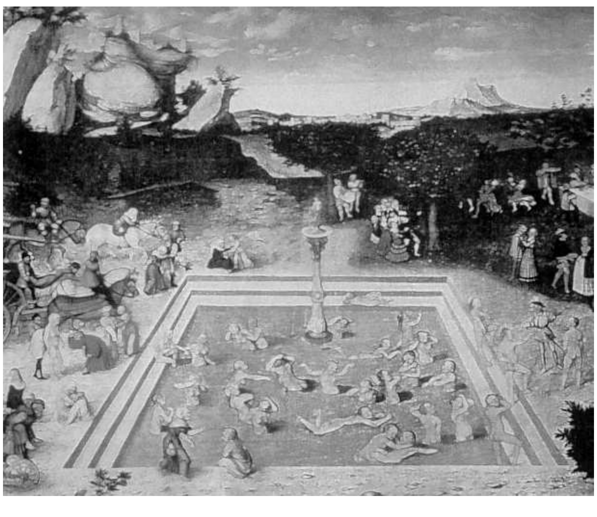

Figure 13: *Fountain of Youth by Lucas von Cranach the Elder, 1546*

Figure 14: *Engraving of Jan Gillisz van Vliet, 17th century, collection of Christoph Müller, Tübingen*

9 Does there Exist an Interface between Mortality and Immortality?

As soon as the molecular biological fundamentals of programmed aging will have been elucidated, we can speak of an interface, of an interface which can be manipulated. Michael Fossel's proposal to achieve immortality through telomerase induction in dividing somatic cells was an early proposal [16] and was followed by a first example in a Petri dish [10] and recently by experiments on cells of cloned calves [24], as mentioned. The findings of a longer life in cell culture open up the prospect of a longer life span of the whole organism.

The famous painting by von Cranach the Elder of the 16th century features the old dream of mankind to take a bath in the fountain and step out youthfully (Fig. 13). The astonishing life-prolonging effect of melatonin in mice and rats comes to mind again. Is melatonin the fountain of youth? Up to now there is no proof that melatonin supplements at night can extent human life span. On the other hand, there is evidence that melatonin aleviates many symptoms characteristic of old age (like insomnia, nykturia, early morning prostatic problem, elevated blood pressure, osteoporosis, arthrosis and susceptibility to tumour growth). Clinical studies have substantiated several of these findings [31, 35, 38, 51]. Thus supplementary melatonin can not yet be said to act as a fountain of youth, but it can, perhaps, be said to act as a fountain of health in the elderly. In this way melatonin can help to make the physician a clever doctor like Christoph W. Hufeland, about whom Goethe said two centuries ago: we live as long as God determines, but it makes a big difference if we live miserably like old dogs or well and fresh and this is something a good physician can provide (quoted after [6]). This remark refers to the possibility of manipulating the interface between disease and health which is sometimes possible.

Modern genome technology seems to promise immortality in the long run. The question whether we humans are able to handle potential immortality has a very old tradition. In Greek mythology, the godess Eos (also called Aurora in Latin) asked her father Zeus for the gift of immortality to Tithonus, her human lover. Zeus granted immortality, but he granted only everlasting life and not everlasting youth. And so Tithonus was condemned to eternal senility.

It may be hoped that in the search for the interface, we do not forget the beauty and wisdom of old age. The dignity of old age is captured by an engraving of Jan Gillisz van Vliet (Fig. 14)

Figure 15: *His beloved grandmother by Reinhard Crämer*

of the 17th century (collection of Christoph Müller, Tübingen) and in the more recent red chalk portrait of his beloved grandmother (Fig. 15) by our friend Reinhard Crämer. When we take notice we will always find an elderly person in our neighborhood who exemplarily manages his or her daily course. Uncle Max, the father of a school friend, was such an exemplary person. As an engineer on sea he navigated all oceans and remained active in old age, managed his house and garden and did most of the necessary repair works – even high on the roof – all by himself. He had to offer some very useful advice and keen observations. One of his favorite sayings was, love helps sometimes, work helps always. Apple sauce was his medicine against a biological problem that many elderly are aware of. 4-5 apples cooked without sugar, kept the motor running, as he said. He reached an age of 95.

We humans are mortal, but there even exists a royal way to become almost immortal, namely by having good ideas, performing good deeds and by being fortunate enough to find good friends who remember them – like this was done by the old epic of Gilgamesh, for immortal are only the gods...

Thank you all, and thank you, Peter Weibel. For J.O.R.

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The Biophysics of Light

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1 Anaximander and Parmenides

One of the few sentences of Anaximander which was preserved through the millennia, states, that everything is included in the sphere of being except Moira. Moira is the goddess of fate and this makes clear that ontology, the study of being, cannot dominate fate. For Parmenides being included everything and not being was not. So if one would apply Parmenidean thought to the Anaximandrian scenery one might be tempted to say that Moira is and because of this she is the form of being which would mean that she is included within the sphere.

In some sense it seems to be recommendable to read the Anaximandrian sentence as the fist formulation of the Goedelian theory. In Anaximander it reads that "totality" cannot control its own fate. Truth therefore is in the hands of more than just thinking totality. This shows the structure of what Goedel demonstrated in his arithmetical theory.

If one takes this perspective, Parmenides, though being later than Anaximander would have shown much less insight into the problem of completeness than did Anaximander. But to analyse the problems of completeness of ontology one has to look also for the performative dimension of coping with ontology. Parmenides' saying about there being only being and no no-being is a part of a poetic hymn to the goddess of truth. So performatively Parmenides respects the female figure which in Anaximander goes beyond domination, but is in Anaximander nevertheless included into a discourse looking for completeness. So one has to see that in both, in Anaximander just as in Parmenides a female figure find special reference. In Anaximander it is stated with distinction that this figure gives fate. In Parmenides the process of fate becomes evident by the entanglement into the hymn act towards the goddess. Parmenides makes the scenic installation for fate and Anaximander states the structure of fate. In some sense both are right. The ontology of Parmenides is right as long as it is realized in the context of hymn poetry. This of course was not true for the history of ontology. So the true sentence of Parmenides became wrong by the form of performance. The great question is whether the sentence of Anaximander is right, and even more right than the sentence of Parmenides, because it is in the beginning abstracted from the kind of performance. Perhaps one should more correctly say that its performance is not bound to hymn poetry. Many attempts and present philosophy who try to overcome ontology are on the way of Anaximander. They are ant-poetic and the great question is whether to leave ontology, it is necessary also to leave poetry. If you read Parmenides in the proper sense there would be a possibility to go on with ontology if you respect the need for hymn poetry which after two and a half thousand years I would like to correct by those experiences which were made in these long times in saying that going beyond ontology may also be attempted with a hope to meet Him in his femality (Shechina).

2 Principles of the Organism

The early historical questions for completeness and totality started with a metaphor of the sphere. We will come back to this metaphor. At the moment we want to look for a special aspect of this metaphor which lies in the fact that it gives a distinction between outside and inside. So the question for being is the question whether everything is inside or whether something is left outside. The Goedelian argument seems to make it necessary to be able to live with things remaining outside. The interesting thing with the organism is that in some sense all its distinctions between inside and outside remain inside. Out of this one could draw the conclusion that it would be better to speak only of inside because the distinction between inside and outside out of the organisms perspective can only be made inside. So one could try to make the claim that cognition has to stick to the methodological restriction which says that nothing can be said about the outside. But this would be a not well founded conclusion from the Goedelian situation. The system functions better when it tries to make estimations about its whole state. For this purpose the dual organization of the brain is helpful because the communication between the two hemispheres by the corpus callosum is something in between fact that one hemisphere is outside the other and the fact that both are one brain. The processes in the two hemispheres may be performed more in a one brain manner or in a dual brain manner. So the fate of the individual realizes itself by the way in how far the individual with its processes tries to get out of one hemisphere. The splitting of the Anaximandrian sphere into the two cerebral hemispheres is the attempt to prevent fate by a biological organization principle. But now fate lies in the process of transfer between the two hemispheres. Neuropsychologically the different fates of the individuals can be described by the different degree of acceptance of contradictions. The cutting of the sphere of the brain and the two hemispheres with some small interrelation between them (the corpus callosum) gives the biological structure for the individual "solution" of the Goedel problem which is the life of a person. The image of the two hemispheres and their relation is an illustration of mans Goedel situation as was Leonardos man a symbol for mens ability to solve in practice what could not be solved in theory (the quadrangulation of the circle). Probably, meaning has to be attributed to the two hemispheres as a whole and cannot be attributed to processes in one hemisphere only (automatic speech from one hemisphere is no counterargument, this is true for the infarction of one hemisphere because the system then has changed from a two hemisphere to a one hemisphere system which of course changes the meaning).

3 Energy, Information and Time

Organisms receive energy out of the breakdown of complex molecules which is called metabolism. These energies reinstall molecule concentrations at semipermeable membranes. Thereby, informations (novelties) coming from the outside world can be transcoded in the nervous system into impulse series of neuronal spikes. The energetic supply for the production of these spikes is guaranteed by blood circulation. But in some sense the neuronal spikes are not only for information processing but give also an energetic supply. In case that there are no spikes coming to a neuron it is delivered to apoptosis. One my describe apoptosis by an information theory approach as a loss of an element for the information processing system. But this is not akin to a loss of information. This relation is more complex. In apoptosis the system looses elements but may on a first level of analysis keep its information by building "abstractions" or "supersigns". So on an abstract level the information of the whole brain may be preserved also when it is loosing neurons by changing the code of the remaining neurons. But this is an insufficient procedure of describing the effects of apoptosis on general "information" processing. If there is a loss of elements (neurons) in the brain then also the quantities of connections are reduced which means that the quantity of associative dimensions is reduced. Such a reduction is to a certain degree necessary for the nervous system to be able to develop on the cognitive level

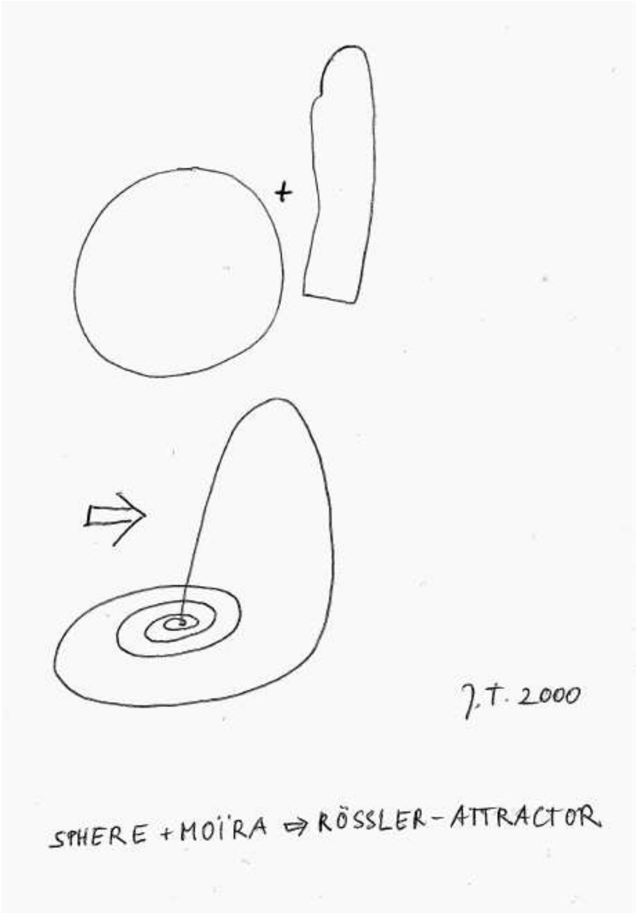

Figure 1: *Sketch by Jan Tulp*

clear and distinctive categories and notions.

But the extrapolation of this process does not make the cognitive processing more clear and distinct but less meaningful because the loss of associative possibilities is also a loss of meaning. The cultural notions of "category" and "notion" reflect a certain bandwidth between associative low level manifold and associative high level manifold. There is a certain quantity of associations which is best compatible with communication. In this way communication offers a parameter for optimizing the parameters of associative possibilities. This makes clear why innovative acts giving rise to new and more associations sometimes are a difficulty for communication.

If one extrapolates the process of reduction of neurons in the course of later age one would arrive at the last neuron at about the age of 450 years. Which information would the last neuron preserve? One might describe this process of decay as a kind of epsilontic (which is known from differential geometry as the approximation to zero) taking the way from vitality to Buddhism. In the end there would be the totality of meaning represented into nothing because in a "last neuron" there is no way to unfold it.

4 Energy and Information

If one takes the energy supply for the neurons and their information processing as granted it is possible on this level of abstraction to describe the information processes between the neurons also as a process with the causality of energy transmission. This is true for a certain range of processing because the neuron being able to give information has to a certain degree to receive information.

On a certain descriptive level information processing is independent of energy supply. If one looks for this level "mind" impresses as a "nous poetikos" and the soul as a self- moving system. Aristotle describing the soul as self-moving neglected the fact that he was coping with novelty when he was writing this. So he made the category mistake of omitting novelty in the process of self-movement. This omission is no more possible after so many variations of Aristotelian thought having come onto the world.

Now we see that the human soul if one wants to describe it as a perpetuum mobile one has to see that it is a perpetuum mobile using novelty instead of energy on a certain level of abstraction. And this abstraction shows that the human soul is dependent on more than on energy alone. It depends on energy and novelty which both can be derived from thermodynamics. So to give a sufficient description for organisms in which there is not only a short circuit of energy supply but in which complex neuronal activities are necessary to be able to get the food, it is necessary to see that the neurons cannot always be in the activity of securing food supply (in such a case obesity would be the way out).

If the short way out which consists in using the long loop for food supply just for this activity also when it is not necessary is not a pleasent way out. That the neurons necessary for finding "prey" do not fall into apoptosis the system of neurons tries to keep activated by producing novelty. In human beings both supplies are looked for: food and novelty. I think it is helpful to see that the supply with novelty has many similarities with energy supply, though it is active on the level primarily described as information processing. There is a causal relation of energy processing with information processing in the nervous system. It occurs on two levels. First on the level of apoptosis, second on the level of scarcity of spiking in case of no receiving many spikes. Taking this seriously this would mean that not to have any communication is worse then having bad communication.

5 Skin and Energy.

In the brain there is an interesting correlation between energy supply and information processing. In producing neuronal spikes by ion transfer potassium is enriched in the extracellular space. This potassium has an effect onto the muscles of the vessels supplying the brain with blood. In the brain there is no general maximal possible blood supply suppression but a fine regulated localized blood supply increased in correlation with a local neuronal spiking (which is in certain correlation to the information processing). This fine regulation saves energy. But this correlation between blood supply and information processing (or at least neuronal spiking) does mean that information processing is causal for energy supply. It is important to see that in the nervous system there are neighbourhood principles of information processing and energy supply. So neurons which are in the neighbourhood of a neuron which is in active information processing have more energy supply to activate information processing for special dimensions and will activate neighbouring neurons which are not specifically concerned with a "topic" of information processing going on.

As this principle allows the organism to bring neurons into information processing which usually are not activated, it is only necessary to find the activation for certain areas of function to activate other functions too. For this the organism seeks activation by unspecific stimuli to come to an activation of specific cognitive processes.

One of the preferred measures to be taken by the organism to activate neurons which are difficult to activate by cognitive processes alone is the activation of skin receptors. The skin receptors react preferentially to changing stimuli (differential preception). Therefore, bodily contact and touching (in a moving fashion) is of great importance for heightening the level of activity for the organism to prosecure sometimes rare cognitive processes. Information roots which are rarely used may find their activation in this way. If the organism would be an information processing system working with rules only it would sometimes difficult to find the proper point for action. It can much be better be found by activating also the remote informations for processing.

The neighbourhood principle in the nervous system is also active by the use of gas diffusion principles for information processing between the neurons. This makes a vicinity principle active in the nervous system which uses gradients of diffusion which is not known in computer technology.

On the basis of this sketch it seems to be interesting to look for a general formula which preserves the relation of information processing and energy supply, supersign production in apoptotic information decay and preservation, vicinity and energy-dynamics-like causality into a general model.

The main aspect for such a formula is to look for the processes of intrusion of energetics into information processing. It is very difficult for an organism to give borders to energy processes in its information processing. Even the skin is no border for the autonomy of its informational processings. It is just the opposition of what intuition tells: Skin is not a border but the origin of most vehement energetic processes in the neurosystem because rhythmic stimulation gives a rise to strong (partially unspecific) arousal in nervous activity. Very often this is looked for because it gives a possibility for synchronizations, setting the basis for new time parameters in the nervous systems and therefore, giving rise to new codings between the neurons. Out of this reason. Therefore rhythmic stimulation as in emotional and sexual interaction is no release of energy in the usual sense but the giving of a new time course for information processing (which is only preliminarily described as “Verschiebung”). It is even possible by such interaction to “exchange” time and energy. Because information is dependent on the structure of time there is even exchange of information though not especially on the explicit level between individuals. The fact is that communication is time exchange (as long as it is not performed by technological time structures with control pacemakers) thereby giving rise to informational exchange (which not necessarily must be explicit but usually is even implicit).

6 Energy and Love

Only shortly we will touch the fact there are many possibilities for the nervous system to activate its own state. Many sources are at the borders or inter-faces between systems. This not only because new arrangements of time course have to be set up with interaction but also because there is a rich nervous supply at the interfaces. The nervous system even in the brain has many interfaces and some can artificially be put up at trying to structure the elements of activity according to group theory. The relation between the two hemispheres is only one of the possibilities, though one of the most strong and biologically to a certain degree performed possibilities. Other possibilities are the loose correlation between perception and cognition as is the case in face perception where the processing correlated to looking into one’s face cannot be described as continuous extrapolation of face perception but has to be described by the gap between cognition and perception. This is why Levinas says that with the face infinity starts. The biological basis for this lies in the gap between perception and the freedom of cognitive processes which are only loosely correlated to the external perception of one it is face perception. Because the cognitive process might get its energy out of the face and the gap to this face at the same time, in a deeper sense every face therefore is an interface.

The theory of surfaces as being interfaces has to look for the most strong energetic interface processor in the brain which is the amygdala which is the organ for making borders between individuals on the conceptional and emotional level. It is very hard to withstand the impression that the amygdala could be conceived as the organ which is the origin for all interfaces producing energies. The amygdala is able to give rise to flight and aggression and therefore to the most energetic activities of the organism. Of course on the neuronal level it therefore gives rise to most energetic spreading (general blood supply being granted). Out of the perspective of the amygdala love would be a process of coming narrow to the object. But this is an illusionary game(except for the exchange of time and energy and some loosely connected information).

7 Love and Universals

It is no wonder that the problem of universals was of great importance for the philosophy which was looking for will which had its greatest idea in the idea of love. So in a hidden way the discussion about universals is a discussion about love. I would like to resituate love in the context of the theory of universals and would like to promote a new cognitive model in which love is the process in which the individual is put into the energetically forceful processor of the universals. The identification of an individual with a universal is the processing of an individual as a universal.

In this concept love and knowledge are not separate systems but love is the very special (the individual oriented) processing with the system of universals (therefore angels are love because they are appearing as universals). It is good for love to know this relation of love and knowledge and it would be very bad to go to the root of those metaphors of bridges which are positioned on the amygdalian level to describe love. It is not necessary to go over the bridge and it is not necessary to enter an entrance but it is necessary to stand energies the of the amygdala. It is even more necessary to stand the energies which are activated when an individual is projected into the processors for universals. Of course taking an individual as a universal is a “category mistake” and therefore love is a kind of madness. But this madness is the appropriate disposition of a universal cognitive machine to have a relation to an individual.

8 Biophysics and Light.

On the way to a theory of the brain one has to ask oneself how far one is on the side of love and how far one makes universal processing without reference to an individual.

The great dream is to stand the energies of the amygdala and I think it is possible when we know more. On the way to this we may proceed to the degree to which we have love. But sometimes one of the both, love or knowledge may be in advance of the other. It is hard to wait for the second or stand one going first. But perhaps also this is a source of energy.

Perhaps it may help when we come to a theory of the soul and consciousness to think of the light as not only being in perception but sometimes even more in thinking, as a force which is in correlation to the electromagnetic activity of the brain. The mind-brain problem is so difficult for analysis because it is not possible experimentally to separate neuronal activity and the dimensions of mind. Therefore, biophysics is necessary to fill the gap. The proposed idea is that the light which is in the mind is in relation to the electromagnetic activity of the brain as are the quantum corpuscles in relation to the electromagnetic fields and their oscillations.

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The Interface Problem in Cognitive Psychology

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Introduction to the Problem

Cognitive psychology is a comparatively young discipline. Thinking and cognition have always been fields of interest genuine to psychology [1], with regard to the debate concerning the "first principles" of psychological research though concensus has rarely been achieved. During the long behaviorist era, for example, directly observable *behavior* constituted the scientific core of the discipline, and cognition, at best, was rendered a subject of dubious scientific standing. Computer science has not been subject to such ambivalence, provided that cognitive processes were conceptualized as the processing of symbolic tokens ready to be implemented on any material substrate (the computational premise of "physical symbol systems", [2]). Therefore, computer science and, especially, the research program of artificial intelligence (AI), were among the major driving forces concerned with the reintegration of cognition into scientific psychology in the 1960s. Since then, psychology to a great extent relied on AI research results [3], and psychologists were impressed by the projects of artificial intelligence engineers' to implement information processing in machines. This tendency, eventually, lead the mainstream of psychology to adopt a computational foundation for cognitive psychology, which is the computer metaphor of cognition [4].

During the last decade, however, computer scientists grew increasingly disenchanted with their approach towards intelligence. More and more unexpected problems surfaced, and none of the great expectations of AI could be realized [5]; and it is precisely those same problems that have handicapped the progress of cognitive psychology [6].

Thus, while psychology increasingly assumed a computationalist-perspective, computer science has, in a way, become more psychological, and has started to (re)consider concepts such as embodiment, semantic grounding of symbols and the various facets of the mind-body problem [7, 8].

Novel approaches to cognition and action, as a keynote, emphasize that complexity theory and dynamics may considerably facilitate the progress of cognitive science [9, 10]. The dynamical approach introduces the terminology and methods of dynamical systems theory in cognition research – using key concepts such as attractor, phase transition, etc. Complexity theory, especially the fields of self-organization theory and synergetics adds to this methodology by considering evolution, i.e. the emergence of patterns in open, complex systems. Order is considered to evolve from the cooperation, or from the "synergy" of microscopic components of a system [11]. The core question arising here is: how stable and adaptive can cognition and, consequently, behavior, growing out of the interaction between agent and environment, be? Or, rephrased in synergetic terms the interface between a complex open system and environmental control parameters, which leads to emergent pattern formation.

In this chapter, the problems that are faced by cognitive psychology as well as by computational cognitive science are outlined. These problems are grouped into problems of intentionality, problems of representation, and of stability, although the discussion will show that they are merely facets of a single underlying problem, namely an interface problem [12]. Consequently, a possible avenue to solve the interface problem is discussed, where it will be proposed that a solution can be assumed in a synergetic approach to cognition.

The Problems

Intentionality

There is little reasonable doubt that humans and animals are intentional systems. Systems of that kind construct goals, have intentions, wishes, and longing; in short, their behavior can be described as purposeful. By adopting Dennett's "intentional stance" [13] we achieve a descriptive code for human and animal behavior that is quite appropriate for and successful in forecasting the future behavior and action of intelligent agents. The intentional stance is analogous to the tradition of action psychology - explicit knowledge of an individual's wishes together with knowledge of the constraints imposed on the individual enable an observer to predict consequent intentions and the ensueing behavior of this individual [14, 15]. Such predictability is the foundation of folk psychology but also – in a refined version – of the expertise in professional psychotherapy and other applications of cognitive psychology. It must be noted, however, that whereas the intentional stance offers a convincing description of behavior, it fails to tell *why* intentions are formed, and *how* they are formed. The reason is that in order to predict behavior on the basis of the intentional stance, an insightful (i.e., intentional) observer is required who can understand the transformation of wishes into intentions and finally into action. It takes intentional cognition to anticipate the destiny of wishes. Thus, the very fundament of action psychology suffers from circularity and is at the risk of introducing a "homunculus". As soon as the intentional stance is adopted in order to *explain* intentional behavior (rather than just to serve as a shortcut descriptive terminology for intentional behavior), a tacit homunculus is formed. Psychology lacks explanatory (i.e. scientific) power as long as the intentionality of the observer remains unexplained.

Representation

Two sorts of representations have been distinguished by Clancey [16], once a proponent of computational (symbolic) AI. First, internal representations are transformations of perceived entities of the outside world into sensorimotor coordinations, i.e. into cognition. Second, external representations of entities of the outside world are signifyers such as signs, maps, written or spoken language that stand for these entities by pointing to them. Clancey observed that, quite habitually, the former, internal representations, are explained by the latter, as if cognitive internal representations were the same as "signs" or "maps". His subsequent diagnosis is that of a category error [17]: External representations, analogous to the intentional stance mentioned above, presuppose an intentional observer, one who can read signs and maps, and who can understand language. Internal representations, on the other hand, must not rely on an intentional observer; since they are hypothetical constructs to explain how an observer is in a position to "understand" in the first place. Thus, the notion of internal "mental maps" has no explanatory power.

As mentioned above, the physical symbol system hypothesis is the theoretical basis of computational AI. This hypothesis states that cognition can be understood as an interrelated network of symbolic tokens. A basic advantage of the physical symbol systems hypothesis is that such formal symbols can be implemented on any kind of substrate, e.g. in the brain or on a Turing computer. This abstraction, however, leaves open a crucial question unanswered, namely, how can the realm of computation (the syntax) be coupled to the meanings in the world outside (the semantics)?. This problem of the missing link between syntax and semantics has been called the symbol-grounding problem: "How can the meanings of the meaningless symbol tokens, manipulated solely on the basis of their (arbitrary) shapes, be grounded in anything but other meaningless symbols?" [18, p. 335].

Stability

The third group of well-known problems of the computationalist symbolic approach to cognition focusses on cognitive stability. In general, the Gestalt-like quality of perception as well as cognition is addressed here. For instance, we can recognize a chair in a diverse set of different stimulus arrays. Thus, the category "chair" is invariant with respect to many alterations of the physical properties of the input. This invariance is known in psychology as a Gestalt property (Fig. 1). The holistic quality of Gestalt perception is difficult to explain in computational terms. It certainly does not rest on a passive mapping of physical attributes into the mind, but it requires active processes of completion and construction. This problem is instrumental in the broad connectionist movement in contemporary cognitive science [19]. A symptom of the stability problem is the brittleness and fragility of actually implemented propositional systems, such as so-called expert systems. Any single new line of computational code can lead to the break-down of the whole system. In other words, the acquisition of new propositions, i.e., the extension of the knowledge base of the system is badly modeled by propositional clauses. The physical symbol systems perspective, in general, has not been capable of providing stable models of cognitive representation.

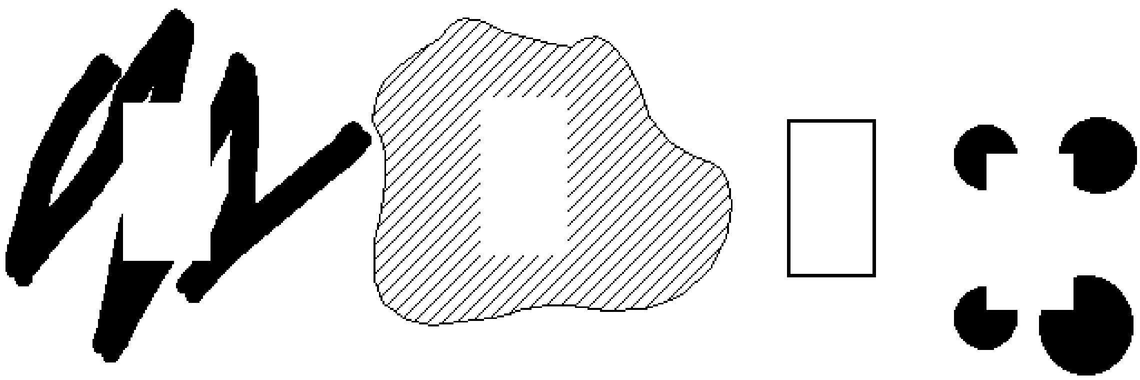

Figure 1: *Cognitive stability: the same rectangle is perceived in various stimulus arrays.*

Another serious problem of computationalist models of representation is encountered in the form of the frame problem [20]. Let us again suppose that the environment of an agent is represented in symbolic form (basically, by logical propositions). The world model of the agent must be complex, since the world is complex. Thus, the agent's keeping track of permanent changes in the environment leads to tremendous computational overload, as, in the world, any state, any single item can change at any time with implications unknown to the agent. As a consequence, the agent is forced to browse through all or most of the logical propositions that make up her world model in order to find out the implications of any, even if trivial, change. The result is combinatorial explosion that cannot be handled computationally. The importance of the frame problem has first been recognized in the very beginning of cognitive psychology. At the same time, some psychologists [21] deviated from the behaviorist mainstream by concepts such as the cognitive map. Their seemingly compelling argument was that animal learning (e.g. the classical rat that finds its way through a maze) could not be founded solely on simple stimulus-response associations but that it had to be based on representations of spatial relationships laid down in some sort of internal map. The frame problem, therefore, would affect Tolman's rat, as it is endowed with a propositional cognitive map: the rat would have to sit lost in thought at many crossings of the maze because of the mere number of cognitive computations necessary to come to even simple decisions. But we seldomly observe rats doing that.

An Interface Problem?

The three classes of problems outlined above are held to originate in just one problem, namely a problem of interfaces. The system of interest being the cognitive system, then we always deal with the connection of mind and world, and with the relationship between endo and exo [22, 23, 24] call for close examination.

With regard to intentionality, the intentionality problem may be stated as follows: how can we engineer or explain (exo) that which appears intentional in introspection (endo)? Thus, we search for an exo-point of view for the first-person's endo-experience.

The representation problem directly addresses the mind-world relationship (how is the world mapped into the mind?) as well as, more specifically, the endo-exo interface: how can symbolic representations be imbued with meaning?

Stability is a necessary property of representations, in whichever form they may exist. At the concrete level, stability is encountered as a problem of AI applications: how can symbolic representations deal with changes in the input? From a more fundamental perspective, we are confronted with the dilemma between flexibility and stability: how can a cognitive system "know" whether it is better to remain in some stable state A or to switch to stable state B? Stability, therefore, has to do with adaptation and optimality, which are crucial operations of the interface between mind and world.

Possible Avenues Towards Solutions to the Problems

Within the last decade, the discussion in cognitive science have provided possible ways out of this impasse of the interface problem. As suggested in the introduction, these ways may emerge in connection with the mechanism of self-organization of complex systems. But let us first look at the requirements that are placed on any remedy to the well-known problems listed above.

- A way out of the impasse of the intentionality problem must open up possibilities to proceed to a design stance or to a physical stance, and thereby to avoiding the pitfall of homunculi inside explanatory theory. Thus, we first claim that a (physical) theory of intentionality is possible on a scientific basis.

- Second, a solution to the representation problem must account for the coupling of world and mind and of endo and exo.

- Third, a prerequisite of a solution to the stability problem is the provision for asymptotically stable dynamics in the first place, as mere stability alone will not suffice, of course. Additionally, the model must include mechanisms that account for adaptation and optimality.

Can self-organization theory (synergetics) supply such a physical theory of intentionality? Although it is probably premature to answer this question in the affirmative, we have argued that synergetics, at least in a formal way, covers all listed requirements [10, 25]. Self-organization does not need an external agent because it describes the ability of various complex far-from-equilibrium systems to self-organize spontaneously. Thus, order and pattern evolve without any external homunculus. Moreover, it has also been shown that these self-organized patterns have the property of asymptotic stability; low-dimensional attractors of different kinds (fixed points, limit cycles, chaotic attractors) may emerge from the cooperation of components in a complex system. This synergetic approach to cognition is best illustrated by an example taken from perception.

Perception of Gestalts: an Example

Two sorts of general mechanisms can be distinguished with respect to stability. Piaget [26], a Swiss psychologist, termed these cognitive mechanisms accommodation and assimilation. Accommodation means the change of cognitive categories in accordance with environmental changes. The complementary mechanism, assimilation, stands for the phenomenon of cognition remaining unaltered in the face of actual changes in the stimuli that are offered.

Figure 2 provides an example for both principles. If the words in the left column are presented from the top to the bottom, subjects read "chaos" until the perceived gestalt abruptly switches to "order", say in cell 4. In other words, perception accommodates to the category "chaos" throughout the sequence of cells 1,2, and 3, until the category "order" is assimilated by the cognitive system in cell 4. This flip of Gestalts is symbolized by the metaphorical illustration in the right column of Fig. 2. The state of the system (i.e. the ball in the potential well symbolizing the respective attractor for the two patterns "chaos" and "order") changes from "chaos" to "order" after cell 3 whenever the presentation is started off in cell 1. The turning point, however, between the accommodative and the assimilative preponderance of the sequence is not symmetrical (hysteresis). The switch between the Gestalts usually occurs at a different point if the presentation is in the bottom-to-top. The stability of a system and the transition from accommodation to assimilation thus depend on the history of the system. Hysteresis is a fingerprint of nonlinearity - as is predicted by the synergetic approach [27] for systems where transitions between attractors occur. Additionally, the rapid switch into the second attractor does not have the 'flavor' of step-by-step computation; it is a catastrophic event [28], signaling the sudden reorganization of a complex system.

What is the interface in our example? The perceptual system is certainly "controlled" by the stimuli printed in the left column, but also by the history of past recognitions of stimuli. This history influences the probability of perceiving either "chaos" or "order" (in intentional terms, it changes the expectations of the subject). Further control parameters can be introduced that may also influence the perception of a stimulus. If, for some reason, a subject actively searches for chaos, she may recognize chaos in cell 3 even without previous presentation of cells 1 and 2. All of these influences effected by instructions and tasks etc. constitute the space of control parameters governing the response of the system. Picking up a thread from the history of psychology [29], the control parameters in psychological tasks are termed valences [24]. The valences of stimuli are the respective control parameters of the situation. Thus, the interface is given by the relationship between valences and the response of the complex cognitive system.

With respect to the two cognitive mechanisms of stability, accommodation and assimilation, one prominent question prevails which of the two functions will provide for the best fit in any

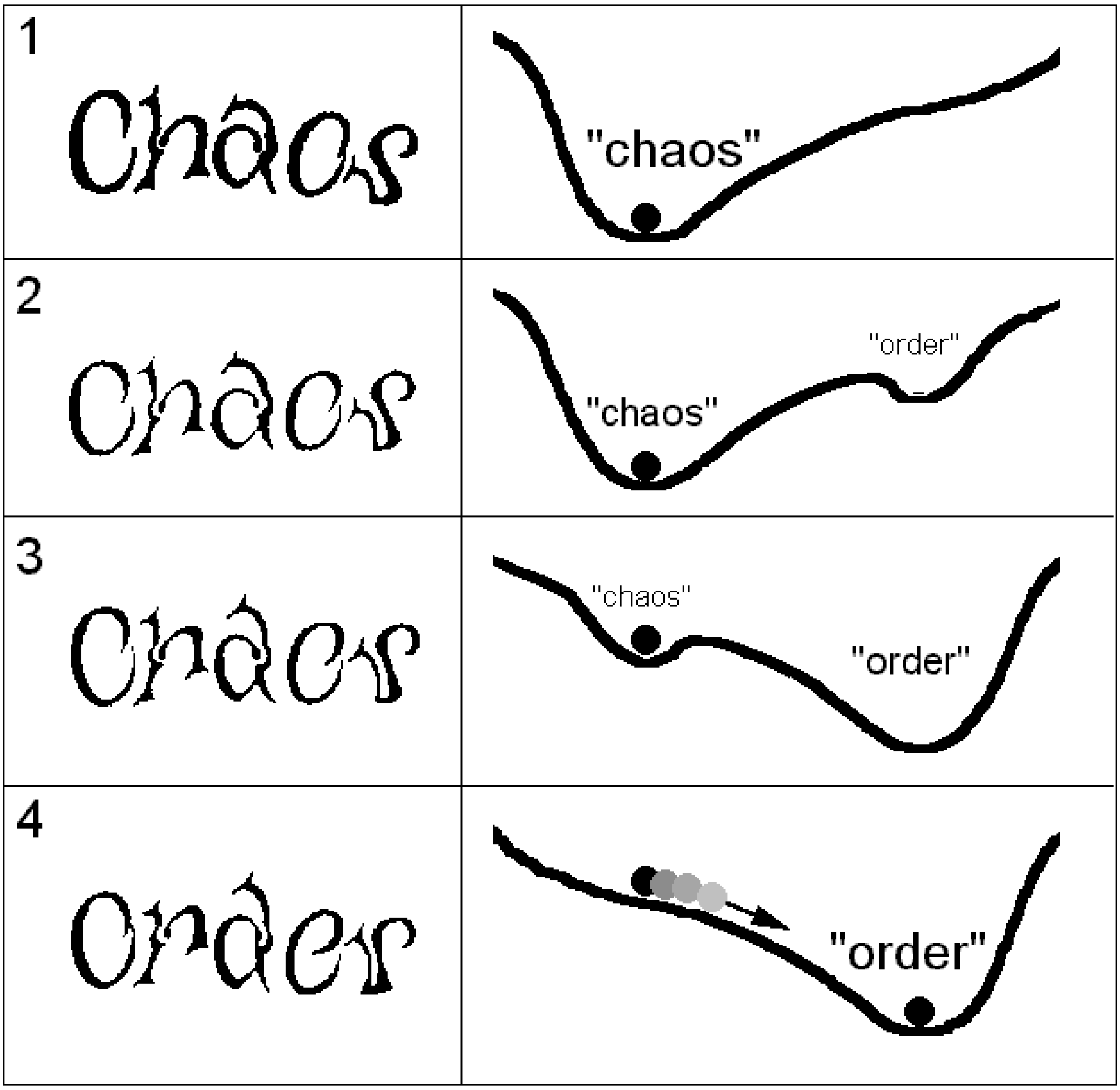

Figure 2: *An example for Gestalt perception (see text).*

given situation? This stability-flexibility trade-off, which is of frequent concern to AI engineers [5]. It points to the necessity of an optimizing principle. It is not sufficient for an AI system or cognitive system to be stable, it must be adaptive as well. Consequently, the stability of the system is to make sense in the ecological environment of the system.

The clue offered by synergetics is that the response of a complex system exposed to a set of control parameters is such an adaptive compromise. Given the set of valent constraints imposed on the system the most appropriate pattern (a "good Gestalt") is realized. The roots of the adaptive property of self-organized pattern formation can not be examined in detail in this chapter. In short, adaptivity can be based on a restated second law of thermodynamics [30, 31]. The control parameters are viewed as gradients that drive the system away from equilibrium. These gradients are countered by corresponding responses of the system such that the system acts towards a restitution of (thermodynamic) equilibrium. An appropriate measure for that process is entropy production [32]. The result is a synergetic mechanism of tension reduction in the service of optimality and adaptivity [24].

In this view, the concept of representation in cognitive psychology receives a novel connotation. We no longer need to suppose that representations are like mental maps read by some unknown cognitive mechanism. What is experienced in the endo-perspective as "representation" is actually the impact of valences, i.e. of non-equilibrium gradients (control parameters). This view is congruent with suggestions concerning the representation problem that have been put forward recently. One of these suggestions has been proposed as a guideline in a roboticist approach to cognition: Avoid internal representation as much as possible [33]. Brooks argued that a major portion of intelligent behavior can be modeled without the assumption of detailed world models, i.e. without explicit mental representation. This same reduction in the need for mental representation is found in a theory of ecological psychology, the theory of direct perception [34, 35]. The Gibsonian approach claims that in many situations there is simply no need for representation because valent information is already present in the environmental field in the form of "affordances"; all animals are adapted to this kind of information which is ready to be picked up directly from the environment. Thus, more direct ways of a coupling between world and mind, more immediate links between endo and exo can be expected. To summarise, the optimality of self-organizing systems rests on the interface of the cognitive system and its control parameters, which is the valent environment. This interface, the coupling of cognition and valences, is immediate and direct. An exo-theory of the interface may be developed starting from principles of synergetics [36] which does not require a medium such as the "conscious representation" of introspective experience.

Discussion

Synergetics is basically a micro-macro theory – patterns are macro phenomena evolving from a complex microscopic substrate. This produces open questions. What are the micro-components of the self-organizing cognitive system like? Are they observable? Maybe the micro-components can be conceptualized as simple perception-action primitives, but at this moment they are still largely hypothetical constructs (much as the stimulus-response associations of behaviorism). It may be noted that the synergetic approach resembles the approach of behavior-based cognitive science in several respects. Cognition obviously needs behavior. Examples for that abound, such as epistemic action, i.e. action performed in order to think [37]. Quite often perception, cognition, and action cannot be differentiated clearly [38]. In accordance with this observation, Thelen et al. [39] claim that "one currency" exists throughout the cognitive system.

The view sketched in this chapter is a possible interpretation of synergetics as a behavior-based theory of cognitive agency. It is an attempt at explaining intentionality by a scientific theory [40]. One may notice the dilemma that this exo-approach does not really meet with our subjective, qualitative experience. We certainly are equipped with the introspective experience of using mental maps and inner images. Our mental worlds look, feel and taste like real – how can theory say that internal representation of this kind is not necessary, nor may even be effective? Additionally, there is perception in the absence of stimulation, in psychopathological states such as hallucinations as well as in everyday remembering and day-dreaming. Are these processes just cognitive luxury?

The view that qualia are merely epiphenomena, that they have no evolutionary effect [41] appears strange. The study of consciousness has been receiving supreme attention within the cognitive science discussion of the last decade, often on the background of self-organization theory. Yet, the impression prevails that the subject is evanescent.

If a theory of cognition, however, does not succeed in integrating the endo-perspective with exo-theory, it will not be successful in the long run. In the history of psychology, this has happened repeatedly. Research programs have vanished even though they were neither falsified nor exhausted. Behavior-based psychology and Gestalt psychology, notably from opposite poles of the psychological spectrum, are good examples for that process. Therefore, a large effort of cognitive science based on self-organization is still on the agenda – the integration of endo and exo still remains to be accomplished.

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The NeuroLoop: Biofeedback Interfaces and Structural Mode Interactions as an Approach to Introspective Sciences and Neuroaesthetics

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1 Introduction

My contribution about interactionism of matter and sense is understood to be of programmatic and prospective character dealing with the complementarity of a structural an dynamical approach to semantic and symbolic communication. Within the framework of cognitive science, neuroscience, psychophysics, philosophy, aesthetics and virtual reality we will focus on applicable phenomenological theories of representation and reference.

Searching for explicit methodologies for implicit processes we will present our operational and interactive concept of the "NeuroLoop" utilizing specified Psychophysical Interface Devices. These must facilitate both, individual and concrete dynamical actualization and subjective experience, as well as a general and abstract description of the objective structural potentiality of complex psychophysical states. This will also lead to a new kind of experimental approach instead of the common manner of stimulus-response investigations.

Dealing with the general issue of perception we are faced with the complex problem of an human observer. Among all the variants of human observers which may appear we would like to begin in a metaphoric way with a literary quotation from a poetic point of view. From that Grillparzer gives us a very rough distinction between three main classes of human observers: "The ignorant observer will everywhere see the isolated case, the half-educated observer will see the rule and the educated observer will see the exception". Also within the different sensory pathways of any sensory system we will find some functionalities which may be classed as "ignorant" observers, obviously at the very lowest level of primary receptor processes, which also may be described as "trivial machines". Due to the higher levels we will estimate more advanced and specifically generalized "half-educated" observers, which commonly may be described as "non-trivial" machines and which are for the most part provided in a modular manner. According to perceptive respectively cognitive processes a variety of cortical specificly educated observers may be identified, providing syntactical, pragmatical and semantical information processing in a very distributed way which will lead to a neurosemiotic approach employing linguistic concepts.

Within the framework of Neuroscience, Sensory Physiology and Cognition Sciences dealing with perception at higher levels of observation and interpretation, such as information theories are mainly derived from an engineering notion of a computational model. But extended information theories must cover more than only syntactical aspects and must therefore include also pragmatic and semantic aspects of information. But even qualitative definitions or operational methods and measurements of semantic information are difficult to find.

In order to develop appropriate methodologies and technologies for observing various specified observers at different levels of perception, we want to emphasize at this point that the notion of perception is understood to be more general than computation. Therefore let us primarily look onto the issue of perception in terms of structure and dynamics with ensuing computation and engineering.

Depending on the specific view different research areas on the issue of perception are basically related to an interface problem such as the mind-matter, mind-body or mind-brain problem, expressing the relationship between material and mental properties which will always arise together.

Therefore we want both to distinguish and unify the different aspects of reality as mind-matter-correlations now from this particular viewpoint of the interface, which will differ from the usual view of a linear and causal relationship. After that we would make several attempts for an experimental and technological approach which is furtheron stated as the "NeuroLoop" concept.

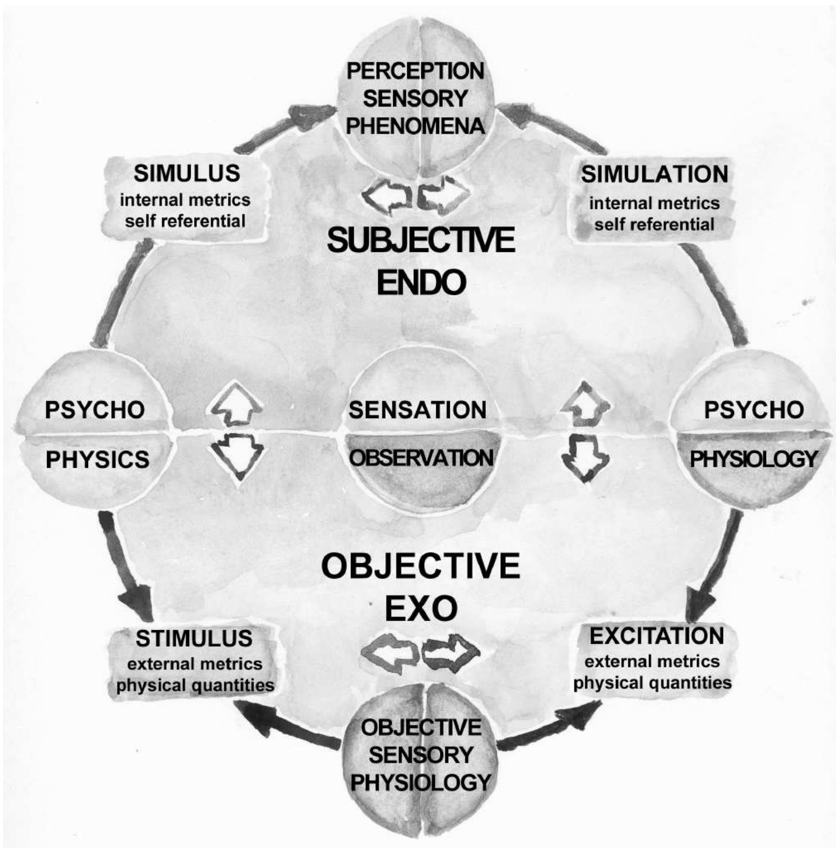


Figure 1:

2 Psychophysical Observers and Interfaces

Figure 1 gives you a synopsis of different common research areas on the issue of perception now being related to the viewpoint of various psychophysical observers.

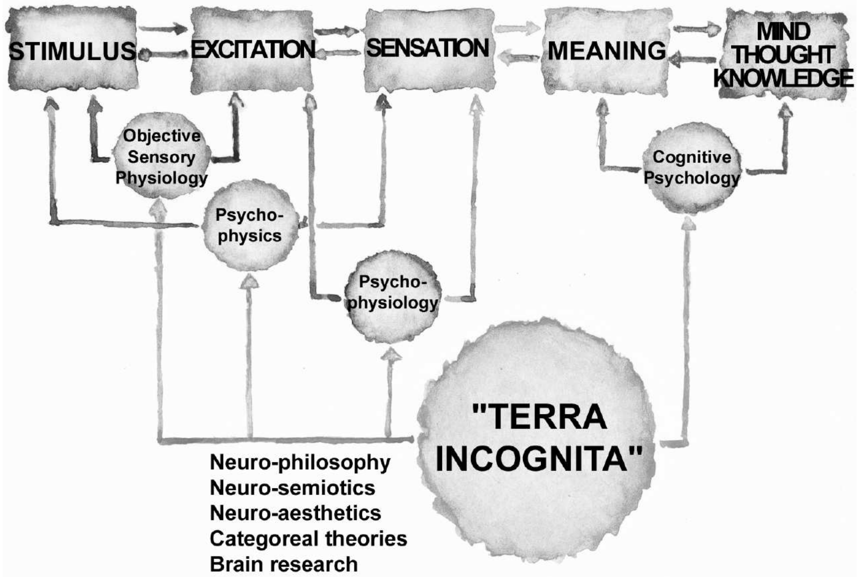


Figure 2:

1. Hereby all sensory phenomena through all sense modalities as perceived as specified mental properties and provided by the subjects internal interactions are inevitably self referential. Empirical methods investigating subjective sensation are therefore restricted to the subject's internal metrics.

2. Within the research area of psychophysics internal mental sensation is directly related to the external physical quantities of the stimulus. Hereby psychophysical interactions may be investigated by means of various psychophysical-interface-concepts.

3. Mind-body and mind-brain-interactions are situated in the domain of psychophysiology, interfacing between implicit sensory phenomena and various physiological processes, which may be objectively and explicitely measured as correlated and covariant physiological parameters.

4. Finally objective sensory physiology is connected with both external features which will constitute an interface between explicit physical stimuli and physiological processes accessible to external physical measurements.

Empirical human perception research is therefore in a most priviledged situation, because it may utilize and combine various types of the different interfaces due to each one of the four concepts mentioned above. This will lead to a more complete epistemological approach. During sensation also sensory phenomena will be perceived and experienced in parallel to the objective measurements. Hereby an epistemological and ontological approach is facilitated simultaneously. Therefrom it seems to be possible that also some primordial philosophical and aesthetical questions in the context of the mind-matter-problem may be treated empirically. Concerning how philosophical and aesthetical concepts could be engineered, we are looking for appliable and adaequate theoretical models as well as for neurotechnological methods in order to design various specified psychophysical interfaces including both, theoretical abstraction and subjective experiences due to a single or to multiple sense modalities.

First of all I would give you a basic example for a typical $\psi\phi$-observer on the issue of color perception. For instance a physical radiant energy of $\lambda = 500nm$ wavelength leads to the visual sensation of green color but only for the normal sighted human observer. The notion of color may be defined as that aspect of visual perception by which an human observer may distinguish differences between two structure-free fields of view of the same size and shape, such as may be caused by differences in the spectral composition of the radiant energy (ϕ) concerned in the observation (ψ). It should be noted that a pure color stimulus is restricted only to the physical property of radiant power of a given magnitude and spectral composition of the radiant power entering the eye and producing a sensation of color whereby all other physical properties beyond that restriction such as structure and dynamics, size and shape are excluded by definition. Nevertheless real life visual stimuli will even exhibit versatile physical properties with a high degree of chromatic-, structural- and dynamic-complexity. Thus every perceivable phenomenon which is not forbidden by physical laws will definitely occur within a natural sensory stimulus.

But even if a psychophysical observer will only perceive a single and pure color let's say "green" he may interprete this "green" in a manyfold and arbitrary manner such as a "traffic light", where "green" means "to go" or as the "green" of a "plant", "leaf", "fruit" which means "unripe" and furthermore it might be associated with a an "immature" state or behaviour of a person and so on. Our cognitive observer may therefore create any kind of derivative meanings which primarily have been evoked just by this specific physical radiant energy. Again we are faced with the frame problem of perception as well as with the various intermediating interfaces between sensation and cognition as shown in the synopsis of Fig. 2. It must be pointed out, that the notion of the interface implies also interaction from higher hierarchic levels of information processing, from its semantic content, intentionality or knowledge, down to the various subsystems which will lead to variances or instabilities of sensation in a recursive way.

So let us first start in a bottom up fashion with an experimental psychophysical approach to the $\psi\phi$-interface problem as shown in Fig. 3. Commonly such investigations are dealing with a causal relationship between several specific physical quantities of the stimulus and various observers responding to that stimulus at different levels of the sensory pathway, whereby an objective response may be obtained by means of various sensors and physiological recording techniques. These so called objective psychophysiological methods and measurement conditions are usually guided from the viewpoint of linear system theory.

Otherwise so called subjective psychophysical methods are related to the observer's subjective judgements of thresholds or small differences that he may perceive according to differences of the applied physical stimulus. In other words: The general questions adressed to the observer "What do you see?" or "What do you hear?" or "What do you feel?" cannot be answered at all. If we therefore will restrict our question to "How do you see or hear or feel?" we may have an oportunity to simulate and thereby communicate the sensorial appearance of the alikeness of a well specified stimulus according to the judgements of different individual observers which will be seen as deviations to a reference observer classified as the normal or standard observer. This kind of psychophysical approach is commonly based on the very simplified question "Do you see, hear or feel?" and this will lead to psychophysical methods in determining sensory thresholds. The otherwise question: "Do these two stimuli appear alike?" will lead to the determination of a balance or match depending on the observers subjective judgements.

In this first instance with specifying numerically the quantities of a well defined psychophysical stimulus in such a matter, that when observed by a so called normal observer or the same observer under the same observing conditions, stimuli with the same physical specifications will appear alike or equivalent. Also the symmetric notion will hold that stimuli that appear alike within an observer must have the same physical specifications and the numbers comprising the

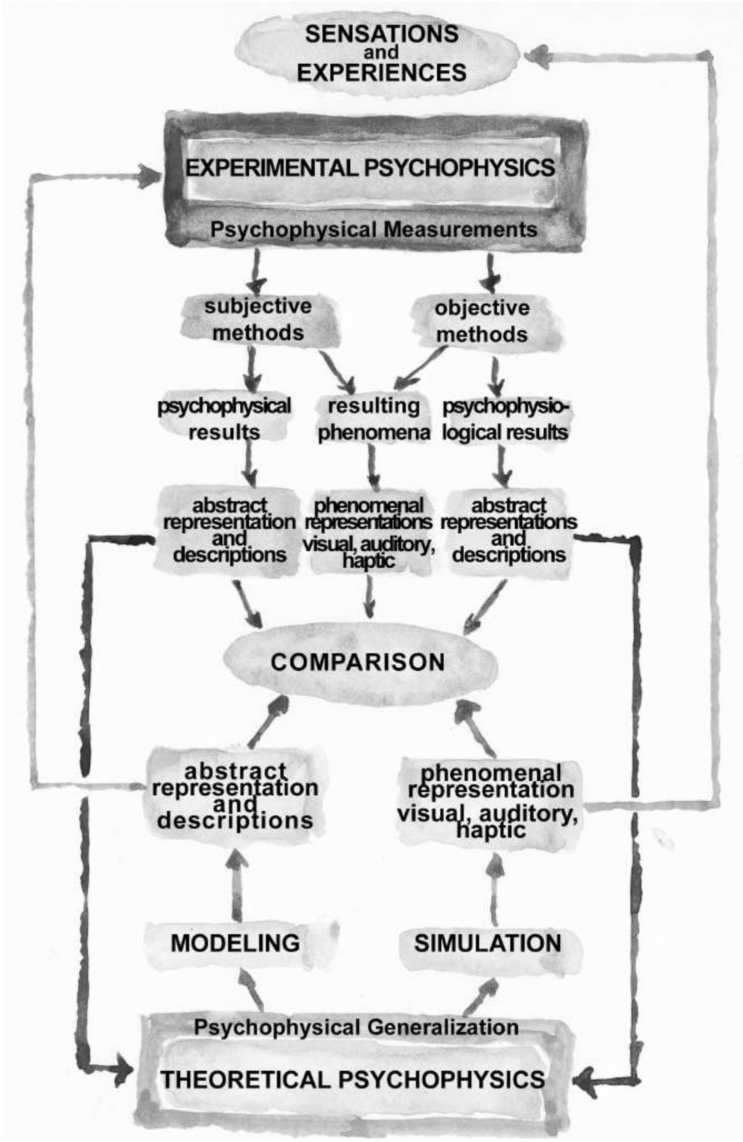


Figure 3:

specification are continuous functions of the physical parameters defining the physical properties of the stimulus. By thus experimental laws of matching may be summed up in an empirical generalization which provides the foundation of any system of psychophysical measurement.

As you can see from Fig. 4 (upper part) such psychophysical methods which are based on the underlying model of system theory are suitable for the determination of specific characteristic curves due to the selected physical parameter P_i and due to the investigated sensory pathway. For example the visual stimulus parameters P_i could be of spectral (λ), spatial (r) or temporal (t) nature. Under the condition that the so measured characteristic curves would exhibit a causal and unambiguous relationship as well as univariant features according to the parameter P_i one might derive specificly related partial relative sensitivity curves for the chosen parameter by means of a suitable constant action criterion. Hence that psychophysical measurement of the partial relative sensitivity functions $S_{rel}(P_i)$ for any selected parameter P_i will tell you how selected features of sensory information will be independently processed within the investigated section of arbitrary sensory pathway which has been derived from any individual subject per-

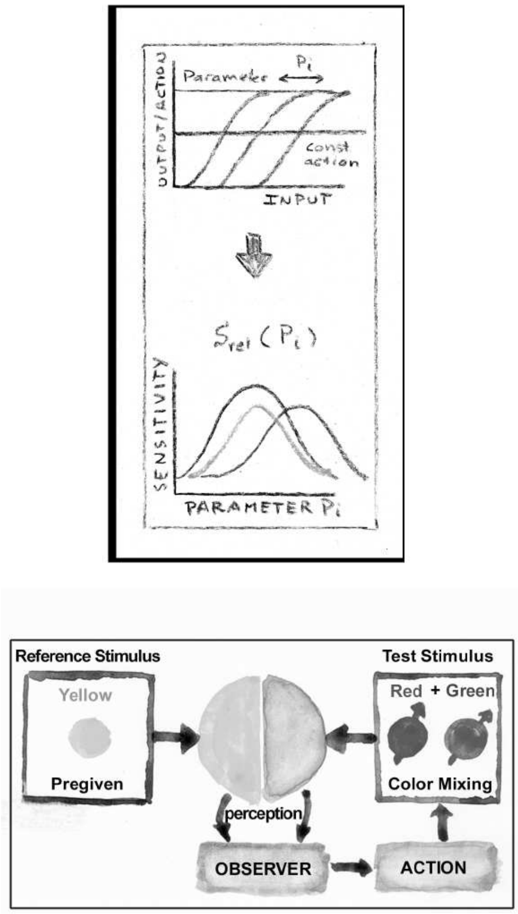


Figure 4:

ceiving a given set of stimuli under the given conditions. Thereby the average interindividual behavior of a collective group is classified and comprised as a reference which is described as the normal or standard observer. Against that any deviations related to this reference will be denoted as abnormal or altered perception. Due to the fact that a subjects internal sensory information processing features can thereby be made explicit will lead to the possibility that any measurable individual perceptive system behavior may as well be simulated by means of an artificial signal processing system and again be applied back to the observation. Thus a normal observer now may also perceive and experience some aspects of deviant perception either related to a collective normal reference or to his own foregoing reference which may have been substituted as a consequence of his internal adaptivity or instability. However for the alterated, pseudonormal or specificly adapted observer the simulation of normal perceptual features will appear as abnormal and vice versa. It should be pointed out that by means of psychophysical simulation some processual aspects of any observers perception now may be communicable also at a phenomenological level among many different observers as it may be fed back to an observers own observation. This outstanding feature will give rise to an interactive and immersive approach to an introspective view onto perception by means of a psychophysical interface employing some methods of psychophysical measurements and medial simulations in order to achieve some types of immersive perception action loops.

3 A processual view onto color

As an example for the underlying principle and the ability of this $\psi\phi$-interface concept we would like to stress this extended interactive view first of all onto the context of color perception and color measurement as given by the recent method of colorimetry. As we will see that colorimetric approach already includes the concept of an perception-action-loop but in a very implicit and restricted manner. Our proposed operational and dynamic viewpoint onto colorimetry as anticipated as an interface and interactive information processing system is up to now not within the range of the CIE colorimetric system which comprises the essential standards and procedures of color measurement.

Even if we again cannot answer the question: "What is color?" or "Which color do you see?" we nevertheless may colorimetricly define the notion of color in a more simple manner namely in a psychophysical sense as a physical characteristic of a visible radiant power by which an observer may distinguish differences between two homogeneous color fields of the same size and shape, such it may be caused only by differences in the spectral composition of the radiant power concerned in the observation. By this definition a color stimulus may thus be denoted as a well defined physical property such as a radiant power of a given magnitude and spectral composition entering the human observers eye and producing a sensation of light and color, whereby psychophysical color is specified by the tristimulus values of the radiant power (color stimulus). So called primary color stimuli are specified color stimuli by whose additional mixture nearly all other color stimuli may be completely matched in color.

Or more commonly speaking about the principle of the psychophysical intention and approach: Even if you do not understand color but let everybody play with colors in an interactive manner according to the same model and laws while using the same rules of composition and observe all these plays and show them to the other players and try to classify the players.

One of the most simple games based on the trichromatic generalization is shown in Fig.4 (lower part) denoted as the Nagel-Anomaloscope. It now appears to us as a manifestation of a psychophysical interface with an human observer as a constitutional part of a perception–action–loop, playing the game of color composition in order to reach the goal of color matching. This scenario leads to both an explicit description as well as to an implicit experience when the observer takes part in the game. Or more detailed, Nagel's game simply consists in color matching tasks of two visual color stimuli typically presented in the two halves of a bipartite visual field and in the judgement of similarities and degree of difference (deviation) between these two stimuli. Within this very restricted and limited case of a bistimulus matching procedure the observer should act by means of a specified user platform containing two regulators in order to match a pregiven reference color (yellow) with his mixture of the two primary stimuli (red and green) for achieving the same color (yellow) as seen from the reference. By this psychophysical terms of color will thereby specify numerically the color of a physically defined visual stimulus in such a manner that stimuli with the same physical specifications will look alike. But this holds only for the same observer when viewed under the same observing conditions.

Generally speaking, even this very restricted psychophysical interface concept will allow to get a more complete view onto the nature of color namely in an epistemological and ontological sense, where the concepts and terms employed in this specific case of colorimetry are bound up with the trichromatic generalization, since it applies an externalized manifestation of a common theoretical model. At this point of the model chromaticity coordinates of any color stimulus can be explicitly determined and represented in an abstract manner by vectors in a tristimulus space as well as by a formulation of basic colorimetric equations and transformations which will lead to a theoretical as well as an empirical treatment of the color interface. The individual color observer's color-matching results obtained by means of this interface are required for further calculations and/or simulations. By this procedural view several inherent primordial features of our psychophysical interface concept may already be demonstrated and will now be summarized: By means of perception-action closed loop procedures, wherein an individual subject is involved who is simply tuning an additive mixture of primary color stimuli in order to match a variable test stimulus to a given reference stimulus the processing and matching procedure results in:

1. a numerically specified quantitative method
2. a representatation in an abstract manner within a color space
3. a method to communicate respectively simulate in an abstract theoretical as well as in a perceivable phenomenological manner in terms of the observer's composition of his actual color match
4. a subjective experience about how individual or interindividual deviations and alterations may look like when shown as visual phenomena to various observers.

According to the latter point we are also faced with pronounced (aha!) or unusual experiences accompanied with the mentioned reference problem of perception. For example, if an individual observer will look at the result of a color match of another observer it will either appear matched as well or it will appear as not appreciable and vice versa.

For making an invariant reference a hypothetical ideal or average normal observer is regarded and classed as normal. Anomaly is thereby constituted as a deviation from the average and commonly denoted as perceptual aberrations or defectives. As in ordinary judgements if someone appears to be in contrast to the average people it is commonly stated that something must be wrong with him. Alterated perception which is implicit is thereby made perceivable to the others as from the degree of difference which can be seen from the production of alterated and explicitely represented phenomena. These may either be produced by the matches of versatile subjects or by adaptive matches of substitutional internal changes within an individual observer during his perception-action scenario or by means of a simulation based on diverse empirical data and calculations according to the underlying theoretical model which has been established from empirical generalization.

4 Generalization of the Psychophysical Interface principle

At this point we would like to work out the domain of further applications derived from the general psychophysical interface concept primarily under the viewpoint of its processual features and first of all within this specifically limited but as well exemplaric case of an interactive approach to the issue of color perception and after that we will go to an increased generality of perception extended to its spatial and temporal aspects. Then we will admit this basic concept of $\psi\phi$-interfaces to possible investigations and to the practical opinion questioning how these several kinds of manifestations may be engineered.

As shown in Fig. 5 we can utilize a basic model of colorimetry and try to operate its equations in a constructive manner by:

1. making a stimulus generator which basic hardware mainly consists of an externally tunable mixing device superimposing two or three different specified spectral radiant power sources each with a unique spectral composition.

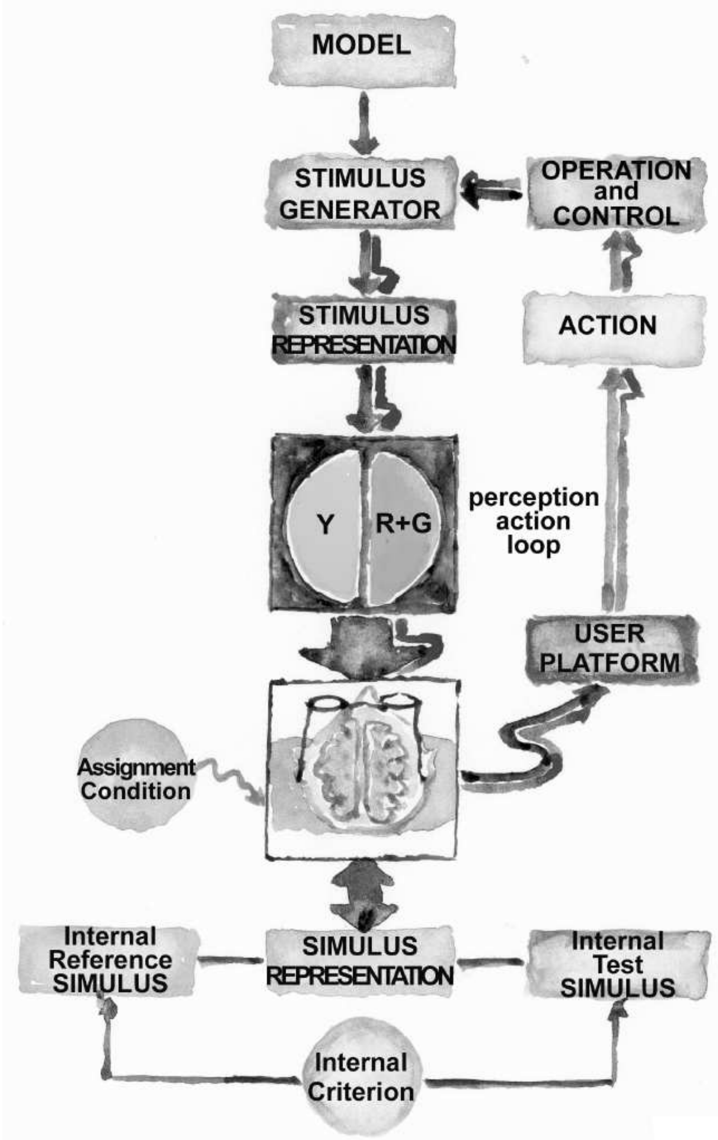


Figure 5:

2. establishing an appropriate visual stimulus representation in a well defined way with respect to the same specified observing conditions (i.e., typically presented as a bipartite visual color field or by means of consecutive color field substitution).

3. installing an appropriate user platform in a way that an interacting subject may operate the perception-action-manoeuvre in an optimized fashion to the pregiven assignment condition and action-criterion (i.e., color match as equivalence of appearance). The operating features and chosen controllers which will actualize the test stimulus generation in a recursive way is executed by means of specified feedback loops, performing an immersive perception-action circle.

4. Several further experimental methods may be found for utilizing different principles of controlling an adaptive fit with also inserting different kinds of action criteria (i.e. tolerance criteria as a weaker criterion than equivalence, or implementation of the dynamic properties of the iterative matching procedure).

5. introducing additional different uniquely specified parallel observations from both a theoretical and phenomenological aspect undergoing a comparative and correlational analysis.

Obviously the internal counterpart due to the comprised notion of an external "stimulus" with its various phenomenological representations is furtheron denoted as the "simulus" including its internal mental or neuronal representations. Internal simulation is also comprising the capability, ability and competence of the human observer. By means of a perception–action–loop any external stimulus and internal simulus may actually be matched within the perceptual process.

A more general and common description of our proposed $\psi\phi$-interface concerning any sense modality is grounded in the said very basic concept namely that such specifiable stimulus valences of a given sensory stimulus which will appear as externally controllable variables as derived from an underlying theoretical or empirically generalizable model. They must be operated and actualized in real time and such stimuli will guide the immersive observer to specific perception related actions and these stimuli are themselves specifically changed by the observers response by means of unique perception–action–loops, designed upon the properties of the implemented model.

Within the framework of visual perception our previous example about colorimetry which was grounded in a trichromatic generalization-model is of course very restricted by its own definition. Other aspects of visual information had therefore to be ignored or intentionally left out, especially the aspects of structure and dynamics as well as the issue of adaptivity and contextuality. Therefore we would propose an extended concept for $\psi\phi$-interface design denoted as the NeuroLoop and then we should look towards possible implementations of structural and dynamical features to our interface approach, which would open the road towards some new kind of investigations.

For practical applications and further psychophysical investigations the NeuroLoop instrumentation must be designed with respect to temporal as well as to spatial features onto variant space-time-scales. Basically such a hybrid instrument must consist of well suited complex pattern generators forming an adequate visual, auditory or/and haptic stimulus perceived by the recipient who will be connected to a multi-sensor biofeedback interface which also exhibits the features of recursive control of dynamic and structural order of the stimulus pattern. This recursive zone of interactivity may be expressed more briefly such as event related activity from the brain and body will be evoked by activity related events from the stimulus and vice versa.

Within a psychophysical human–machine–interface the implemented recipient acting in this self-referential scenario is able to play coherently only when he is producing the same constraints which inform him what kind of representation will be relevant in the next moment. These consistent relations among the processing contributors and elements become coherent relations. Our concept is also bearing several philosophical and aesthetical implications with respect to the synchronic emergence of entities which will be demonstrated in Figs. 10–13.

Fig. 6 will give you a synoptic view of the NeuroLoop concept which is based on a chosen theoretical model on the issue of structure and dynamics and which must be operated in order to form suitable complex pattern generators. It must also be deliberated that in contrast to the usual manner in designing various forms of stimulus generators made for conventional neurophysiological investigations are using storage of data based processes and let the experimentee response or make choice on stored data, must be contradictory and useless within the framework of our $\psi\phi$-interface concept. This is not only because the preparation of infinite set of specified stimulus representations will be practically impossible. Furthermore an infinite set of specific phenomena could not always cover all the possible phenomena according to the self-organizational capabilities of the underlying generating model and its stimulus valences

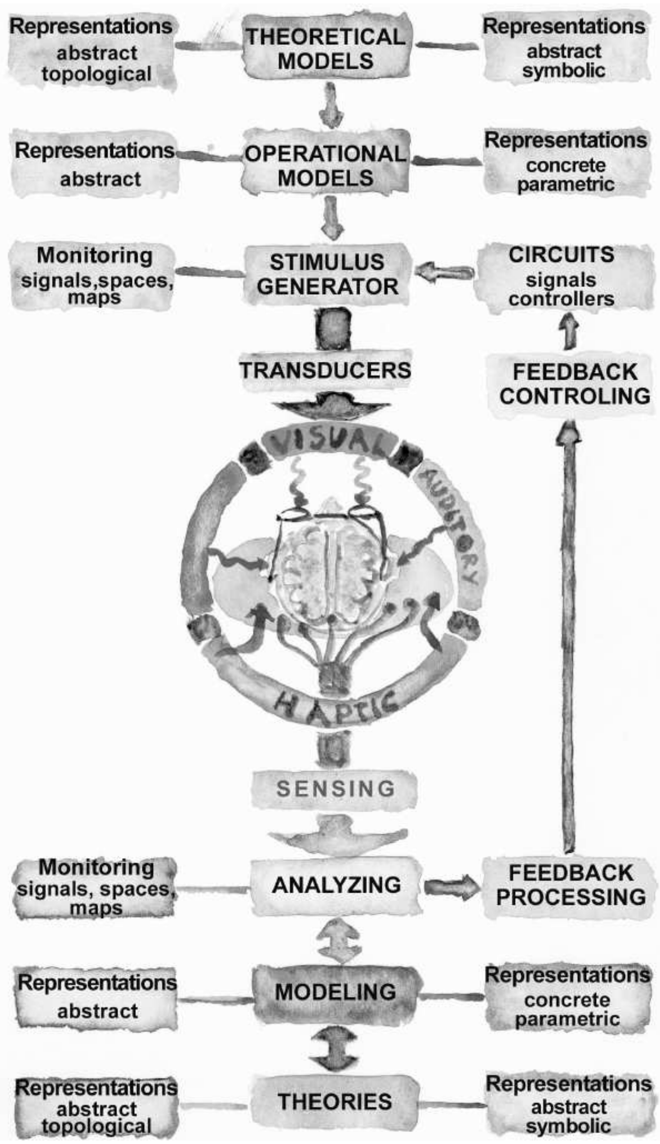


Figure 6:

which in principle are indefinite. It will therefore be the common feature of the complex embodied stimulus–simulus interactivity which includes the ability for extrapolative discovery of the actual suitable external stimulus pattern by generating an internal simulus which is able to give appropriate functions and meanings to the entities emerging within the NeuroLoop scenario. On this occasion it also must be emphasized that for any arbitrary structured or patterned phenomena a generative view onto structures and forms is proposed which is settled beyond pure topology. Morphology is therefore understood as actualized terms in morphogenesis as a spatial expression of temporal symmetries. (For further connotations you may look at Nottale's contribution on scale space relativity and scale laws, page 38). Structure- or pattern-generation processes are grounded on specific rules and operated in a recursive and iterative manner. Therefore even complex patterns are based on simple generative rules which may be animated in order to perform a covariant dynamic pattern development. By this methodology structured phenomena are therefore not encoded and treated in the classical and explicit manner with respect to the pattern or image itself but merely from the implicit rule of the generator together with the initiator. The actual pattern evolution will emerge therefrom by recursive feedback operations. (Some extended models like on the basis of the collage theorem may employ three different models within an Iterated Function System IFS like terrain-, evolution- and stochastic models.)

That means engineering of loop controlled stimulus generators must be based on sufficient theoretical and operational models and must contain intelligent autonomeous agent interaction which is grounded in the self-organizational capabilities of the hybrid NeuroLoop system.

Further extensions of that closed loop approach should also introduce some specified environmental activities as from external sources (i.e. noise sources). Two different fundamental concepts for making stimulus generators may be employed serving for various purposes.

a. The one is designed as for making a variable and tunable stimulator which permits a parametric control or manipulation of some distincted stimulus valences which in principle must have a causal drive as well as an internal stability and will lead to a controllable and reproducable invariant stimulus behaviour. Hereby several models of linear system theory and control theory will be operated commonly in a modular and algorithmic manner in order to achieve an adaptive fit of the variant stimulus. (I.e. the varied parameters can be of spatiotemporal nature with its related spectral parameters or interference-, modulation-, contrast-parameters or mixing ratios, composition values, combinatoric relations, multi-scale-analysis and multi-scale-resynthesis as given from wavelet transform.)

   The phenomena will appear as a metamorphosis of stationary objects which will causally depend on various selected drive- or control signals. These types of stimulators were mainly used so far for our biomedical applications and will be shown later on.

b. The other intention is to make a generic type of stimulator determined by the inherent multistability of non-linear-system's dynamics which are designed for the realization of non-stationary stimuli moving in space-time and showing changes of structural order as dynamic pattern generators. The stimulus generators are altogether grounded on a specificly chosen nonlinear dynamic system exhibiting chaotic states as they will be started there from and will be dynamically controlled in its structural conformation by means of an human observer's perception-action manoeuvre. Such systems with delay-induced instabilities will show an extensive pattern generative potential as well as the characteristics of exhibiting classifiable instabilities and the features of chaos control. Thereby it is maintained that one may externally stabilize multiple stimulus trajectories by small adaptive interventions and that will force the system to a distinctive attractor. This can be realized by means of minimal drive signals where its adaptive control is performed by the several means of the perception action-loop, by which also the covariant perceptual attraction is adaptively stabilized. Hereby the offspring of the perception-related action from the human observer may also be voluntary, involuntary, spontaneous or by means of a specific reflex action. That is because the stimulus and simulus will constitute each other while an observer as well as the observed object will generate a morphism. Thus multiple structures may remain stable for the characteristic time sequence of the attractor's life time and decay or change under specifiable feedback drive conditions.

   According to the operated model of non-linear system dynamics this type of stimulus generation will lead to a morphogenetic type of perceivable phenomena which also will include the intrinsic features of selectivity which is constituted by the perception-action loop in actualizing a particular context of the whole in a deductive interference manner.

The versatile states of that self-referential psychophysical-system will appear due to an "adaptive morphogenetic fit" whereby the interfacing system will make structure and also give the actual and appropriate meaning to its structure providing semantic information by means of versatile "ordered erratic matches". This procedure can be viewed as a structural analogon to the adaptive color fit and color match in colorimetry which was merely restricted to the notion of color as already shown before.

This approach implies in fact a construction of a very private, generative and sensitive stimulating environment for the embodied human observer which inherently contains an actualized real time animation of the phenomenological representations as allowed by the capability of the underlying operated model. That means that the stimulus generating process due to the selected and settled phenomenological theory may be formulated by mathematical descriptions. We will therefore have the possibility and the choice in interfacing alternative confined universes as alternative parallel worlds which may be applied and operated either by virtual simulations or as specified physical embodiments of the chosen model for that particular $\psi\phi$-universe. For this several different models may serve as a grounding for the $\psi\phi$-interface design such as synergetics, fractal geometry, fractal space-time generalization, cellular automata, genetic algorithms, topological models, fuzzy set and fuzzy control, artificial neural networks, neuro-fuzzy etc. which will give rise to derivated phenomenological theories (this is because the particular subsystems are not known).

According to the aspect of fractal space-time with respect to Nottale's contribution (page 38, defining motion as scalespace states of an inherent reference system another type of fractal simulus generators may be designed which are controlled by external variables and wherein resolution is treated as a variable. Nottale's approach beyond scale invariance will lead to fractal objects serving as a stimulus which might hold for similar scale laws as for the simulus. For this speculative expectation we have already found some evidence from our neurophysiological findings from investigations at various levels of sensory systems. Our future perspective in that direction is to make scale law based stimulators which should imply non-linear scale laws and scale-motion coupling and for making an attempt at further experimental NeuroLoop investigations under the view that specified states of scale and covariant stimulus-simulus behaviour will appear as reference frame transforms.

Once we would like to summarize the recent state of the art at its general view: Create any selected and confined private $\psi\phi$-universe being either of pure physical nature or artificially simulated and which will exhibit perceivable phenomenological representations to the feedback-coupled observer under immersive conditions by means of a perception-action loop interfacing the observer's individual subjective internal categoreal simulus representations to the stimulus which includes the opportunity that various mathematical models and physical embodiments will be at the disposal of the investigator.

For practicable interface solutions several well suited transducers must be employed which should transform the generated stimulus into perceivable phenomena due to the different sense modalities in order to perform a visual-, auditory and/ or haptic stimulating universe embedding the subject. Our proposed setup constitutes in fact a very specified, restricted and sensitive autistic universe. The advantage gained therefrom is that this universe may be governed in a theoretical manner by fundamental laws and may be supervised by a demiurge. By means of a perception–action–loop the structural and dynamic options are provided by the valences of the stimulus and they are perceived by the subject from the ongoing stimulus representation and depleted by the recipient's action seamlessly and in real time. For this purpose various well suited sensing devices may be applied responding from different parts of the central nervous system and from other psychophysiological activities.

Furthermore data acquisition and analyzing devices must be processed in parallel and in real time. Various concepts for signal and system analysis may be employed according to the underlying theoretical concepts to perform suitable unique feedback features within the recursive zone due to the actualized model. The chosen concept and realization of possible perception–action–loops is selected by its purpose which is grounded in the valences of the stimulus and simulus as well as in the valences of the interface. A more detailed description of our own $\psi\phi$-interface methods, projects and results as well as a proposal for future instrument development and investigations will be settled later.

The synopsis in Fig. 6 additionally contains several monitoring features as different online protocols implying different kinds of representations due to several phenomenological or theoretical frames giving a more complete and supervising view to an external demiurge observer of the NeuroLoop scenario.

5 Interfacing Mimesis and Poiesis

Our explicit methodologies for dealing with implicit psychophysical processes are altogether guided by two different but complementary intentions leading to diverse kinds of $\psi\phi$-interface instrumentation. One aspect which is denoted as a "mimetic" approach holds for any type of "metamorphosis" within the range of structural and dynamic stability and non-emergent behaviour (like stimulators type a mentioned above). These instruments will primarily be implemented as interactive servo-controlled tools for investigating the structural and dynamic properties of various sensorimotor loops or pathways in determining and controlling specific system transfer functions as they will first and foremost be applied within the framework of biomedical sciences.

The other aspect, denoted as a "poietic" approach is dedicated to the issue of "morphogenesis" including regimes of structural and dynamical instabilities and emergent behavior (like stimulators type b mentioned above). This type of interfaces is envolved within manifold frameworks reaching from neuroscience, complex dynamics, semantic information theories up to philosophy, media theory and diverse genres of art. Some selected examples for both versions can be seen in Figs. 9–13

Other complementary viewpoints are implemented and unified within the $\psi\phi$-interface concept as dealing with structure and dynamics. Although the internal dynamical and the external structural viewpoint seem to be incommensurable in a very well defined manner they may nevertheless be experienced and observed together for a more complete theoretical, empirical, epistemological and ontological approach towards meaning. This is because the human brain and psyche is the only system which is capable of both, internal participation in its dynamics and external observation of its structure. Our main issues for $\psi\phi$-feedback interactivity and interface design are therefore related to order generation and order tracking of complex modes while looking at the structures of appearances and searching for coherences.

For designing and specifying suitable $\psi\phi$-interface solutions several theoretical suggestions have to be considered including the notion and aspects of structure and dynamics mutually determining the conditions of the release of semantic information. Also the general challenges of psychophysics as exo- and endo-concepts of observation have to be considered theoretically as well as the question, how external reality is internally represented and how categories, viewed as a structural concept will be processed.

Therefore we will compile a survey of our recent considerations, suggestions and proposals in a very condensed way by the following statements. It is suggested and proposed that:

1. experienced phenomena are based on stimulus-simulus (or exo-endo) -interactivity.
2. a common concept exists, namely that structural and dynamic evolution is governed by self-consistency dynamics.

3. mind–body–interactivity has essential communality of structural and dynamic properties.

4. the notion of category may be considered as a structural concept which is related to the structural aspect of representation as an internal mode and may be considered as information storage or rather reprocessing (closely related to H. Atmanspacher).

5. the dynamic representation will be considered as information processing. (H.A.)

6. the actual $\psi\phi$-state at the boundary between two basins of attraction may be regarded as the release state of "meaning". (H.A.)

7. extended information theories applied to the NeuroLoop-concept must show the capability for exploring the emergence of semantics.

8. even within a restricted and simplified interface-reality (interface's bottleneck) which is merely structural and dynamic interactivity with respect to the options of the operated theoretical model it may nevertheless facilitate emergence of self-establishing iterative semantics whereby the release of meaning is accompanied by characteristic phase transitions.

9. perception–action–circularity between observed objects and observers in connection with immersive real-time interactivity will be essential in order to achieve epistemological and ontological correspondences within a processual point of view, where the $\psi\phi$-interface features will behave as autonomeous systems exhibiting emergent properties.

10. morphogenetic principles will be operated in an effective and significant manner at various sensomotorial and informational biological levels (i.e. genetic-, cellular-, subcellular-, intercellular-, organic- and organism-level) and should be taken as living examples in order to search for appropriate technical solutions for $\psi\phi$-interface design.

11. a common modality between several senses should exist at a primordial level and will lead to a common concept for an empirical approach to aesthetics, synaesthetics and kinaesthetics.

6 Interface Engineering

Now we would like to apply some more details to our basic block diagram already shown in Fig. 6 which will furthermore be specified by Fig. 7. This synoptic overview should be left without any further explanation as it should be self explanatory and self instructive for the appropriately qualified expert with specialized knowledge. It will give some inherent instructions for the usage and for various applications of the NeuroLoop concept.

But we should add a single comment for a more detailed information on the issue of the stimulus representation. As to be seen in the synopsis virtual media or physical processes may be used either alternatively or in combination as well for making an adequate stimulus generation and representation. For physically based visual stimulators we have implied some new type of excitable optically active liquid crystal lattices inserted to an imaging beam. These externally excitable liquid crystal devices have been developed by making use of the covariant features of the elastic-, dielectric- and optical anisotropy of liquid crystal phase transitions where local as well as global excitation modes were implied and may be excited by means of different contact- and non-contact applicators (i.e. radiation-, thermal-, elastic-, sonic- and

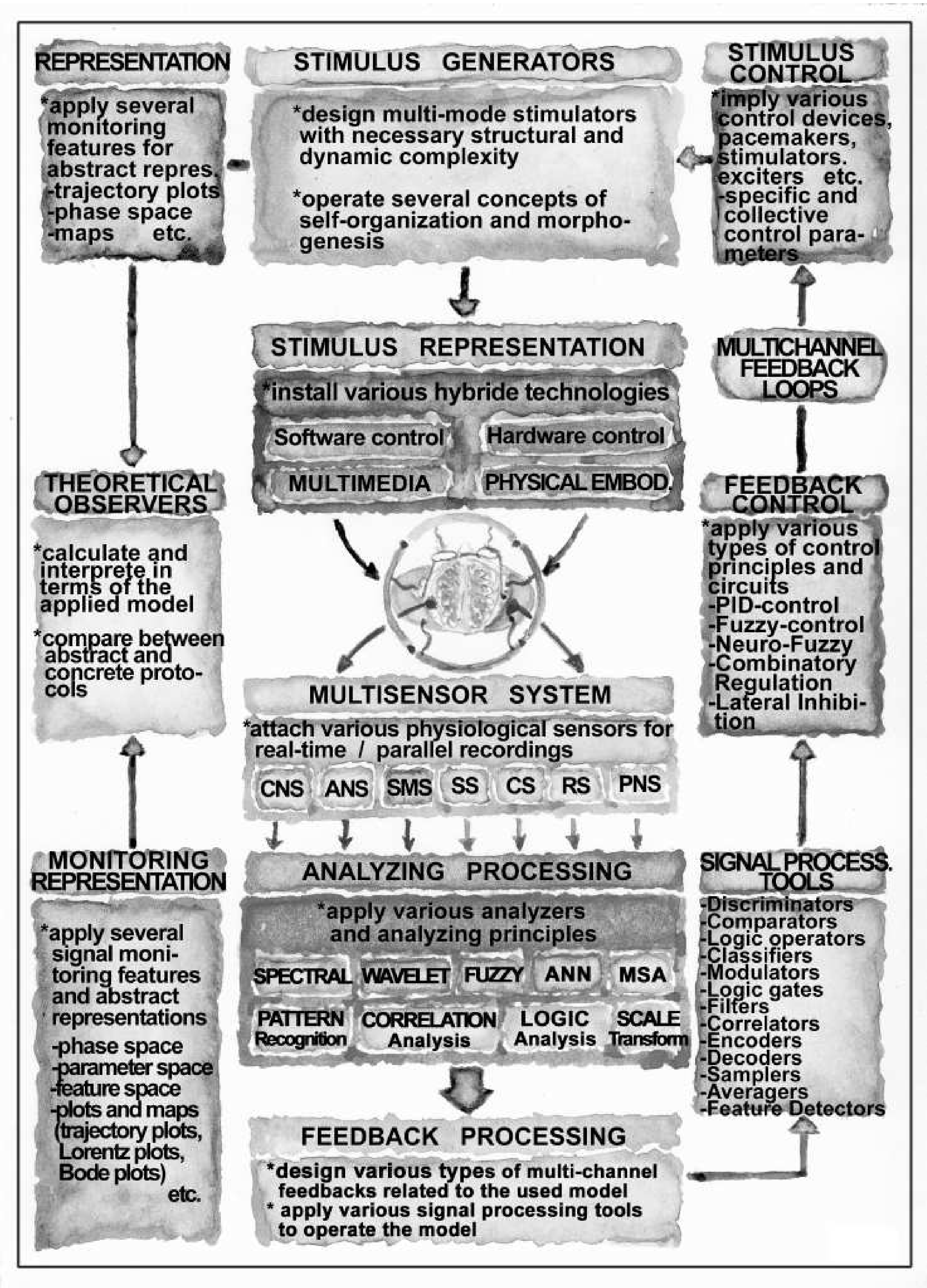

REPRESENTATION
*apply several monitoring features for abstract repres.
-trajectory plots
-phase space
-maps etc.
STIMULUS GENERATORS
*design multi-mode stimulators with necessary structural and dynamic complexity
*operate several concepts of self-organization and morphogenesis
STIMULUS CONTROL
*imply various control devices, pacemakers, stimulators, exciters etc.
-specific and collective control parameters
STIMULUS REPRESENTATION
*install various hybride technologies
Software control
Hardware control
MULTIMEDIA
PHYSICAL EMBOD.
MULTICHANNEL FEEDBACK LOOPS
THEORETICAL OBSERVERS
*calculate and interprete in terms of the applied model
*compare between abstract and concrete protocols
FEEDBACK CONTROL
*apply various types of control principles and circuits
-PID-control
-Fuzzy-control
-Neuro-Fuzzy
-Combinatory Regulation
-Lateral Inhibition
MULTISENSOR SYSTEM
*attach various physiological sensors for real-time / parallel recordings
CNS
ANS
SMS
SS
CS
RS
PNS
MONITORING REPRESENTATION
*apply several signal monitoring features and abstract representations
-phase space
-parameter space
-feature space
-plots and maps (trajectory plots, Lorentz plots, Bode plots) etc.
ANALYZING PROCESSING
*apply various analyzers and analyzing principles
SPECTRAL
WAVELET
FUZZY
ANN
MSA
PATTERN Recognition
CORRELATION Analysis
LOGIC Analysis
SCALE Transform
SIGNAL PROCESS. TOOLS
-Discriminators
-Comparators
-Logic operators
-Classifiers
-Modulators
-Logic gates
-Filters
-Correlators
-Encoders
-Decoders
-Samplers
-Averagers
-Feature Detectors
FEEDBACK PROCESSING
*design various types of multi-channel feedbacks related to the used model
* apply various signal processing tools to operate the model

Figure 7:

NEURO-SEMIOTICS

SYNTAX	PRAGMATICS	SEMANTICS
Abstract Construction	**Medial Construction**	**Intermediate Construction**
basic approach: Install various types of corresponding models in order to simulate physical stimuli and neuronal properties according to specified theories.	**basic approach:** Install various types of representations for the stimuli according to the selected sense modalities as well as for the covariant neuroelectric activities.	**basic approach:** a. Specify and install adequate and efficient encoding and decoding features. (a priori) b. Install specified features of dialogic interactivity between stimulus and simulus for self-establishing coding. (a posteriori)
proposed theories: Certain theories on structure and dynamics which may be utilized within any substrate and over a wide range of scales: - Non-Linear Dynamics - Synergetics - Theory of the Fractals - Neural Networks - Genetic Algorithms - Cellular Automata - Information Theories - Tensegrity - Artificial Life (AL) - SIM-Life - Artificial Intelligence(AI) - Endophysics - Fractal-Scale-Space-Relativity - Models of Chaos-Control etc. ***Compare with*** **Frameworks of:** - Neuro Sciences - Psychophysics - Genetics - Cognitive sciences - Linguistics	**proposed media:** Certain media designed for corresponding sense modalities which must exhibit perceivable (visible, audible, tactile) patterns for the stimulus as well as for the neural activity and its various representations: - Electronic Media - Virtual Environments - Physical Embodiments ***Compare with*** **Frameworks of:** - Theoretical Physics - Aesthetics and Arts - Sociocultural Systems - Biomorphogenetic Systems Producing observable complex structural phenomena which may be related to cortical representations such as - Somatotopic- or - Retino-cortical- or - Tonotopic-Repres. - Receptive or Perceptive Field Organization - Phase space - Feature Space	**proposed communication systems:** Certain human-machine-communication devices exhibiting the capability of complex structural and dynamic change within selected communication channels. ***Communicate with*** - Physical Observers - Symbolic Observers - Cognitive Observers - Autonomeous Agents **Frameworks of:** - Relational Structural and Semiotic Interactivity - Self-establishing- Iterative-Semantics - (weak semantics) - Code Proceeding

Figure 8:

Recent Biomedical Applications of the NeuroLoop

Brain-research	Neuro-Ophtalmology	Audiology

Brain-Mapping	Color-Anomalia	Refraction Anomalia	Subjective and objective Audiometry	Wavelet-Audiometry	Speech Processing
models and methods for real-time topological and functional symbolic representa-tions and for therapeutical interventions i.e. central lesions	models of color-vision colorimetric and spectral-radiometric methods	models of spatial contrast – visibility and diagnostic methods	models of system theory and methods for measurement of system-transfer functions i.e. auditory pathway and cortex	models of wavelet- and multi-scale analysis and methods for psychophysical match of wavelet-level-resynthesis	models of speech and methods for hearing aids and cochlea implants (CI)

Figure 9:

electric-fields) serving as specified control parameters due to the structural dynamics of the nematic phases of the utilized liquid crystal cells (for more details see Prehn [8, 12]. Some of the gained visual phenomena obtained from our LC-Visual Stimulator will be demonstrated in Figs. 10–13.

According to the instrumentation of possible NeuroLoop interfaces just sketched before we should now represent some of our proposed intentions for versatile possible NeuroLoop experiments which will be summarized by the following statements:

1. Create a sensitive and perceivable complex "stimulating universe" constructed as a collective system on various substrates made from simple elements or particles and governed by physical interactions.

2. Observe various different observers at different levels and from different views including the ability to make observations on a wide range of scales.

3. Let the observer's manyfold behavioral actions due to his observation change the observed universe in a unique way according to the underlying stimulus and simulus modelling by means of retrograde stimulation of the stimulator itself within a closed loop circuitry.

4. Observe the evolution of the covariant stimulus and response in terms of their processual

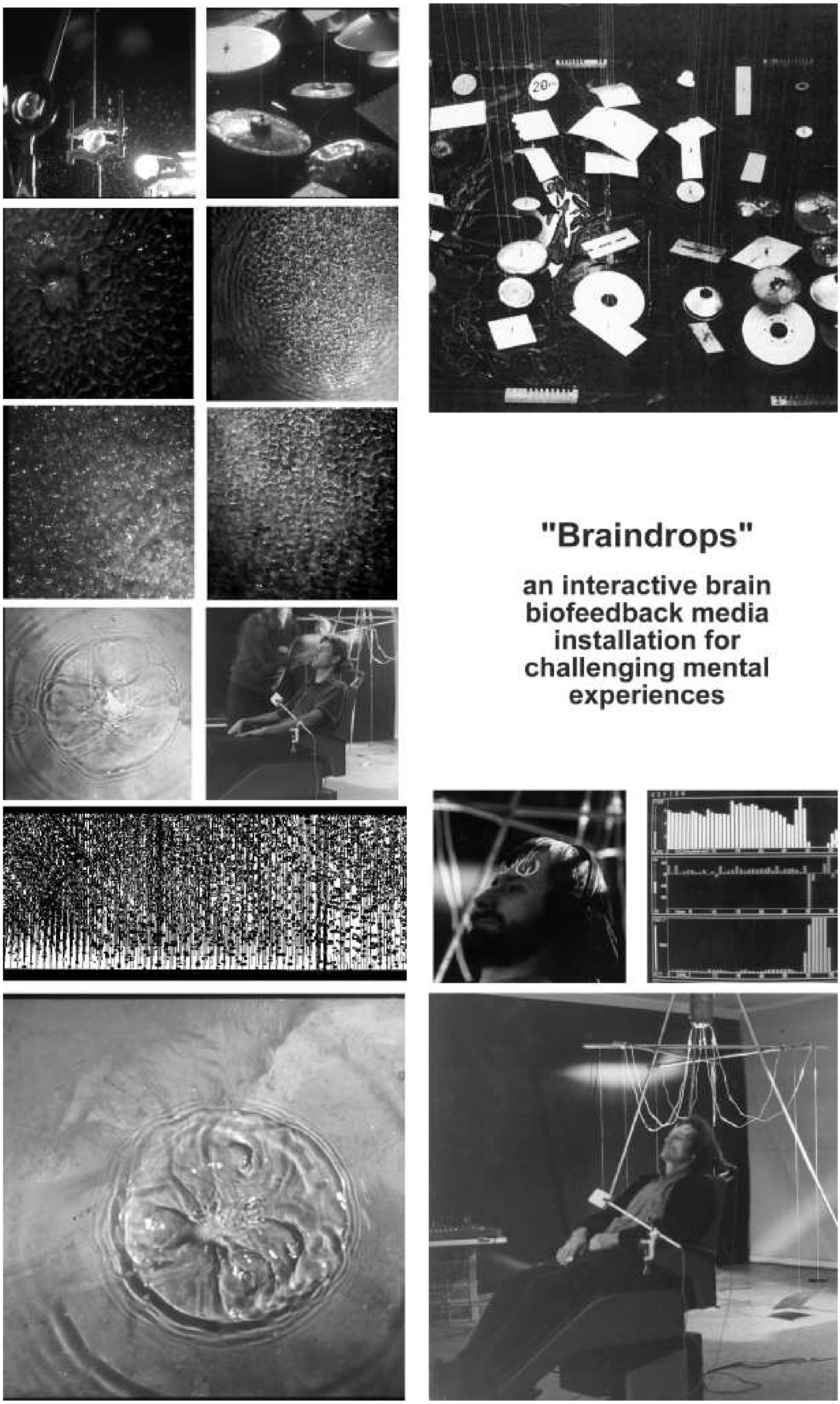

"Braindrops"
an interactive brain biofeedback media installation for challenging mental experiences

Figure 10:

structural and dynamical behavior by means of the accompanying objective protocols (i.e. as abstract-, logical-, phenomenological-representations and by various maps).

5. Participate (i.e. get connected) to the NeuroLoop scenario an try to realize various kinds of introspective views and self-reflections during your immersive interactions.

6. Experience different and altered sensational, mental, emotional and corporal conscious states and awareness.

7. Observe the characteristic conditions, objective protocols directly corresponding with the arousal and emergence of significant internal imaginations exhibiting aesthetic charm or alterated or paradox states of consciousness, autogeneous hypnosis, ecstasy or ergotropic excitation.

It has to be emphasized at now that the appearance of the stimulus universe as well as its internal pacemakers is merely pure physics and will just be guided or stimulated by a human observer's perceptual judgements by which a chosen theory is operated in a physical manner and nothing else. But this may nevertheless lead also to illusory, suggestive, halluzinatory or strange perceptions and mental states which will be perceived from an external observer outside as ordinary physical objects in contrast to the immersive observation from inside. The question must be raised, what kind of reality is fabricated within that psychophysical world and should be answered by means of $\psi\phi$- interface investigations.

For another example the notion of an "image" now turns out to be also a psychophysical entity such as the notion of "reality".

The summarized benefits gained from such confined and reduced private reality of the $\psi\phi$-universe is that an interacting observer under immersive condition (total or partial immersion) who is coupled to his own private objectivated subjective universe and which is reduced only to its structural and dynamic properties and which may thus be modelled theoretically and as well be explored empirically and experienced subjectively. Furthermore it may be matched by several kinds of adaptive fits by means of diverse sensorimotoric coordinations onto visual, auditory and/or haptic stimuli due to a multisensory perception. These distincted episodes of correlated interactivity will show up as generic and will therefore be not permanently observable.

Even if the emerging representations are not known in advance and even that nobody knows the inherent language of descriptions, one may nonetheless start with that chaotic dynamic system and by means of diverse intrinsic communication channels being embedded in this concept it will lead to particularly specified stimulus-simulus self-representations, whereby stimuli and simuli will keep their own covariant descriptions. Its dynamics in between will be denoted as "interface dynamics".

During total immersion the interface appears to the percipient to be totally transparent as a monistic position in which the interface will disappear. By this introspective observation inside the observer an experience of global consistency is associated where separated experiences may also disappear leading to a "all-in-one-experience".

7 Interfacing Neurosemiotics

Such uniquely animated theoretical models may also be recommended to be viewed as "syntax motion" which is governed by the observers perceptual conclusions being encoded as the specified control parameters and operated as the driving signals and which is also affected by

Sensible Systems

an interactive Psychophysical Interface and audiovisual Media Installation within a polychromatic space for immersive explorations of the self

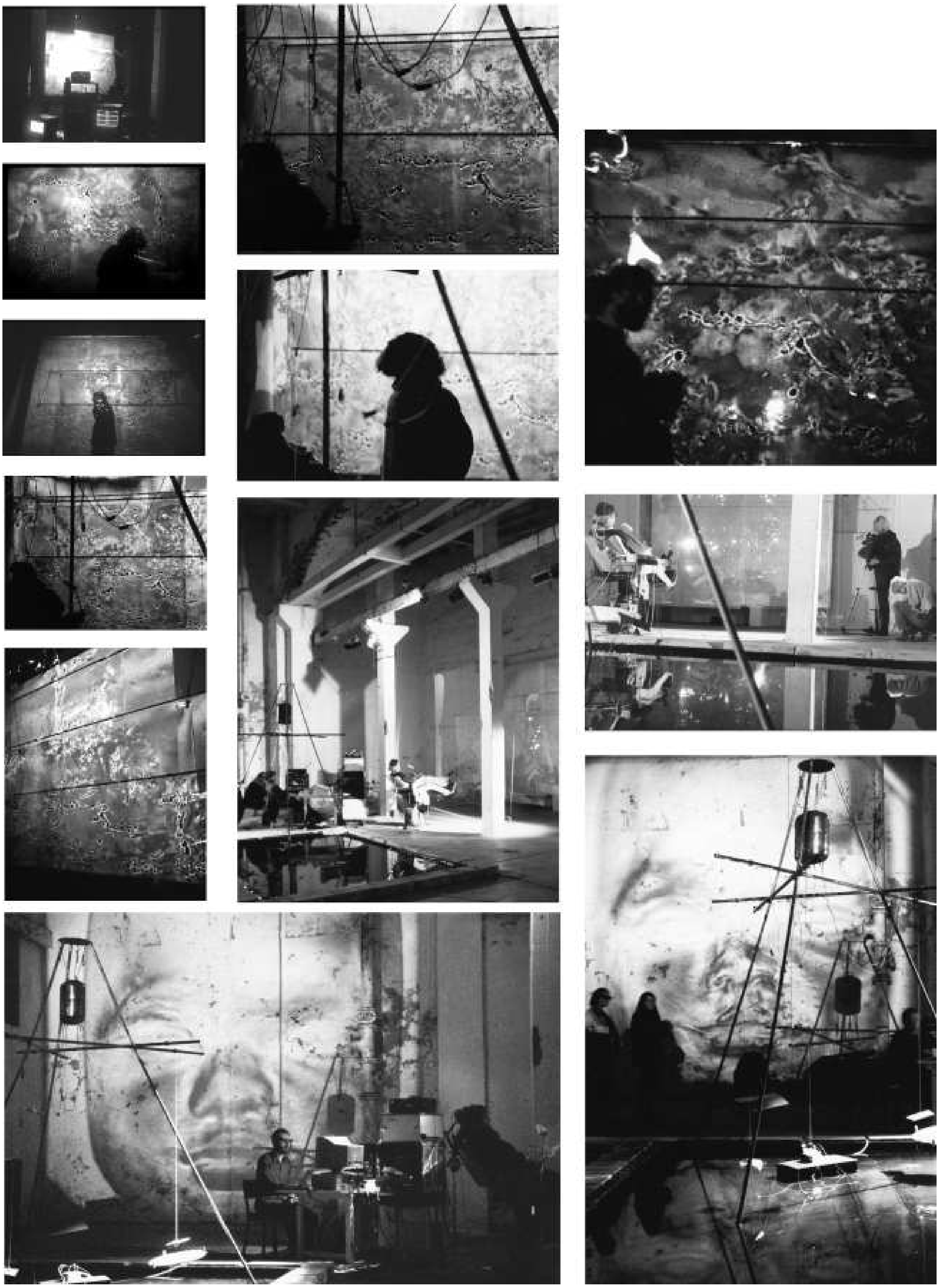


Figure 11:

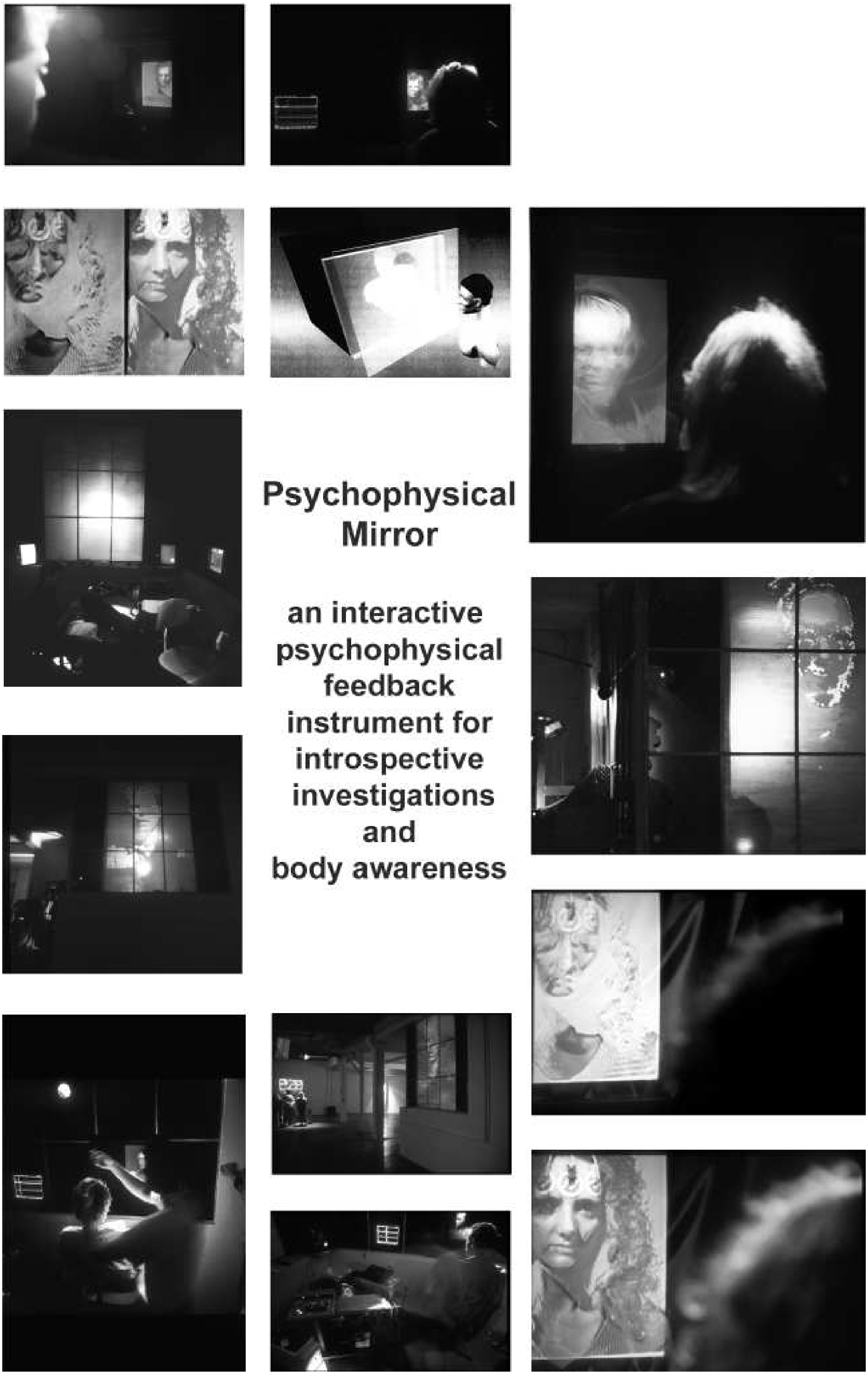

Psychophysical
Mirror
an interactive
psychophysical
feedback
instrument for
introspective
investigations
and
body awareness

Figure 12:

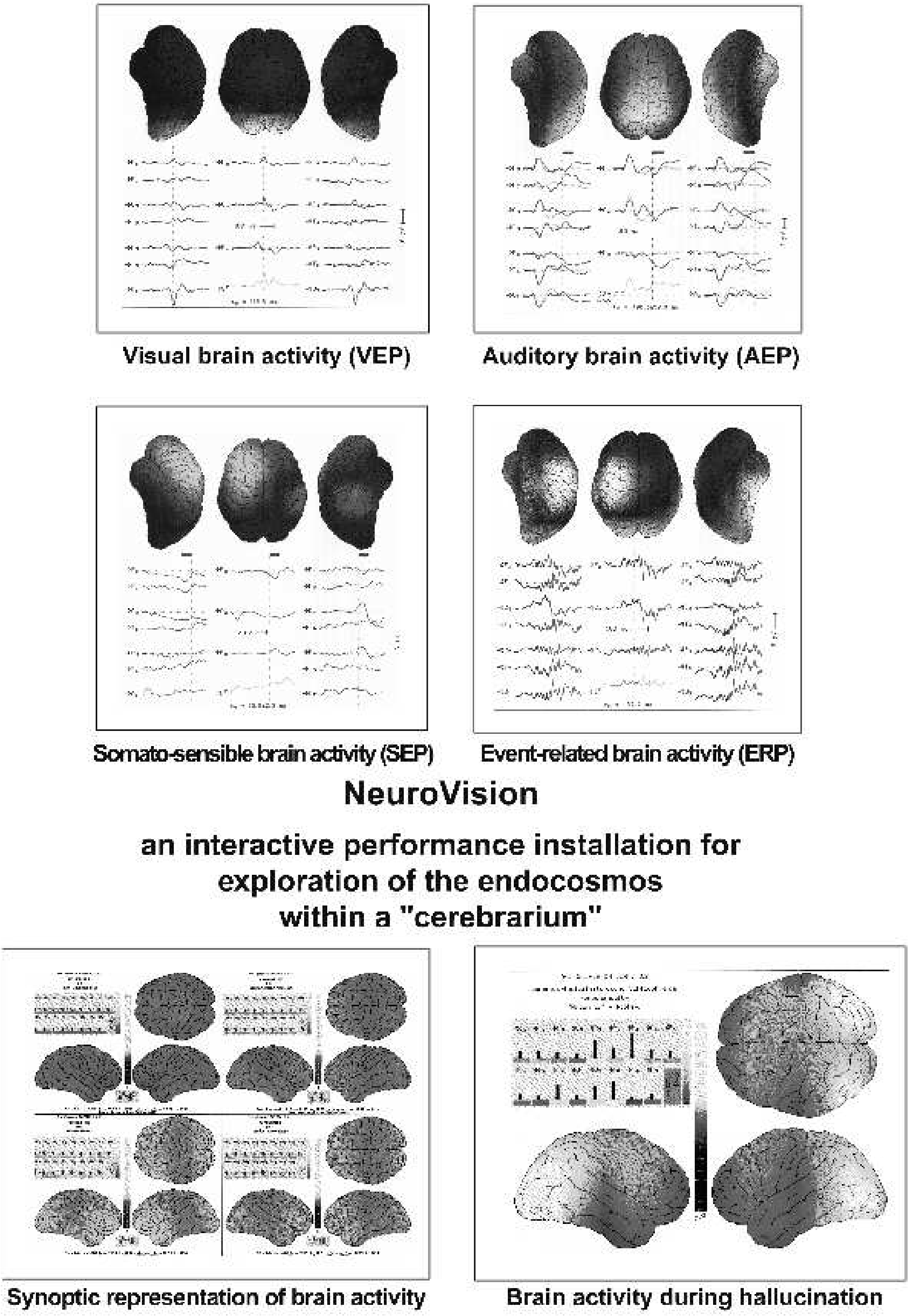

Visual brain activity (VEP)
Auditory brain activity (AEP)
Somato-sensible brain activity (SEP)
Event-related brain activity (ERP)
NeuroVision
an interactive performance installation for
exploration of the endocosmos
within a "cerebrarium"
Synoptic representation of brain activity
Brain activity during hallucination

Figure 13:

some kind of random motion containing various other interacting contextual aspects like the subject's intention, attention, emotion or beliefs.

We have already pointed out that our suggestions also have to include the semiotic aspect of structure and dynamics as well as the determination of the crucial conditions for the release of semantic information out of specific structural appearances. Examining the organization of representational states in the brain we will now focus on the release state of "meaning", categoreal, non-categoreal or acategoreal representations and in particular whenever an intrinsic structural instability is dynamically stabilized. (On this issue see H. Atmanspacher). Our suggestions will lead to a semiotic approach by means of an $\psi\phi$-interface at a very primordial level and our synopsis in Fig. 8 will go with that. Hereby the syntactic and pragmatic aspects of very basic and rudimentary level of structural semiotics may as well be evaluated by the reader from the scheme itself without any further comments. However the semantic aspect needs some comments respectively attributed to Yukio-Pegio Gunji's lecture with reference to his issue of "weak semantics" (page 111).

As already stated, semantics is based on an intermediate construction where dialogic interactivity is maintained between stimulus and simulus within the NeuroLoop interface, establishing an human-machine communication system. Within the framework of the said "mimetic" approach a distinctive code is given "a priori" with respect to the chosen syntax formed by the applied model and pragmatics as formed by the applied and sufficient representation due to the versatile media adapted to the selected perceptual modality.

On the other side, within the said "poietic" approach semantics is emerging in an "a posteriori" manner as self establishing and iterative semantics (i.e., as proposed by Gunji's weak semantics, (page 111)). This kind of relational structural semiotic interactivity is already known, and may therefore be studied under this aspect, within the context of functional electrostimulation (FES) of the human ear as utilized by means of cochlea implants (CI).

Even on an oversimplified model (neuro-syntax) and by means of an electroacoustic speech-processing and stimulation system (machine syntax and pragmatics) based on a very restricted and coarse (few channels) tonotopic representation (interface syntax and pragmatics) which is only related to different spectral selectivities, the formerly deaf patient will surprisingly be able to understand most complex language sufficiently just after a very short time of training.

This biomedical psychophysical interface application will teach us that even with these limitations of the interfaces bottleneck, meaningful informations may be provided out of a very simple processual interactivity. The example shows as well that an individual suitable semantic code is self establishing in an interactive manner by means of the outstanding capabilities of the human brain in order to establish adaptive complex decoding and encoding mechanisms, whereby the code is proceeded from initially indefinite to definite in the end. From these exemplaric cases we may derive some essential hints and guidance for our methodological applicability according to versatile $\psi\phi$-interface investigations onto the issue of neurosemiotics. Hereby the $\psi\phi$-NeuroLoop appears as a conceptualization of the principle of self-reflection in a phenomenological as well as in a fundamental theoretical manner giving rise to several constructions of interpretations of ourselves.

The participant of a NeuroLoop scenario enters his private universe through a $\psi\phi$-interface as through a door and he may observe, manipulate and interprete his individual universe of experiences. Also he himself as well as other investigators acting as external observers may monitor, protocol and interprete the actual scenario by means of the underlying theory and model. Because of that an external demiurge may create diverse related theories which may be applied in order to construct specified observable objects as covariant animations of perceivable phenomena as well as the diverse interface solutions and operate them according to the various concepts. Thereby many confined $\psi\phi$-universes and several kinds of interfaces are possible to enter this new type of a subject's private environment. Because the recursive zone is neither an object nor an observer alone it will therefore appear as a new entity of recursive operationality between an exo- and endo-world. In a metaphoric sense these $\psi\phi$-interfaces may serve as introspective vehicles moving between physical and mental states and we can drive and play that interface by treating that vehicle's motion by means of communication. For extended operationality one should look for adequate models and representations which may be optimized to be operationally more efficient. For construction and simulation of diverse shaping technologies we will find further guidance from biological and neurophysiological operationalities (i.e. neuroinformatics and neural networks).

By means of a specific $\psi\phi$-interface vehicle one may explore several psychophysical states living within this hybrid human–machine–interactivity. It should also be noted that any exo-observer will only get what he will see, hear or feel from the corresponding physical stimulus representation while the immersive endo-observer will get more than what is to be seen, heard or felt from outside.

By this new discipline of playing $\psi\phi$-interfaces one may create some new type of sense. These extended senses will also provide a new type of psychophysical interplay with artificial sensing being implied by means of various sensors responding to sensation and sensory activity behind our sense organs which is in contrast to up to now when playing with physical objects alone. Metaphorically speaking hereby a psychophysical meta-observer may look as through a "mental fog" for the underlying structures where that type of computer-mind-consciousness is serving as a "conscious-radar" as well as for reduction of complexity.

One may perceive, experience and learn other aspects of reality now being viewed as a unity, and no longer as a cartesian cut, constituting diversive recursive zones which are in fact based on an intermedium respectively an interface.

Some further perspectives for investigating several processual aspects onto intelligence and cognition will thus be stated in the following resumé.

1. Investigate several technologies which will sufficiently meet the requirements of the proposed theoretical and methodological concepts as well as for aesthetic charm.

2. Design various types of interface systems according to the variety of possible constructions.

3. Undertake versatile experimental investigations in order to obtain further knowledge and experience in gaining technological evolution of instrument design.

4. Explore the crucial conditions and limitations in order to establish efficient immersive interactivity.

5. Let many different observers explore various $\psi\phi$-scenarios by multiple and parallel ways with respect to distinguishable and/or unified ontological and epistemological aspects.

6. Investigate the $\psi\phi$-scenario when distortions, uncertainty, randomness is externally and/or internally induced.

7. Search for appearances of sensorial, emotional, cognitive and/or logic ambivalences, ambiguities, paradoxes and/or incommensurabilities.

8. Search for appearances of fluctuations, phase transitions, mode locked orders and for conditions of dynamic stabilization.

9. Investigate various kinds of categoreal (structural), non-categoreal and acategoreal representations on various levels.

10. Investigate individual and interindividual development of intentionality and temporal directivity.

11. Search for parallels and coherences to the experienced situations in which the participant finds himself within the actual scenario and let him navigate with respect to his actual intention.

12. Search for parallels between other means, technologies and/or rituals which have already been established within various cultures, cults and spiritual communities (anthropological view).

13. Investigate the effects of specific drugs, sensorial stimuli and/or bodily techniques being used to induce sensational illusions, meditations, trances, ecstasy, lucid dreams, altered states of consciousnes, out-of-body-experiences, subconscious states etc. as well as consequences of neurological and psychic diseases and disorders under the view of the Psychophysical modeling.

14. Cultivate metaphors, metamorphosis and morphogenesis under the aspect of creativity and holistic models.

Several further questions will arise from these investigations but mainly how would this private psychophysical universe split as a consequence of the actual coupling? What kind of conflicts or paradox or ambiguous sensation with the testimony of our senses will arise? When and under which conditions will these splits occur and how can they be forced by means of interactivity and by the possibilities to decisions? Which finite set of eigenvectors may be observable and which kind of meanings will emerge from them?

In addition, meaningfullness will be understood as well as a mental mode of existence. In the context of the self, as a constitutive process, thus experience of consciousness, subconsciousness, altered states of consciousness, illusion, halluzination and lucid dreams might be identifiable empirically as ontological mental state transitions within immersive Neuroloop episodes. According to a correlation theory of brain states and psychodynamics it is obvious, that mental states of concrete awareness of different, in particular of opposing potentialities and their possible actualization is a necessary condition to form novel categories and experiences. Hereby the principal question is raised: can immersive experience fill the explanatory gap ?, or the other way round: can explanation fill the gap of experiences?

8 Recent and future Interfaces

Our contribution may hopefully stimulate further technological development of various types of $\psi\phi$-interface designing and with applications within the sciences of the interface which may give rise to further promising investigations and theoretical descriptions of the recursive zone.

Finally we would give you a brief survey about our recent applications assigned to the field of biomedical sciences and to the issue of empirical aesthetics as shown in the synopsis in Figs. 9–13.

According to our medical applications we had employed several technologies of brain mapping implied for Topological Electroencephalometry and Magnetoencephalometry using extended methods of real time topological and symbolized representations of various evoked brain activities applied to our NeuroLoop interface. This type of instrument was specifically designed for interactive neurological diagnosis with sorts of combined physiotherapeutical interventions in order to treat patients with central lesions in a feedback loop manner. Therefore several methods of real time monitoring of the corresponding brain activity and with the additional ability of encoding this activity by several types of color codes which represents specified actual neuronal activity as relevant symbolic representations.

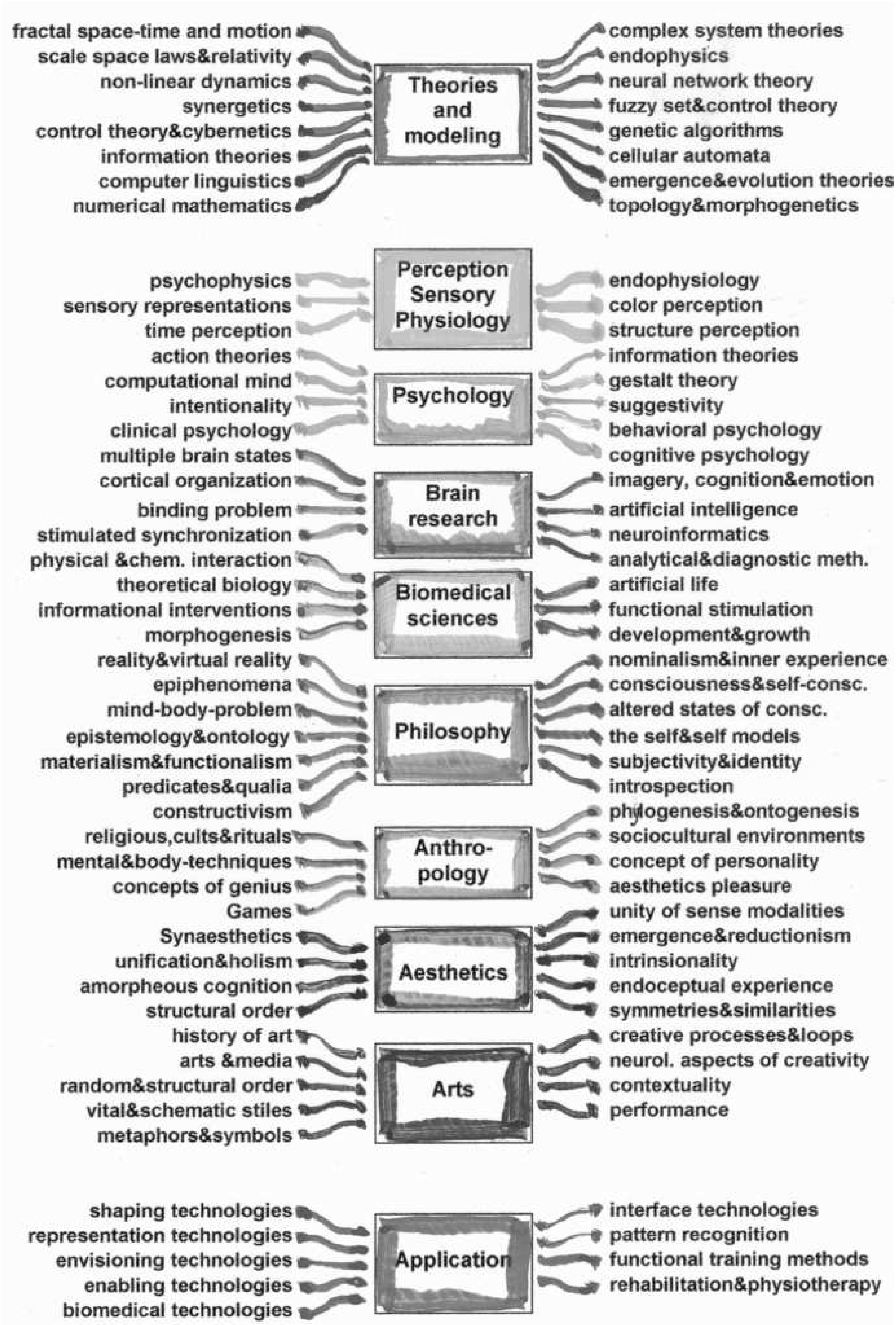
Another biomedical application goes with neuro-ophthalmological investigations. Once the color-perception-action loop is using a new "Interferometric Stimulation Technique" (IST) for fast dynamic analysis of the implicit spectral performance of any visual system. As a dynamic stimulus generator an interferogram was used, which is the spectral Fourier Transform of the applied light source spectra and which will be perceived as a unique color modulation. Certain response parameters from the human visual system were derived from Electroretinogram (ERG) or from Visual Evoked Cortical Potential (VECP)-recordings and fed back to the dynamic IS-generator in order to detect and control its parameters (i.e. pathlength). By means of a real time dynamic analysis the visual spectral sensitivity will thus be determined.

Another NeuroLoop investigation is dealing with the spatial features of the human visual system using a parametric visual stimulus generator formed as a controllable spatial pattern generator and which spatial frequency and modulation may be feedback-controlled by means of specified control-parameters derived and calculated from visual evoked cortical potential (VECP)-recordings from the recipient closely related to our model of neuro-system-analysis.

Hereby the actual internal modulation transfer function (MTF) as well as the coupling function derived from that may objectively be measured by this method and furthermore may also be fed back by means of a convolution operation onto the actually shown image function for making a phenomenological representation of functional deviations of the internal spatial modulation transfer processing. This kind of phenomenological representation may also be attached to any other arbitrary pregiven image and may therefore simulate the perceived phenomena under altered, distorted or abnormal vision and may such be presented to a normal observer who there from will get an impression what a given image may look like as seen under several perceptual aberrations or defectives. That issue of the simulation capabilities has already been pointed out previously within the context of colorimetry.

Also the feedback conditions may be manipulated or installed in a particular and specific way for serving various purposes. On the one hand the feedback may act as a pure servo control which will lead to a regular spatial perception and objective analytical determination of the observer's spatial sensitivity function, on the other hand different features of the chosen feedback conditions which may arbitrarily be implied will lead to some kinds of very strange, paradox sensations or visual hallucinations. In the particular case that the feedback parameters are inversed or alterated in a very defined manner it will give rise to strange sensations which uniquely will depend on the selected feedback conditions and which may be adjusted and experienced within every NeuroLoop experiment. We have observed this further experimental option for the very first time when we occasionally had inversed the feedback acting onto the focus of the stimulus pattern in such a way that, when the recipient attempts to focus the image it will go on to be defocussed and vice versa.

Furthermore we have also undertaken several $\psi\phi$-interface investigations in the field of Objective- and Subjective Audiometry for diagnostic purposes and for making various speech processors attributed to our development of novel hearing aids and cochlea implants. Hereby the features of multi-scale-analysis (MSA), Wavelet-Transform and Filtering have been implied to the interface using the wavelet analysis on the recipient's evoked responses and wavelet-resynthesis on the stimulus side wherby the perceptive action will affect the different adaptive


fractal space-time and motion
scale space laws&relativity
non-linear dynamics
synergetics
control theory&cybernetics
information theories
computer linguistics
numerical mathematics
Theories and modeling
complex system theories
endophysics
neural network theory
fuzzy set&control theory
genetic algorithms
cellular automata
emergence&evolution theories
topology&morphogenetics
psychophysics
sensory representations
time perception
Perception Sensory Physiology
endophysiology
color perception
structure perception
action theories
computational mind
intentionality
clinical psychology
Psychology
information theories
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behavioral psychology
cognitive psychology
multiple brain states
cortical organization
binding problem
stimulated synchronization
Brain research
imagery, cognition&emotion
artificial intelligence
neuroinformatics
analytical&diagnostic meth.
physical &chem. interaction
theoretical biology
informational interventions
morphogenesis
Biomedical sciences
artificial life
functional stimulation
development&growth
reality&virtual reality
epiphenomena
mind-body-problem
epistemology&ontology
materialism&functionalism
predicates&qualia
constructivism
Philosophy
nominalism&inner experience
consciousness&self-consc.
altered states of consc.
the self&self models
subjectivity&identity
introspection
religious,cults&rituals
mental&body-techniques
concepts of genius
Games
Anthro-pology
phylogenesis&ontogenesis
sociocultural environments
concept of personality
aesthetics pleasure
Synaesthetics
unification&holism
amorpheous cognition
structural order
Aesthetics
unity of sense modalities
emergence&reductionism
intrinsionality
endoceptual experience
symmetries&similarities
history of art
arts &media
random&structural order
vital&schematic stiles
metaphors&symbols
Arts
creative processes&loops
neurol. aspects of creativity
contextuality
performance
shaping technologies
representation technologies
envisioning technologies
enabling technologies
biomedical technologies
Application
interface technologies
pattern recognition
functional training methods
rehabilitation&physiotherapy

Figure 14:

wavelet levels within the feedback loop. (This application may also be related to Nottale's lecture about his concept of scale space, page 38.)

Now on the issues of media arts and empirical aesthetics we have undertaken several studies mainly using the intrumentation derived from our biomedical applications but under different questionings to the experiment. Meanwhile several interactive biofeedback performance installations have been produced and exhibited within the context of science and media art and some of our works as entitled in Figs. 10–13.

These works are essentially based on our scientific theories, concepts and modelling in accordance with our artistic practice and aesthetic experiences. According to correlation theory of brain states and psychophysical dynamics with respect to its self-organizational features we are faced with the problem how can aesthetics provide for the "terra incognita" between structural dynamics and the accompanying meaningful symbolizations as emulated modes of a circular perception-action-causality and how basic semantic operations might be understood and experienced as an embodied and situated neuroaesthetic interaction by looking for primary attractors as a categoreal and dynamical view onto aesthetics. Hereby aesthetics is understood, beyond the context of arts, as a more general and fundamental principle which acts between any kind of structures and forms and the release of semantics and information and therefore might be as well empirically investigated in both an epistemological as well as in an ontological (ontogenetical) manner.

At least by Fig. 14 we will give you a survey covering the diverse programmatic aspects of possible investigations and applications proposed by our NeuroLoop concept on various topics such as sensory physiology and psychophysics, brain research and cognitive sciences, psychology, theoretical physics and modeling, philosophy, aesthetics, enabling technologies and artificial intelligence. Of course all these distinctive issues are multiple interconnected as related to our initially raised question on mind and matter: Does sensation make sense on matter or does matter make sense of sensation? Never mind! This distinction does not matter anymore if we suggest it as a circularity and over and above that we can make mindful experiences if we may change matter by our mind as it would happen with the NeuroLoop.

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The Thought Translation Device and its Applications to the Completely Paralyzed

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Abstract

The Thought Translation Device (TTD) is an EEG-based biofeedback system which has been developed to re-establish communication in severely paralyzed patients. The device relies on self-regulation of slow cortical potentials (SCP) which are used to voluntarily produce binary responses. Operant conditioning strategies are employed in a feedback procedure to train patients to produce two different SCP responses: positivity or negativity.

A graphic signal (cursor) on the feedback screen informs the patients about the course of their SCP amplitude during the feedback interval. Negative SCP shifts move the cursor up, positive shifts move it down. At the end of each trial, the course of the SCP amplitude is classified as either a down ("yes") or up ("no") binary response. When a patient has achieved reliable control over his or her SCP shifts, the responses can be used to select items presented at the bottom of the screen. This chapter describes the different applications of the TTD that paralyzed patients are currently using.

A spelling program allows patients to select 32 letters and punctuation marks presented in a dichotomic structure with five levels. This program has been supplemented by an advanced dictionary which offers complete words after only a few letters have been selected. It has been used by two locked-in patients to write messages or letters of considerable length. A third patient uses a faster but more limited system in which complete phrases can be selected to express his most important wishes and needs. This patient has also learned to use a stand-by option enabling him to turn the system on and off without assistance from others. The latest development, a special internet browser for the TTD, allows patients to access any information in the internet by selecting links with their brain responses and thus navigate through the world-wide web.

The TTD - a brain-computer interface (BCI)

Both cortico-subcortical stroke and neurodegenerative diseases such as amyotrophic lateral sclerosis (ALS) can lead to a state of complete motor paralysis with intact sensory and cognitive

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functions. One of the most terrifying aspects of this "locked-in syndrome" is that the loss of muscle control prevents the expression of even the most basic needs. However, because perceptual and cognitive functions are usually unaffected, direct interaction between brain and computer may offer a unique communication channel for locked-in patients. Research into brain-computer interfaces has shown that humans can acquire control over non-invasively recorded electroencephalographic (EEG) parameters of cortical activity such as the $8-12Hz$ mu rhythm found over sensorimotor cortex [8, 14, 19, 18] and slow cortical potentials (SCP), i.e. changes in cortical polarization that last from $300ms$ to several seconds [3, 2, 5, 12, 17]

Recently, Birbaumer et al. [4] have demonstrated that severely paralyzed patients can operate an electronic communication device ("Thought Translation Device", TTD, see also [9, 13]) by controlling SCP. Negative SCP are most likely to be caused by excitatory postsynaptic potentials in the apical dendrites of cortical layer I that play an important role in the modulation of excitation thresholds of cortical pyramidal cells. Negative SCP shifts have been associated with the preparatory distribution of sensory, motor and attentional resources into the respective cortical areas [1, 2]. The TTD was based on SCP rather than other EEG signals because SCP can be recorded reliably in every individual and because their underlying neurophysiological mechanisms are well understood.

Method

Healthy subjects as well as locked-in patients can learn to produce positive or negative SCP shifts when they are provided with visual feedback of their brain potentials and when potential changes in the desired direction are reinforced. Operant feedback training is conducted at the patients' homes with the users seated in wheelchairs or lying in bed. Figure 1 illustrates the setup of the TTD. EEG is recorded with Ag/AgCl electrodes ($8mm$ diameter) from the patient's vertex (position Cz of the International 10/20 system) referenced to both mastoids. The signals are amplified and transmitted via an EEG amplifier to a personal computer (PC). The experimenter uses this PC to set parameters, start training sessions and visually inspect both ongoing EEG, SCP, frequency spectrum and SCP averages across trials. The TTD operates on the basis of a single trial analysis. A trial typically consists of a $2-s$ passive, preparatory phase in which the cursor remains stationary on the screen and an active feedback phase lasting between $2-3s$ in which the cursor can be moved in accordance with the patient's SCP. The onsets of these two phases are signaled by a high- ($1200Hz$) and a low-pitched ($500Hz$) tone, respectively. The SCP are calculated by a moving average over $500ms$ of ongoing EEG activity recorded with a time constant of $16s$ and a $40-Hz$ low-pass filter which is updated every $62.5ms$. During the active phase, the SCP are fed back visually by a moving cursor on the laptop screen placed in front of the user. For each trial, the user needs to produce either a negative or positive SCP shift, indicated by a lit bar at the top or the bottom of the screen, respectively. Thus, the user has to move the cursor, which rests between the bars when the trials start, into the lit bar presented at the top or the bottom of the screen. The cursor can be moved up or down by producing a negative or positive SCP shift relative to the preceding final $500ms$ of the $2-s$ passive phase. At the end of the subsequent active phase, the SCP shift is classified as a negativity or positivity response according to an algorithm which calculates the integral of the SCP shift across the active phase. A trial is rejected when a) SCP changes remain below $0.5\mu V$ (no response), b) the SCP shift exceeds $100\mu V$ (artifact, caused e.g. by involuntary movements such as swallowing that can still occur even in patients at advanced stages of paralysis), or c) excessive eye movements preventing a meaningful SCP analysis. The electrooculogram correction and rejection algorithm has been described in detail

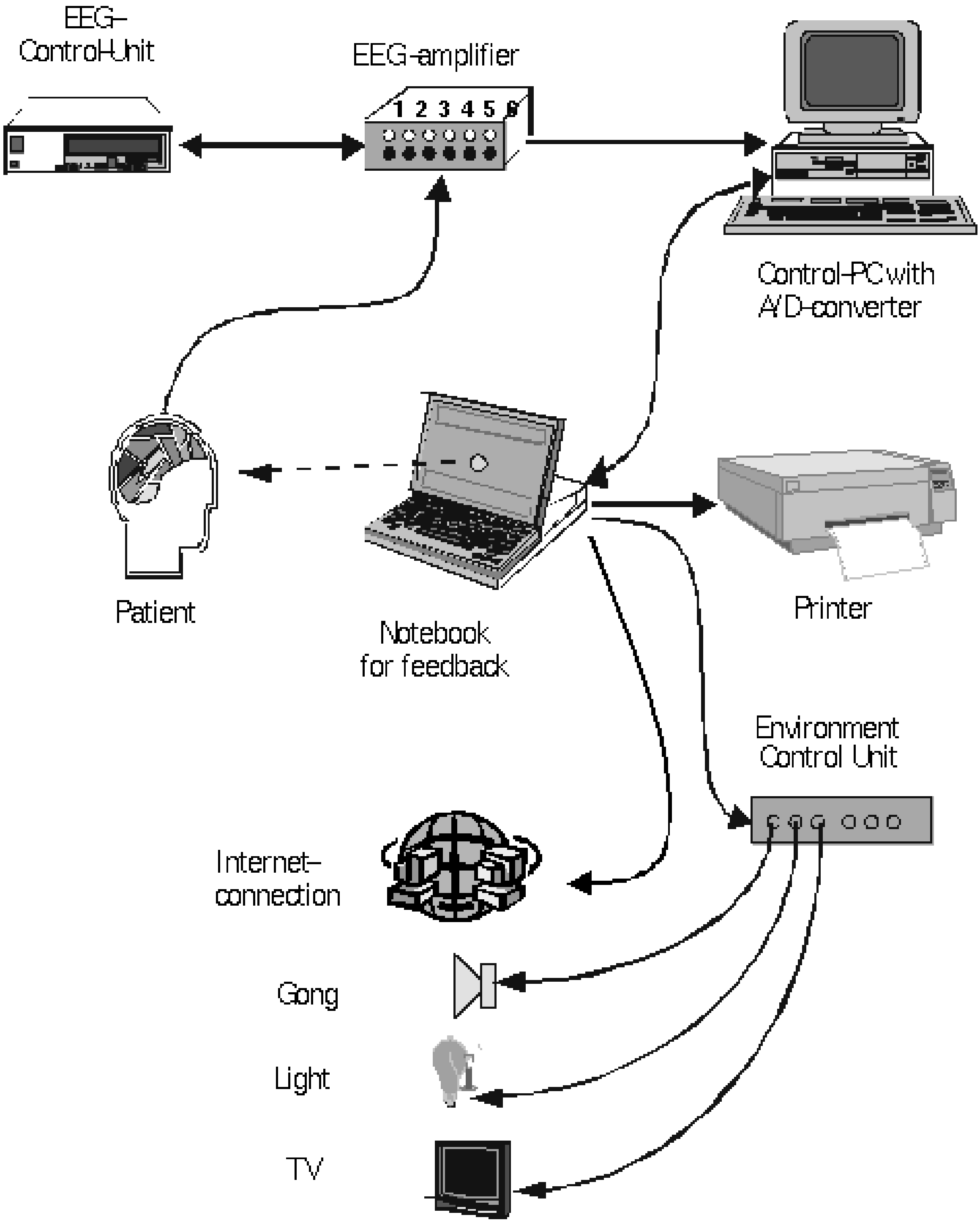

Figure 1: *The TTD - a brain-computer interface. EEG is recorded from the patient's scalp, amplified and transmitted to a control personal computer via an EEG control unit. After analog-to-digital conversion, the analysis program computes slow cortical potential shifts as a moving average of the SCP amplitude across the active phase compared with the average amplitude during a preceding* 500*ms baseline phase. The eye movement corrected SCP curve is fed back to the patient as the vertical movement of a cursor on a laptop screen. At the end of each trial, SCP shifts are classified as positivity or negativity responses based on the amplitude characteristics across the active phase. Positivity responses are used as "select" commands, and negativity responses are used as "reject" commands that serve to operate various applications: a Language Support Program that is connected to a printer, an environmental control unit that can be employed to sound a gong, to switch on the light or other appliances and an internet browser.*

by Kotchoubey et al. [11] and Kübler et al. [13]. In the case of a rejected trial, the position of the lit bar is automatically repeated in the next trial. Because the task has only two possible response outcomes on each trial, the chance accuracy is 50%. A correct SCP shift is reinforced by a "smiley" presented in the center of the screen at the end of the active phase.

When patients have achieved stable response accuracy of more than 70% correct responses, they can start to use the TTD's applications. Patients typically reach such levels of proficiency after $1-5$ months of training with $1-2$ training days per week. A training day comprises $7-12$ sessions, and sessions comprise between $70-100$ trials. The applications that will be described in this paper are a Language Support Program [15] including an advanced dictionary option, a fast communication program for basic desires and an internet browser [16]. All of these programs are driven by simple yes/no responses that serve as "select" or "reject" commands.

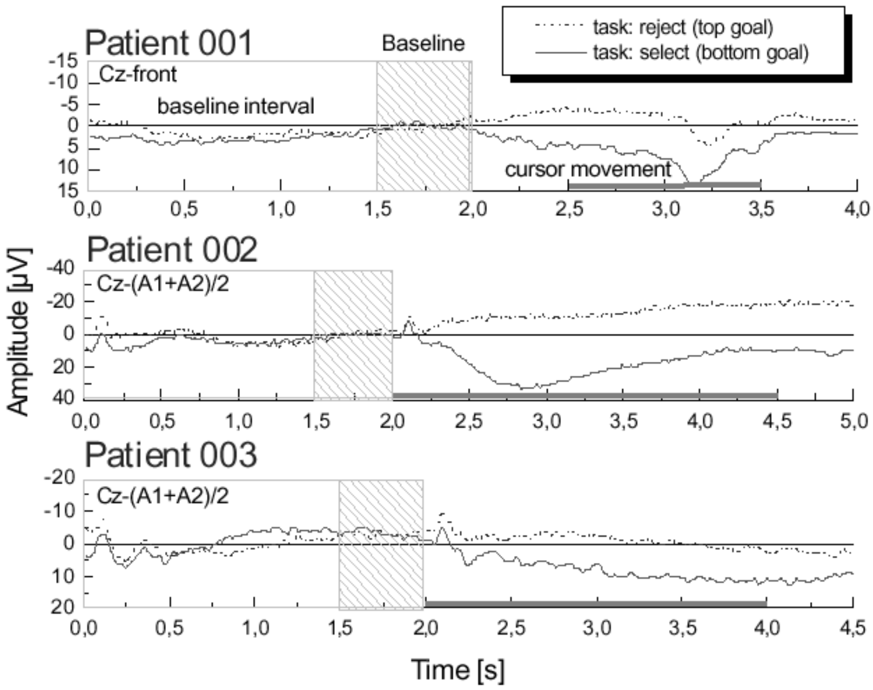

Figure 2: *SCP averages (amplitudes in μV) for each of the three patients. Dotted lines represent the average curves for trials in which negativity (reject) responses were required, solid lines represent average curves for trials in which positivity (select) responses were required. The recording sites were vertex (Cz) in all patients; in patient 001 the forehead was used as a reference, in patients 002 and 003 both mastoids served as reference. The passive, baseline phases had a duration of 2 s, whereas the duration of the active phases varied across patients (001:* 2*s, 002:* 3*s, 003:* 2.5*s). Visual feedback was actually given for* 1*s only in patient 001 (bold line at the abscissa), for* 2.5*s in patient 002 and for* 2*s in patient 003.*

TTD users

All of the TTD users described here were male adults suffering from ALS, a progressive neurodegenerative disease that causes widespread loss of central and peripheral motor neurons, almost invariably progresses to nearly total paralysis and is fatal unless the patient is artificially respirated [6, 7]. Patient 001 (age: 44 years) has suffered from ALS since the age of 33.

He has been artificially respirated and fed for seven years and was almost completely paralyzed except for two facial muscles and unreliable eye movements. Patient 002 (age: 43 years) was first diagnosed at the age of 38. At the beginning of training, he was tetraplegic but still had some control of head and eye movements which he could use to signal yes or no to a communication partner. He could still utter some sounds; however, they were unintelligible even to his closest relatives. Meanwhile his disease has progressed and he is artificially ventilated and fed. Patient 003 (age: 31 years) has been diagnosed with ALS for two years. He had only weak eye movements left and was artificially fed and ventilated. All three patients lived at home and were looked after either by their wives or by professional carers (or both). They have successfully participated in operant feedback training with the TTD lasting from six months to three years and have reached stable correct response rates of above 75% (patients 001 and 003) and 90% (patient 002). Typical SCP averages for each of the three patients are shown in Figure 2.

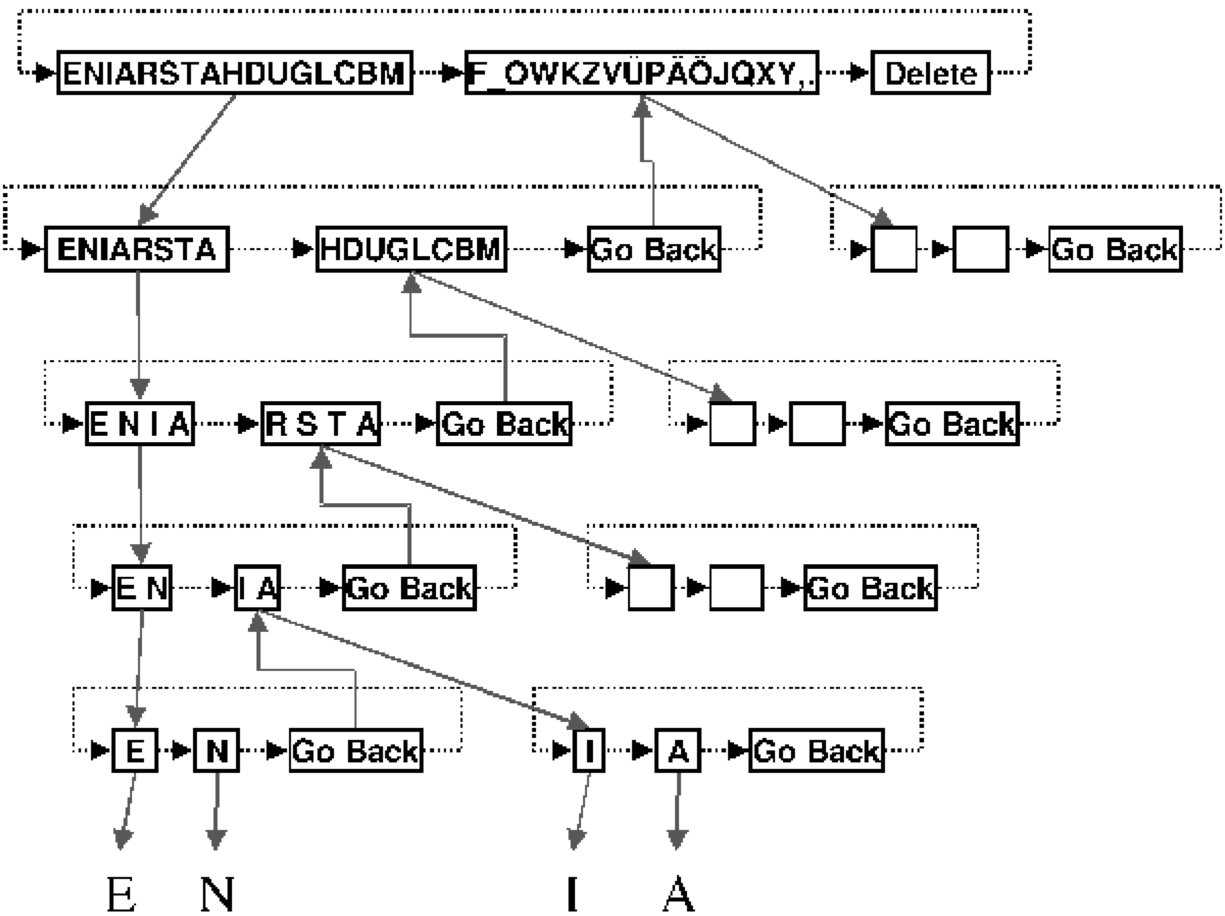

Figure 3: *Schematic structure of the language support program. Boxes show letter sets offered during one trial, solid arrows show the subsequent presentation when a select response is produced; dotted arrows show the presentation following a reject response. When the level of single letters is reached, selection leads to the presentation of this letter at the top of the screen. Texts can thus be generated by adding letter to letter. At all except the uppermost level, failure to select one of the two choices results in the presentation of a "go back" option taking the user back to the previous level. At the top level, double rejection and selection of the delete function results in the deletion of the last written letter.*

Language Support Program

Figure 3 shows the structure of the Language Support Program. The letters are presented in a dichotomous decision tree. At the first level, the alphabet is subdivided into two sets of letters including some punctuation marks. The letters are arranged in a way that facilitates the selection of the more frequent letters, whereas the less frequent letters require more steps to select. In the first trial, one half of the alphabet is presented as the first set of letters. If the patient wants to select one of the letters in this set, he has to generate a positive SCP shift which is coded as a “select” response. In the case of a successful select response (solid arrow), in the next trial the first half of the previous letter set is presented. In the case of a reject response (i.e. negative SCP shift, dotted arrow), the second half of the alphabet is presented. A subsequent select response would then result in the presentation of the first half of this letter set. At the top level, a second rejection would lead to the option for a deletion of the previously spelled letter, after which the program would re-start with the presentation of the first letter set. At subsequent levels, a rejection of the second letter set results in the presentation of a box offering a “go back” option. If the patient selects this box, the program will move up by one level. This is a useful option in the case of unintended selections. If the “go back” option is rejected, the program will again present the first letter set at this level and continue that procedure until a selection is made. At the final level, when the bottom of the decision tree is reached, selection of a single letter will result in this letter being written at the top of the laptop screen. Texts are thus generated by adding further letters to the previously written ones.

In this system, writing the most conveniently situated letter, the “E”, takes five trials, i.e. $20-25s$ depending on the duration of the active phase, whereas writing the most inconveniently situated sign, the period, takes nine trials, i.e. $36-40s$. In an attempt to make free spelling less time-consuming, an advanced dictionary has been introduced in which the experimenters can enter words that are frequently used by the patients. With the dictionary option, a complete word is suggested after at least two letters have been written and a corresponding word is available. This word can then be chosen with a single select response. Initial attempts proved that it was important to keep the number of words in the dictionary small to avoid too many suggestions, therefore we stored only about 500 commonly used words. The Language Support Program including the dictionary option has been used by patients 001 and 003. Patient 001 has already written several letters to his friends and family and enjoys using the program for his private correspondence.

A communicator for basic needs

Patient 002 was unable to use the Language Support Program for free communication because of restricted writing skills. Yet as he was able to read simple sentences, we provided him with a menu containing his most relevant needs and desires. Those 32 statements were grouped under headings and subheadings, and patient 002 could reach the single-statement level by selecting the correct sequence of headings. This structure is not dichotomous but starts with five choices at the top level. For example, if he wants to say ”I want to drink tea”, patient 002 has to select “nutrition”, then reject ”food” and select ”drinks”, then reject “I want to drink water” and select ”I want to drink tea”. Once a complete phrase has been selected, it is written at the top of the screen and a gong sounds to attract the attention of a caregiver.

This program also contains a stand-by option whereby patient 002 can choose to switch on and off the system without assistance from others. Switching it to stand-by is an option in his

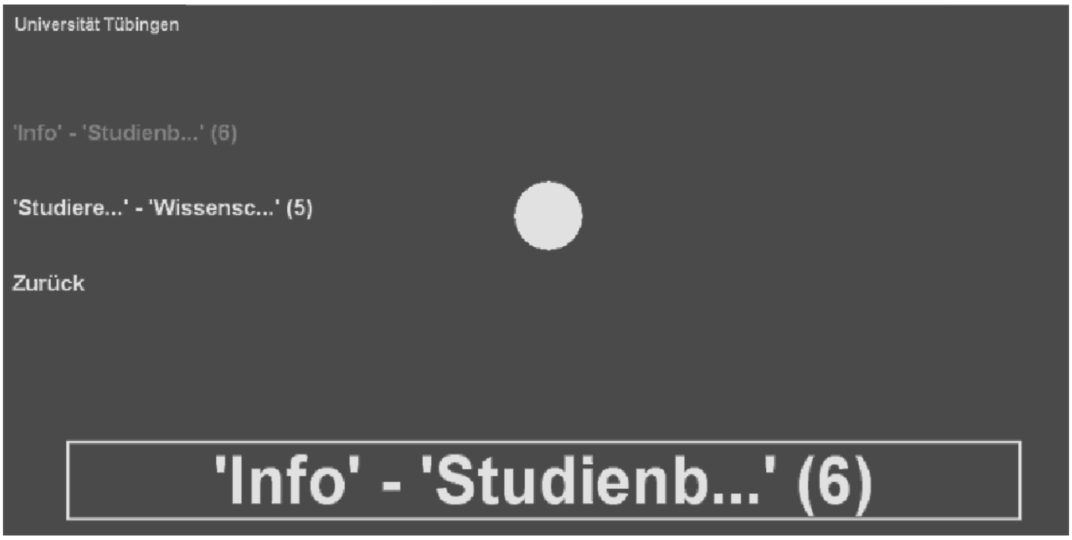

Figure 4: *After an internet page was loaded, a dichotomic decision tree is dynamically produced, containing all links to related sites. During the ongoing selection procedure, the patient has the option to select a link out of this tree. The links are sorted alphabetically. In this figure, the patient can decide whether to choose one of the six links named from 'Info'to 'Studienb ... ', or one of the five links named from 'Studiere ... 'to 'Wissensc... '.*

communicator. In the stand-by mode, the information on the screen is reduced to a minimum and the sounds are removed, so it is not necessary to pay attention to the system. To switch it back to active mode he has to produce a sequence of SCP shifts without continuous feedback of the ongoing SCP changes [10].

The Environment Control Unit

Once a patient is able to switch on and off the system without external aid, it can also be used to control the patients environment, for example for switching on or off the light, selecting a television channel etc. The environment control unit has been built to provide the patient with the option to control up to seven electronic devices. The switch commands are selected similar to the selections of patient 002.

"Descartes": A Brain Controlled Internet Browser

The above described methods help the patients to express their ideas, thoughts and needs. The internet offers an option to get instantaneous access to a desired information. Providing paralyzed patients with a TTD system which allows them to navigate through the world wide web by brain responses, would enable them to take part in the information exchange of the whole world. Therefore a special web-browser named "Descartes" was developed.

"Descartes"is controlled by binary decisions only as they are created in the TTD feedback procedure. The browser functions are arranged in a decision tree as described for spelling words. At the first level the patients can choose whether to write letters, to write an e-mail or to surf in the internet. When they decide to write an e-mail, the e-mail address has to be spelled in the first line using the Language Support Program. When the patients decide to surf in the internet, they first receive a number of predefined links arranged in the dichotomous decision tree. Each web-page the patients have selected with their brain signals will be shown for a predefined time of one to two minutes. The wait-dialog indicates the remaining viewing time for the page until the feedback procedure will continue to select a related page. After the viewing time is over, the current page is analyzed for links on the page. Then a dichotomous decision tree is dynamically produced, containing all links to related sites and the trials continue. The patients now have the option to select a link out of this tree similar to the spelling task. The links are sorted alphabetically so they will quickly find the desired link in the new tree. For example, they are first presented with the links beginning with A-K, then with the links beginning with L-Z and if both were ignored they receive a CANCEL option for returning to the prior level. The lowest level contains the name of the single links which are loaded after selection.

Summary

The TTD offers a wide range of applications which allow patients to communicate even in a totally locked-in state. A language support program with dictionary enables them to communicate verbally and to conduct private correspondence. Patients can switch the system on and off without assistance from others, which provides the option to use the system for 24 hours a day. An environment control unit allows the patients to control devices in their environment and an internet browser, controlled by binary responses gives access to the world wide web. All applications are independent of muscular activity and are operated by self-control of slow cortical potentials only.
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Video Tracking Interface for Dolphins: A New Approach to Interspecies Communication

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Abstract

Over the past fifteen years, laboratory research has revealed a high level of intelligence in the bottlenosed dolphin, where intelligence is defined as adaptive flexibility in behavior. These findings are in keeping with expectations based on the large size of the dolphin brain, especially in neocortex development. Dolphins extract information from their world through both vision and hearing, the latter including a highly developed and specialized echolocation (sonar) system. Studies have shown that bottlenosed dolphins have an excellent memory for sounds heard and things seen. Recent discoveries have shown that their sonar gives them highly accurate 3-D information about their environment that they can easily integrate with their visual world. Additionally, dolphins have an excellent ability to learn rules and concepts, to learn through observation, to imitate sounds or behaviors of others, and to understand symbols as references to things or events in the real world.

Scientists have long sought to find ways to enhance communication with these animals. Attempts to decode their vocalizations using different kinds of acoustic interfaces or even to teach them to produce sounds that resemble English phrases were not successful. On the other hand, dolphins can learn to understand instructions conveyed by sequences of sounds or gestural signals. In so doing, they take account of both the meanings of individual symbols (the semantic component) and of symbol sequences (the syntactic component). Moreover, they can understand these sequences even when presented on a television screen. Even degraded images can be interpreted.

We have been exploring the possibility to use video tracking and other virtual reality technology to build a new interface between humans and dolphins in a shared virtual space. This approach is highly adaptable and allows for both analogue (interaction with virtual objects) as well as symbolic (pointing and clicking at symbols) interactions. Practical aspects of a computer-based interface, such as protection of the electronics against saltwater while still allowing unrestricted access for the dolphins, have to be considered as well as communication with remote human participants via the Internet. The video interface will also allow new forms of interactions between dolphins and computers (games) as well as between dolphins and their environment. For instance, dolphins could turn on and select TV and music programs, and operate other utilities in their environments such as water faucets etc. With the capability of computer based interfaces to store messages one can also expect the emergence of new forms of dolphin-dolphin interactions, both synchronous as well as asynchronous. While this interface can provide new insights into dolphin

communication, it can also enrich the environment of captive dolphins. Once the basic interfaces and communication protocols are established, wireless communication networks will open new, exciting possibilities for human-dolphin interactions.

Dolphins Have Large And Complex Brains

The brain of a bottle nosed dolphin weighs about $1500g$, slightly more than the brain of a modern human, which weighs in the average about $1400g$ and about three times the weight of a gorilla brain. Dolphin brains are also highly convoluted, yielding a large cortical surface area, similar to that of human brains. The cortical volume, however, is slightly less than that of the human brain. Images comparing a dolphin brain with a human brain can be found in the University of Wisconsin and Michigan State Comparative Mammalian Brain Collections [1].

Since dolphins did not evolve the capability to manipulate their environment through the use of tools they apparently did not use their intelligence to create cultural artifacts like the human species. One question that one might ask is what they did use their large brains for instead. There are more than 30 species in the family of dolphins (*Dephinidae*), including, for example, the killer whale, pilot whale, and bottlenosed dolphin. Thirty years of study of the bottlenosed dolphin at the Kewalo Basin Marine Mammal Laboratory has revealed the exceptional intelligence and cognitive flexibility of this species (e.g., see reviews in [2, 3, 4]).

Figure 1: *Dolphin using ultrasound to recognize an object hidden in a box (left).*

Acoustic 3D Vision Interface of Dolphins

In their interaction with the environment humans primarily rely on vision and hearing. While we can learn to recognize objects through both their image as well as their sounds we only can do that cross modal integration for objects that we are familiar with: If we hear the sound of a drum we can associate it with a picture of a drum. But we cannot hear the shape of a drum or make any inference from the sound of an unknown object to its visual appearance. Dolphins, however, are able to "hear" the shape of completely novel objects even if they have a rather complicated shape. As of today there is no explanation of how the dolphins are able to do that but there are some indications that they might use their lower jaw for "acoustic near-field holography" (Figures 1, 2 and 3).

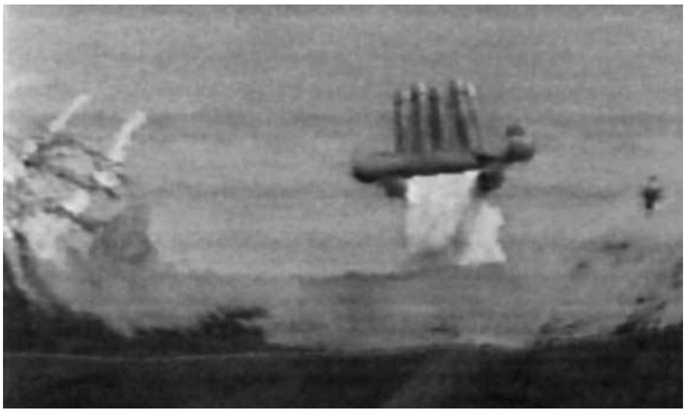

Figure 2: *One of the objects as seen from the dolphin's perspective underwater.*

Figure 3: *Dolphin pointing to an object that she identified as the one hidden in the box. Note that the object is in air so it cannot be scanned by ultrasound.*

Dolphins Understand Syntactic Language

In language, syntactic rules define the grammatical relationships among words and allow us to build complex sentences out of simple language elements. In Figures 4-7 we see experiments that show how dolphins are creative in interpreting novel sentences. The language elements here are "basket", "person", "hoop", "surfboard", "fetch","?". The dolphin can answer yes/no-questions by pressing one of two levers. In fig. 4 we see the dolphin answering "basket?" with "no" since there is no basket in the pool. The general syntax of the sign language that was taught to the dolphins is of the form: object – subject – predicate. For instance the sentence in fig. 5 is: "person- surfboard- fetch" indicating that the dolphin is asked to fetch the surfboard and take it to the person. In fig. 6 we have a sentence that is identical except that the word order is changed, which gives the sentence a new meaning: "surfboard- person- fetch" i.e. this time the dolphin is asked to take the person to the surfboard. Figure 7 illustrates that the dolphin is able to creatively improvise when a new, impossible sentence is constructed: The dolphin is asked to take the person to the hoop, but there is no hoop in the pool. The dolphin answers in the only reasonable way, namely taking the person to the "no"-lever.

Figure 4: *Dolphin pressing the "no" button to indicate that there is no basket in the pool.*

Figure 5: *Dolphin takes the surfboard to the person, indicating that she has correctly understood the sentence.*

Dolphins Are Aware Of Themselves and Others

Dolphins are very capable of social learning. They have no problems to instantaneously imitate different and even new behaviors from other dolphins, humans, and even abstract video images of humans. In the process they can show surprising creativity in displaying closely analog movements. For example, the dolphin uses its tail as an analog to the human leg. If the human raises a leg in the air, the dolphin will raise its tail. Dolphins can also imitate their own actions by responding correctly to requests like "Repeat what you just did" or "Create: Do something that you have not done before."

Figure 6: *Taking the person to the surfboard, the correct response to the changed word order.*

Figure 7: *The dolphin is asked to perform an impossible task, namely to take the person to a non-existent hoop. Instead, the dolphin takes the person to the "no" lever seen in the back to the right.*

Dolphins And Television

We have previously shown that dolphins are surprisingly adept at interpreting television scenes (see e.g., [5]. The dolphins spontaneously responded appropriately to live television images of trainers gesturing to them in a familiar sign language the very first time they were exposed to television. Their responses to the televised trainer were as accurate and as reliable as their responses to trainers in the real world (Figures 8 and 9).

Furthermore, the dolphins were able to interpret degraded or abstracted images of televised trainers (e.g., a pair of hands moving about in black space tracing out gestural commands) almost as accurately as they interpreted whole body images. We have also demonstrated that dolphins can imitate the movements of a televised trainer (for example, if the trainer performs a pirouette, the dolphin will do likewise), can recognize abstract objects presented on a television screen as accurately as they can recognize objects in the real world, and can attend to rapid sequences of abstract shapes flashing by on a television screen and report (by pressing a paddle) the occurrence of selected "critical" symbols. Thus, the video medium is easily accessible to them as an information source and is interpreted by them as a representational world (as contrasted with the real world).

Based on these observations of the intelligence and communication skills of dolphins we were

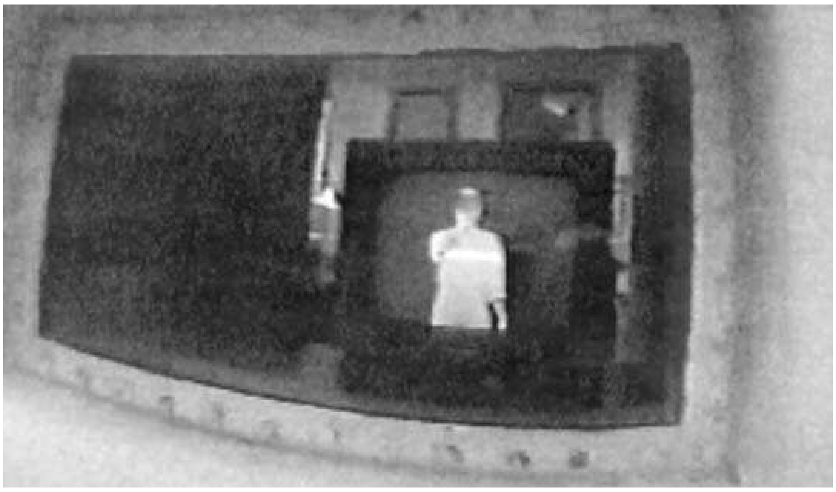

Figure 8: *Dolphin's perspective of TV-image of trainer behind unwater window.*

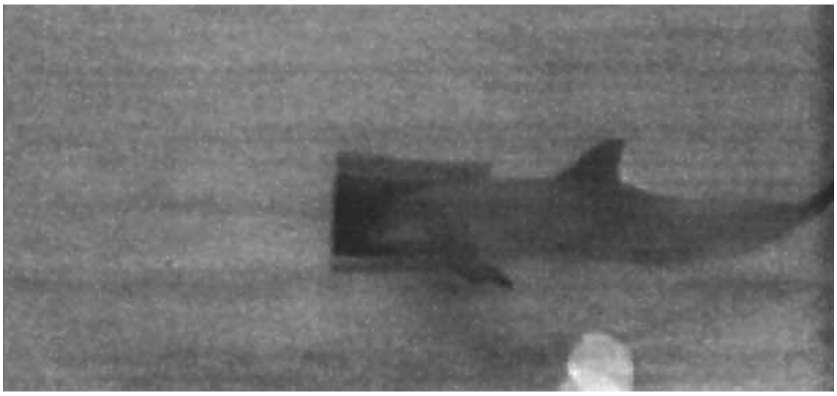

Figure 9: *Dolphin in front of underwater window watching the TV.*

convinced that dolphins would be able to quickly learn a new, computer-based interface. The central problem is to develop an interface for intelligent creatures who have no hands and who live in an environment that is very hostile to modern electronic equipment.

Video Tracking Interface For Dolphins: "Giving Dolphins A Hand"

The video-tracking interface for humans was introduced by P. Weibel more than twenty years ago. Since then it has found many applications in the area of gesture control. Because it avoids exposure of the equipment to aversive environmental conditions (salt water) it is ideally suited for a communications interface between humans and dolphins. A major advantage of this concept is also that it does not require permanent physical installation. In fig. 10 we see the basic setup. Some of the new opportunities of this system are:

- Asynchronous communication (writing, image recording)
- 24h access to humans with specific requests

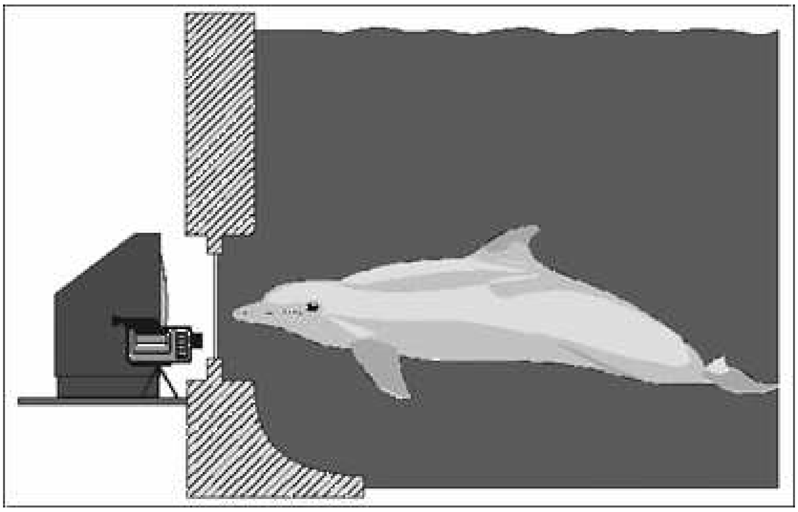

Figure 10: *Current set-up of TV monitor with camera in front of underwater window. The dolphin sees her own image in a computer generated virtual environment. The computer tracks the position of the dolphin's rostrum as captured by the camera.*

- Cooperative activities and games
- Introduction of symbolic money (barter, trade)
- Introduction of shared control (voting)

One concern was that the dolphin anatomy might make it difficult for the dolphins to view the video image head-on. We could confirm, however, that dolphins did indeed gaze at their video image head on and seemed to have no problems with obscured vision. They are aided in this task by an interesting feature of their anatomy that allows them to protrude their eyeballs slightly, thereby enhancing the overlap of their visual field directly in front of them (Figure 11).

Representation Of The Dolphin In The Video Display

Once the location of the dolphin or its rostrum has been tracked there are a number of different options as to how this information will be displayed on the screen so as to provide the most useful information for the dolphin.

The dolphin's rostrum can be represented on the video display by a relatively small, easily distinguished icon, much as a small circle of white light. A small icon will allow for precise positioning. The dolphin will be able to learn that the icon will "do something" if it "touches" (collides with) images on the screen. The actions triggered on the screen can be directly or indirectly associated with reinforcement. The representation of the cursor as a video image of a body part has been used by the Vivid Group and incorporated in a patented, commercial product. It is available in form of the Mandala gesture control system. Games based on this system are widely used in theme parks and virtual reality arcades.

For our project the Mandala system could be modified to satisfy the specific needs of this application. Among them are the adaptation to the dolphin anatomy and the implementation of specific actions as feedback for the dolphins.

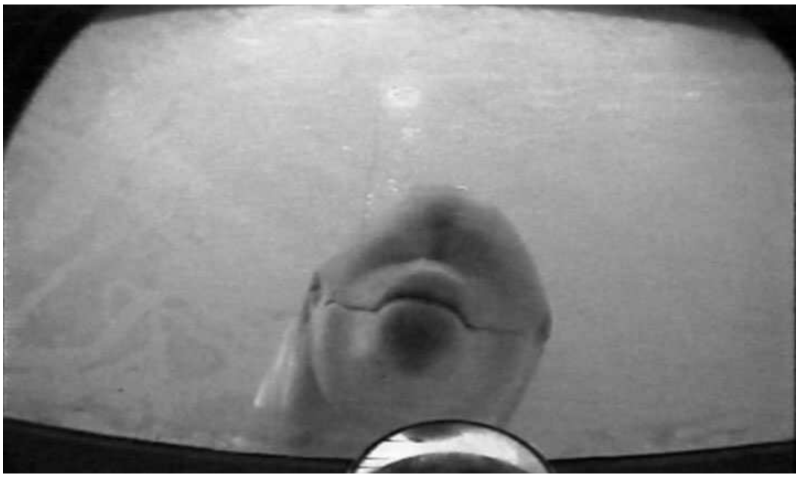

Figure 11: *Elele looking at the screen straight on from a close distance (her rostrum touches the window). Both eyes are clearly visible indicating that she has a binocular view of objects on the video display.*

Other modifications will allow for using the system on a network and across the Internet. Once the dolphin has learned the basic control of objects on the screen, the shape of the cursor can be modified according to specific needs. It can take on abstract forms or the form of avatars that the dolphin can choose or even modify.

Given the availability of appropriate funds the windows and thereby the workspace can be significantly enlarged such that all four dolphins could be tracked simultaneously. The synchronous tracking of several dolphins is not a significant technical complication since tracking needs to occur only in two dimensions.

Connections To Web Cams And Tele-Presence

An interface based on video tracking has a number of potential applications that go well beyond the specific project described. The connection to traditional web-cams is evident and can be implemented with available technology. Added levels of interactivity can be implemented according to needs and availability. Once the basic video-tracking interface is established it can be used like a regular mouse for basically all standard programs with a graphical user interface (GUI). For instance, collaborative tools like Microsoft Net-Meeting can be directly used simultaneously by a dolphin and a human to share applications like a white-board while at the same time being connected via an Internet videophone.

Besides the use of a video-tracking interface for communication with human (or other) partners, its use as a general computer input device could give the dolphins the capability of a tele-presence outside of their tanks by, for example, actively controlling video cameras from the computer screen. In the context of the collaborative computer games discussed in section 3, a dolphin could direct a real camera to real locations that are part of the game.

Real-Time Video Interactions

The dolphins at KBMML understand and respond to more than a hundred symbolic gestures. This is to our knowledge the largest reported repertoire of dolphin behavior associated with human gestures. The dolphins understand how these basic gestures can be combined to build complex sentences, often with new and generalized meanings [6, 3]. Since the dolphin can recognize the gestures when they are given on a TV screen, it is feasible that communication with the dolphins can be established through video-conferencing links. Therefore we propose to install ISDN lines and a video conferencing setup at KBMML to establish the possibility of long distance communication with interested participants from around the world. To our knowledge this has never been done before and therefore could signify a new dimension of global interspecies communication at the beginning of the new millennium (see also [7]). The human interest in real-time interactions with dolphins has witnessed a dramatic growth over the past years, as indicated by, for instance, several hundred volunteers who visit KBMML every year to learn about the dolphins' symbolic language and how to interact with them. The Dolphin Institute can prepare instructional videos and on-line educational material to teach the basic concepts of symbolic communications with the dolphins. With this interface, people from around the world could get hands-on experience in dolphin interaction and training. After completing the video instructions, the participants could make an appointment for a real-time video training session. At the beginning of the session the participant would get an on-line briefing from an on-site instructor about the training session and about the dolphin the participant would be working with. During that briefing an outline of the session structure also would be established, including what types of teaching material and objects would be used during the session. The camera system at KBMML would automatically track the movements of the dolphins so that the participant can at all times follow the dolphin's behavioral responses. The session could be recorded and sent to the participants in the form of videotapes or digital video on the Internet.

Requirements: Video-conferencing hardware + software. Creation of instructional video. *Time schedule*: All of the technical components are commercially available. The dolphins already understand how to interact through video. No new training for the dolphins is required and therefore an installation for this interaction could be set-up within a very short time period.

Audio Interfaces

In the context of human computer interfaces, speech recognition software has seen dramatic progress over the past few years. Commercial software is available both for dictation and for voice control of computer functions. Extensive research experiences at KBMML demonstrate the ability of dolphins to voluntarily produce a number of different vocalizations in response to a hand signal of the human trainer. Among the standard vocalizations the dolphins produce during training sessions are "click", "sing", and "whistle". Earlier attempts to train dolphins to produce a large vocabulary of sounds that can be differentiated by a trained human listener proved to be difficult. Therefore it might be difficult even with modern speech recognition software to reliably discriminate between a large number of different dolphin vocalizations. For our project, however, this might not be necessary.

"Button Down" Signal

In the context of a computer mouse input paradigm, one or two clearly differentiable and reproducible vocalizations are sufficient for all input tasks of a modern graphical user interface. As mentioned above, cursor positioning can be done rapidly and with high precision by tracking the dolphin's rostrum. With the help of special illumination of the space close to the window or with an array of photo-gates, tracking could be restricted to the condition that the rostrum is within a few centimeters of the window. This would reduce the risk of spurious cursor movement and allow the dolphin to reposition herself between cursor movements.

Figure 12: *Hiapo responding to his video image with aggressive jaw clapping.*

If the computer mouse input were connected to the tracking output then a natural choice would be to connect the mouse button input to the output of a device that recognizes one (Apple Macintosh) or two (Windows) distinct vocalizations.

During the training phase the dolphin can learn that a single vocalization in combination with cursor collision with specific screen objects will trigger a desired response. This required combination of position and sound input would avoid unnecessary false alarms by random and inadvertent collisions. This makes the interface more specific and thereby more efficient.

Further specificity could be achieved if the dolphins could be trained to use their characteristic signature whistle as input signal. In that way the response of the computer could be individualized to specific training programs for each individual dolphin.

Preliminary Observations

Self-Recognition

Although the KBMML dolphins had ample prior experience in getting instructions from a video display, as well as watching TV during their unstructured time, they were never before exposed to a live video image of themselves. In the afternoon of May 20, 1999 a video camera was installed next to the video display that showed a live image of the dolphins at the underwater window watching the TV (See Fig. 10). The dolphins had finished their scheduled training program and were quietly swimming in pairs.

As soon as the video display was turned on, the response of the dolphins was quite dramatic. Several dolphins crowded around the window. This is very unusual, since both during training and unstructured TV time the dolphins watched the display one at a time. Most of the dolphins (especially the young male, Hiapo) initially showed strong threat behavior including aggressive jaw clapping (Fig. 12). In addition to the novelty of the experience, the aggressive behavior might have derived from the viewing configuration: the initial camera setup was such that the movement of the video image was opposite to the movement of the dolphin. If the dolphin moved to the left, the video image moved to the right and vice versa.

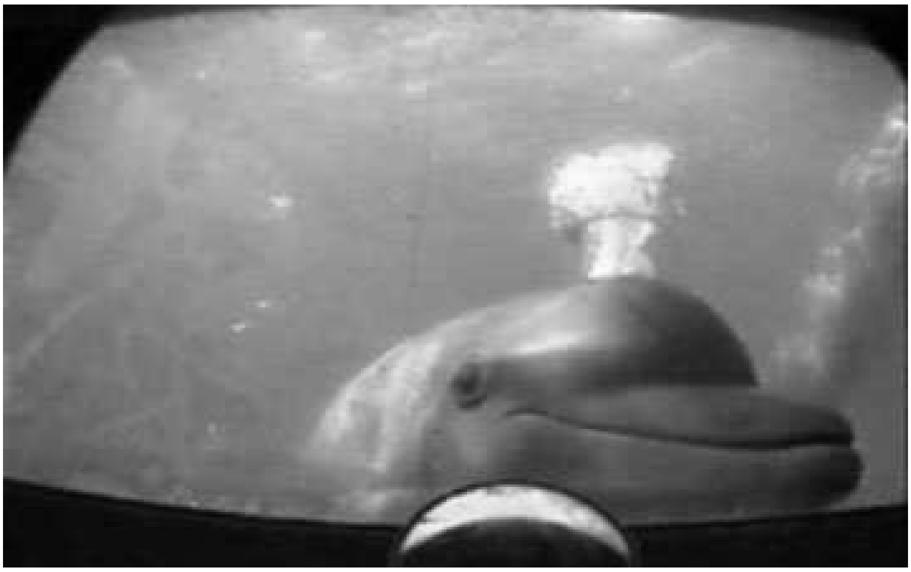

Figure 13: *Elele blowing a bubble ring while watching herself on the video display in real-time.*

We changed the configuration with the help of a mirror in front of the camera so that the dolphins saw an electronic mirror image of themselves with the more intuitive movement direction. It was evident that the dolphin explored this new interactive toy by blowing bubble rings or performing other peculiar behaviors like body rotations (Fig. 13).

Simulating the Computer Interface for Dolphins

After we could observe how dolphins interact spontaneously with their video image we introduced a first interactive interface with computer-generated icons (see Figures 14 and 15). The icons were placed at the four corners of the display and each icon was associated with a simple animation that was triggered when the dolphin image got close to it. For instance, the dot would grow and cover the screen, the star would rotate, the two ovals would oscillate horizontally (simulating human hand clapping gesture), and a ball would bounce over the screen. Each animation would last for a few seconds and take over the whole screen so that during that time the dolphin image would not be displayed. The dolphin would see both the video image and the computer-generated graphics display as shown in Figures 14 and 15. Since we currently do not have access to an appropriate video tracking system, a human observer triggered the appropriate animation as soon as the dolphin got keyed on the vicinity of the icon. Thus, no vocalizations were needed for the trigger. The response time for this prototype was rather slow but from the response of the dolphins we learned a number of very important lessons about details of design requirements for the interface that we propose to build.

These initial pilot studies were very encouraging and we are convinced that within a short training time the dolphins will become proficient at manipulating elements of the video display.

Figure 14: *Video image of Elele superimposed with four computer-generated icons that will trigger different events. Tracking of the dolphin's rostrum was done manually.*

Future Directions: Introduction of Abstract Concepts

Time

One of the most fascinating research results from KBMML is the finding that dolphins are able to understand a reference to their actions that have occurred in the past. Commands like "Do what you just did one more time." are easily understood by the dolphins. To our knowledge this is the only reported case that animals can make an abstract, symbolic reference to their past behavior.

Of course an analog sense of time (time of the day, feeding time, time for training etc.) is present in dolphins, just as it is in many other more or less intelligent animals. The video tracking interface would provide for the first time a natural basis for symbolic communication about time: A display of an analogue clock could create associations between physical time (time for feeding) and symbolic time. It would be interesting to explore other than the standard clock designs of two hands periodically going around in circles. Maybe even some new symbolic designs for digital watches can help us better understand the dolphins' sense and understanding of time.

From a practical perspective a time interface would be very useful, especially for dolphins that regularly interact through the Internet with specific groups of humans. If they had a sense that a session with their remote human partners is nearing they could get ready in front of the video interface.

Barter and Token Economy

In a certain sense dolphins and whales can be compared with human hunter-gatherer societies: They have developed their own communication system, form stable social groups, collaborate in hunting, including the use of fairly sophisticated tools like the bubble nets of humpback whales.

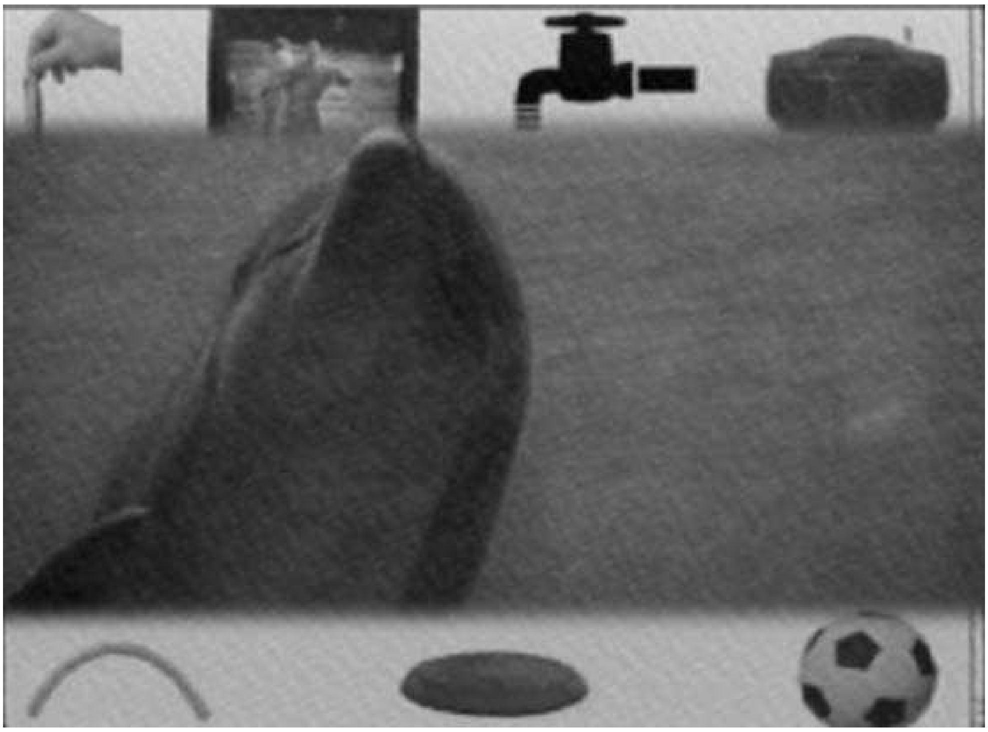

Figure 15: *Similar to Figure 14 with icons representing real objects in the dolphin's environment that are of interest for them: (clockwise from top left): fish, TV, spigot, music, soccer ball, Frisbee, "noodle" toy. The process steps of this universal interface could be for instance: Signature whistle activates interface, Tracking rostrum selects hot spots, Vocalization triggers action.*

At KBMML dolphins sometimes return the last fish of a training session, which is interpreted by some trainers as a request to continue interacting with them. If that interpretation is correct, then the dolphins show some form of bartering behavior: fish in exchange for desired activity or service. For the experienced dolphins, fish is not the only reinforcement. Whistles, hand clapping, etc. can serve as secondary reinforcement that provides feedback to the dolphin that her behavior has been accepted and that a fish reward will be forthcoming.

With the help of our proposed dolphin-computer interface a symbolic token or fish-currency could be introduced: After each completed task an additional fish icon appears on the screen for the corresponding dolphin. If the dolphin "cashes in" the virtual fish for a real one (pointing at the fish icon and then receiving a real fish) the fish-account will be reduced accordingly. With a simple modification the concept of numbers could be introduced if several of the fish tokens would be exchanged for a single real fish.

Other forms of barter emerged spontaneously from the dolphins: They learned that KBMML wanted to keep the tanks free from leaves that were blown in from the surrounding trees. The dolphins quickly adapted to this policy and picked up the leaves to exchange them for extra fish rewards. In another observed example trainers may ask the dolphins to bring them all the toys that were used during the sessions. Some dolphins seemed to not notice certain toys (e.g. plastic rings at the bottom of the tank). When the regular ration of fish was spent they would suddenly "find" the missing toys and only return them to the trainer in return for some extra fish.

Institutional Power and Collaborative Behavior

With the introduction of "fish-money" and the possibility of trading among the dolphins one would generically expect asymmetry (some dolphin ending up with more fish than others.) and therefore the emergence of a power structure. How would that interact with their social "pecking order"?

The formation of such a structure can be controlled to some degree by the trainers. For example, certain actions (like turning on the TV-set) could require that several or all the dolphins activate buttons simultaneously. This process would also introduce a simple concept of "voting" for the dolphins.

One could also speculate about the outcome of giving different dolphins different types of control: One dolphin could have control over the TV while others could control the water fountains or other sources for secondary reinforcement. That means only one of the dolphins could "turn on the TV" and other dolphins would have to "ask" the "TV administrator" to do that for them. Would trading emerge?

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Listening to Chaos: the Aural Representation of Irregular Rhythms

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Abstract

Deterministic chaos is the prototype of an irregular nonrandom pattern generator. We describe the acoustic representation of chaotic time series as a means of analyzing its rhythmic properties. Sound tracks of deterministic chaos and coupled chaotic systems are available on the Internet.

Introduction

The link between the physical world and the human mind is mediated by measurable activity of neurons in the brain. This fundamental interface is composed of myriads of ever-changing rhythmic events. These events are neither strictly periodic nor can they be completely random if they are to generate any meaningful relationship between outside world and mind. A science of this particular interface therefore has to attempt an understanding of its irregular non-random rhythms.

The ear specializes in the detection of transient temporal patterns. It does so by analysing and interpreting pitch, timbre and rhythmic occurrences of tones and noises. In natural environments rhythmic events in general occur in an irregular fashion. In contrast, in classical Western and popular music mostly regular rhythms are employed. However, from classical Indian and several kinds of African music it is known that the ear can be trained to perceive and distinguish even highly irregular musical rhythms that are non-random. We propose that these pattern detection skills can be exploited for the analysis of experimentally recorded temporal events if the corresponding time series is represented aurally.

Deterministic Chaos

The mathematical prototype of a non-random irregular temporal pattern generator is deterministic chaos. Chaos can be created by fairly simple sets of ordinary differential equations. Its most compact presentation is that of a chaotic attractor in the phase space spanned by all variables. Numerous studies have revealed the complex geometric properties of the phase space that give rise to a chaotic solution. The rhythmic properties of its corresponding time series, however, have not been considered in detail so far. Fig. 1 shows a chaotic time series produced by integrating the equations of the so-called Rössler attractor [1]:

$$\begin{aligned} \dot{X} &= -\omega Y + 0.16\,X \\ \dot{Y} &= +\omega X - Z \\ \dot{Z} &= 0.2 + Z(Y - 10) \end{aligned} \tag{1}$$

where X, Y, and Z are time-dependent variables, $\dot{X}$, $\dot{Y}$, and $\dot{Z}$ denote their derivatives with respect to time, and ω is a parameter controlling the frequency of the harmonic oscillator in variables X and Y.

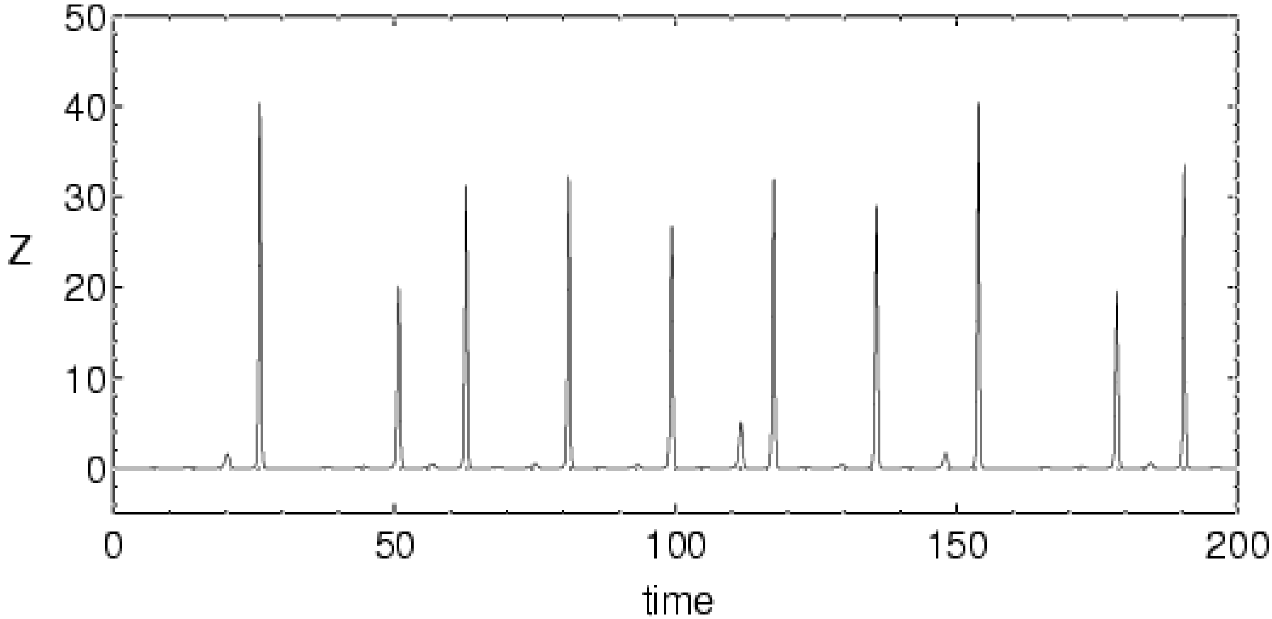

Figure 1: *Time series of variable Z in equation (1).* $\omega = 1$.

Aural Representation

Variable Z keeps switching between a near-zero "resting state" (for values of Y below a threshold) and spikes of varying amplitudes (for values of Y larger than the threshold) and is thus an ideal rhythmic variable that can directly be used for aural representation. We chose the time series of variable Z to modulate the intensity (loudness) of a given synthetic tone. The modulation is tuned such that for the near zero state of the variable the tone cannot be perceived by the ear. The intensity of the tone increases with increasing value of Z during a spike. Thus only spikes above a certain threshold are audible.

A tone or noise is chosen from a sound generator (with arbitrary frequency composition) and the maximum loudness of the largest spike amplitude is adjusted. In addition, the speed of the modulation which is applied to the tone has to be set properly. The human ear has a certain frequency window within which it processes rhythmic events optimally. If, on the one hand, a sound is repeated too quickly (e.g. more than ten times per second) the individual beats are no longer resolved and the perception switches to a continuous sound experience. If, on the other hand, events are separated by too long periods of time (e.g. more than one minute between events) the temporal distances cannot be judged accurately and rhythmic properties are not being detected without additional aid.

As is common with visual representation we have let our perception of the recording judge as to which speed to choose. In general, we found it helpful to select a slower speed for the analysis of specific events on a short time scale and a higher speed for an overall rhythmic impression. The examples presented here are recorded at a comparatively high speed that emphasizes the "rhythmicity" of the chaotic spiking.

The four sound tracks described below are available on the included audio CD (tracks 2–5) and from the Internet as .wav files:

http://basic-research.zkm.de

(The webpage also contains further examples which are not discussed here.)

Results from Simulations

The first track contains the rhythm of a chaotic time series of variable Z from Rössler's attractor (Track 1). A prominent feature of the track is the maintenance of a steady, fairly regular "pulse". This is due to the fact that Rössler's equation has a harmonic oscillator in variables X and Y at its core. Harmonic oscillations regularly perturb the switching variable Z. The spiking response of Z depends on the amplitude of the harmonic oscillations. Chaos is generated in this system when the amplitude of the spikes in Z in turn is fed back to the X/Y-subsystem to modulate the amplitude of the harmonic oscillations. Therefore the "chaoticity" is more prominent in the irregular intensities of consecutive spikes rather than in their frequency. From time to time a short-term expectation of a quasi-regular measure is built up by repetition of some motif but this expectation is soon frustrated by either an additional or a missing beat. With its playful variation of these frustrations the system exhibits a subtle sense of humor.

Track 2 is a recording of the time series of two similar chaotic systems. The difference between them is created by choosing slightly different frequency parameters ω_1 and ω_2. ω of the respective harmonic oscillations. Each system maintains its basic pulse but the individual beats are independent of each other. The frequencies keep phase-shifting relative to one another. However, as both systems produce basically the same limited set of rhythmic motifs they occasionally appear to mimic each other.

Track 3 is a recording of two weakly coupled chaotic systems. The chaotic systems are chosen as in track 2 but this time a linear coupling introduces correlations between the individual beats in the systems. The coupling is added as $\epsilon(X_2 - X_1)$ in the equation for $\dot{X}_1$ and as $\epsilon(X_1 - X_2)$ in the equation for $\dot{X}_2$. The coupling strengh ϵ was chosen such that the complete system of six variables is in a state of intermittent synchronization [2]. Sometimes the two subsystems synchronize and produce the same sequence of beats for a while but then desynchronize again. By adjusting the coupling strength the average duration of synchronizations can be tuned. In addition to the chaoticity of the synchronized system (already present in the uncoupled systems) we found the unpredictable bursts of desynchronization particularly pleasing for the ear.

Experimental Time Series

Clear evidence of deterministic chaos in biochemical and biological systems was obtained for experimentally recorded time series from an enzymatic reaction [3] and from the spontaneous spiking of a pacemaker neuron of the marine pulmonate mollusk *Onchidium* [4]. Recently, some evidence for low-dimensional chaos in calcium signalling of rat liver cells was found [5]. The rhythmic properties of these recordings are remarkably related to the abstract Rössler chaos.

We used an experimentally recorded time trace of the concentration of the so-called compound III in the peroxidase-oxidase reaction. In this system the enzyme peroxidase catalyzes the oxidation of NADH with molecular oxygen in the presence of an aromatic phenole. The reaction is kept far from thermodynamic equilibrium to allow the self-organized formation of dissipative temporal patterns. Depending on the experimental conditions these patterns can be periodic or chaotic. The example of Track 4 was recorded from a stationary chaotic regime that lasted about one hour in real time. There is a certain underlying pulse and the beats are unevenly spaced such that a precise prediction of future events is bound to fail. The system never settles to an exact repetition of a past sequence. Thus the track demonstrates events that are rhythmically organized similar to the chaotic process in Track 1.

Discussion

The aural analysis of deterministic chaos reveals some remarkable features. On the one hand, the intrinsic dynamics of chaotic attractors generates a sequence of pulses that avoids any perfectly regular (=periodic) temporal evolution. This is achieved by the local divergence of any two spike sequences that are not perfectly identical. In eq. (1) divergence is achieved with the additive term $0.16\,X$ in the first line. Variable Z acts as an amplifier of this divergence. Consequently, even two extremely similar but not perfectly identical sets of spikes will evolve differently after some time.

On the other hand, the chaotic process avoids arbitrary irregularity. Both frequency and amplitude of the dynamics are restrained to finite ranges. A given signal follows a smooth, bounded and restricted path on a subset of the phase space. Discontinuities do not occur. Because the chaos is derived from a periodic oscillator by a cascade of subharmonic bifurcations the main frequency of this oscillator is maintained throughout the chaotic spiking and provides a reliable basis for the acoustic perception. In spite of breaks and off-beats the sense for the overall rhtyhm is never lost.

Two independent chaotic systems produce beats without correlation. However, coupling between two chaotic systems introduces a preference for certain rhythmic relationships between the two sources. In the simplest case strong coupling leads to complete synchronization. Another possibility is lag synchronization where one signal follows the other with a fixed phase delay. Between the synchronized and the desynchronized state transient synchronization is found. Transient synchronization gives an example of the complex non-random interplay possible with coupled chaotic beat or spike generators. Among others transient antiphase locking and the change of the mean number of beats within short time intervals can be detected. In the brain, spontaneous transient synchronization of groups of neurons has been observed *in vivo*, for example in the auditory cortex [8].

Taken together these features of the chaotic differential equation create sequences of beat motifs, disctinct rhythms, that arouse more interest in a human perceiver than a strictly periodic or a completely random sequence of beats. It may be of practical interest that nonperiodic yet correlated rhythmic events can be used for the transmission of complex pieces of information as is realized in human language or some kinds of music (albeit on a higher level of complexity).

In the case of the peroxidase-oxidase reaction the physiological relevance of the observed chaos is not clear. A functionally important occurrence of aperiodic rhythms in biological systems, however, is the excitation of nerve cells in ganglia and brains. In that case it is widely assumed that the spike trains encode and convey relevant pieces of information. Although there exists some evidence for simple chaos of the Rössler type in spike sequences from somatosensory cortex in rats [6], the majority of activities shows more complicated irregular porperties. Nevertheless, it was shown convincingly that e.g. neocortical spiking organizes to irregular yet highly reliable spike sequences in response to complex stimulations [7]. This leads to the hypothesis that not only the mean frequency of the spiking but also the individual intervals between spikes and rhythmic motifs may contain informations.

Whether or not deterministic chaotic processes are actually involved in information coding in nerve cells in the brain is an open question at present. However, the rhythmic properties of irregularly firing nerve cells are not well understood and should be examined acoustically. This would allow a search for hidden transient correlations that are not be obvious to the eye and may escape conventional algorithms of analysis that neglect rhythmic properties. Our preliminary studies indicate that the human ear may be capable of detecting changes in irregularity that affect rhythmic properties.

Outlook

It is conceivable that there exist a large number of levels of deterministic irregularities between simple chaos and true randomness. For instance, the unsynchronized behavior of two coupled chaotic systems is an example of hyperchaos, i.e. chaos with two sources of irregularity. In principle hyperchaos can have an arbitrarily high dimension (see e.g. [9]). In systems described by four or more ordinary differential equations other yet unknown irregular types of deterministic behavior may exist. We propose that the rhythm-detecting properties of the human auditory system can be used to classify different levels of irregularity and, in particular, can successfully be trained to detect short-term correlated events in long irregular spike sequences if they are presented as audible rhythms (e.g. in recordings of the EEG from the human scalp [10]).

Acknowledgements—We thank Otto Rössler for training our visual perception of chaos. The experimental data from the peroxidase-oxidase reaction were kindly provided by Lars Olsen, Ursula Kummer and Marcus Hauser. G.B. gratefully acknowledges financial support by CONACyT (catedra patrimonial no. 980071).

List of Sound tracks

Track 1: Rhythm of variable Z as displayed in Fig. 1 $\omega = 1$.

Track 2: Simultaneous rhythms of variables Z_1 and Z_2 in two systems eq. (1) with frequency mismatch. Frequency parameters: $\omega_1 = 1.015$, and $\omega_2 = 0.985$.

Track 3: Combined rhythm of variables Z_1 and Z_2 as in track 2 but with linear coupling between the two systems. Coupling strength $\epsilon = 0.08$.

Track 4: Rhythm of the concentration of compound III during the peroxidase-oxidase reaction under semi-batch conditions.

The tracks can be found on the included audio CD and also on the web-site
http://basic-research.zkm.de

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On the Role of the Micro-Macro-Transition and Control Processes for Understanding the Interface

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Abstract

We review the rationalistic roots of system theory and, thereby, stress the fact that the problem of the micro-macro-transition can be seen as the first and most striking manifestation of an exo-endo-distinction. From system theoretical considerations we outline a possible model for brain dynamics based on control processes. We show, that the control mechanism can be implemented on a microscopic level which provides a link of micro- with macro-dynamics. We distinguish between internal and external control, however, both are entangled with each other. The entanglement leads to a continuous processual "backfolding" of the part onto the whole which is similar to the hermeneutic process. We provide a first working example of a continuous neural network which only partially includes some of the features necessary for a "hermeneutic engine" but supports the clue for the direction of impact. Especially, one can derive possible experimental designs from that model.

1 Introduction

Reading the proceedings in hand one is led to the impression that there is a commonness in the attitute towards interface. The majority of the contributors deal with an *exo-endo* distinction, even if it is not referred to explicitly or is termed different. We should like to add some system theoretical considerations from a dynamical perspective. Therefore, we briefly review the rationalistic roots of system theory in a first step. Thereby, and in the subsequent sections, we focus on the fact that the exo-endo view is by no means a dualistic one as neither the resolution of a Gödelian self-referentialty is when the self-refertial system is embedded into a larger one. The exo-endo distinction is just a manifestation of the complementarity principle.

System theory means to deal with relations. After a discussion of the role of relations with respect to cognition we should like to outline a concept of brain dynamics based on control processes which leads to the suggestion of a continuous neural network. The focus, thereby, is on the distinction of internal and external control processes which are entangled with each other. The interface itself can be understood as a dynamic process as a result of this entanglement namely the "dynamic backfolding" of the part onto the whole. The hermeneutic cycle can be seen as a manifestation of such a process.

Then, we discuss thermodynamical features and the entropy flow with respect to the observational process. To understand thermodynamics – or more precisely: the micro-macro-transition – is crucial for understanding the interface. From a system theoretical point of view, the interface problem can be ruled back to the micro-macro-transition. This insight is almost as old as system theory itself (if one agrees, that the fundament of system theory have been laid by Descartes) and expressed via metaphors like the "Laplace demon" as an exo-observer.

We finish with a first working example of a continuous neural network. This example, so far, is not endowed with all the features necessary to approach the "dynamic backfolding". However, it provides the basis for future studies and, what may be more important, gives an idea how to design experiments by means of feedback loops.

2 Rationalistic roots

When looking out of his window in an upper floor down to the people strolling along the promenade, René Descartes wondered [1]:

> There are people strolling along the promenade – but what do I actually see? I only see hats and cloaks and there can be automata hidden underneath [1].

Descartes' mechanistic universe was translated into a mathematical formalism by Sir Isaac Newton [2]. The alteration of a state is a function of the state itself. This is a possible interpretation of $\dot{x} = f(x)$ – the differential equation.

The consequences of the rationalist's attempts to describe the dynamics of the universe in a consistent way were partially fatal for them, as made evident by the recherche of Eike Pies in his report "Der Mordfall Descartes" (The homicide Descartes) [3]. When being asked whether the planet's motion are indeed caused by themselves, Newton saved his life by claiming:

> Occasionally God has to interfere correctively.

However, Gottfried Wilhelm Leibniz opines:

> This world is the best of all possible worlds.

The latter is in line with Descartes' attempt to rule out the *deus malignus*. God does not scamp and he does not take us on a ride. Well, this is the *consistency principle*. As Hans-Ulrich Reck stresses (see page 292), consistency can not be proved. It rather is a premise, or better "a leitmotif", in order to avoid malignity or malignancy.

Another very important rationalistic pathfinder is Pierre Simon de Laplace. He is famous for the introduction of the *demon* as a metaphor for determinism, now called after him *Laplace's demon*. Given that the demon has precise knowledge on every microstate at an instant of time he is able to predict exactly the states in the future. Unfortunately, the *Laplace demon* led to serious misinterpretations and misunderstandings. The demon is a fictive exo-observer. If one tries to use his knowledge to interfere with the system as proposed by Maxwell (*Maxwell's demon*) than either a *deus ex machina* is created or an *intrinsic observer*. The *deus ex machina* "leaves his marks" in the relational part of the world but is non-relational himself, i.e., he introduces inconsistencies.

It has gradually been corrected through the mathematical theory of communication that the usage of information in Maxwell's sense is contra factual [4, 5, 6]. A concrete example is given in a subsequent section. It seems that Laplace anticipated the findings of modern information theory. As is well known, he is one of the pioneers of probability theory which seems to contradict his deterministic point of view. However, he clearly recognized that probability is only a practical method to account for the fact that we usually have imperfect knowledge – or in other words: that we are *intrinsic observers*. The attempt to realize Laplace's demon and

[1] Ich sehe nur Hüte und Mäntel. Darunter könnten auch Automaten stecken.

to use his information to separate fast from slow molecules, for example, either violates the second law or introduces a relational, information processing, thus physical, being [4, 5, 6].

The principle of complementarity can emerge in different ways. To be empiricist and rationalist at the same time is not a contradiction – just two aspects of complementarity. The laws derived on a rationalistic basis have to match with empiricism. In this respect, microdynamics that has to match with macrodynamics is of fundamental importance. Why do we need microdynamics at all? Despite the fact, that microdynamics supports the basis for statistical mechanics and, thus, is of technical importance it is the inherent quest for consistency. Consistency in turn is nothing else than a leitmotif from which follows a processual optimization which can be called an “hermeneutic cycle”.

3 Brain Dynamics and Relations

Assume a deprivation tank experiment. In such an experiment persons are (in the ideal case) totally isolated from the surrounding. That is, they do not perceive any sensory stimulus. It is well known that this very quickly leads to hallucinations. Relished in a discreet dose, this may enhance consciousness. However, in the long term the brain starts to malfunction and may be irreversibly damaged.

What do we learn from that experiment? The brain cannot be understood by merely investigating the brain’s “hardware”. The brain emerged in the evolutionary history to tackle a complex environment. When being liberated from that task it malfunctions. Otto Rössler build in his papers on deductive biology [7, 8, 9] on Bob Rosen’s relational approach to biology [10]. To think in “relations” goes back to Descartes who’s automaton universe could be called the systems theoretical paradigm. However, the most frequent approach to systems is going upwards from the parts to the whole. No surprise, that the whole turns out to be greater than the sum of the parts. When treating the parts as being created out of or within the whole, this seems less mysterious. According to Rössler, we have to ask: “What are brains good for?”

The brain is a receptor and a simulator (cf. the treatise on “stimuli” and “simuli” by Prehn, p.202). Both features constitute the brain as an *autonomous optimizer*. But no optimizer can be investigated by separating it from the task: What has to be optimized? The term “autonomous” reminds on H. Maturana’s “autopoiesis” [11]. However, as N. Luhmann correctly expatiates, without perception autopoiesis terminates [12]. In other words, the brain itself is not a system. The brain and the environment, together, constitute a system.

Is it possible at all not to think and argue in terms of relations? We doubt. However, we have to scrutinize the simple spatio-temporal approach as given by $\dot{x} = f(x)$, the differential equation, where x is an external variable. As an heuristic example, assume given a neural network that is trained to recognize two images. If one of the images is presented somewhat distorted to the network, it can be recognized unless the distortion is too strong. If the distortion is increased in such a way that it gradually leads to the second trained image then, at a certain level of distortion, the network switches to the second image. The neural network (as well as the brain) discriminates. The number of possible different images that can be discriminated depends on the size of the network, thermodynamical entities and others. The network acts as an operator on a “continuous reality” and leads to a “collapse” onto “eigenstates” of the network. The involved entities of interest are scales which seem to play a fundamental role in physics, too (cf. L. Nottale, page 38). Space and time turn out to have fractal, non-differential, character within the physics framework.

Needless to say, we only have access to the “eigenstates”. A promising approach to describe the functional transformation from an external to an internal dynamics is discussed by Tsuda and Hatakeyama on page 131. In the following we try an approach by means of control.

4 Brain Dynamics and System Controlling

Nicolis and Tsuda recently gave a clear and most promising description of brain dynamics [13] which seems to be in line with the seminal papers by Rössler [7, 8, 9] mentioned above. They devide perception into an expanding and a contracting phase. Sensory input compresses the basin of attraction created in the expanding phase onto one (out of many) coexisting attractor. The observational process leads to a "collapse" of the external representation onto a kind of "eigenstates" – the categories – in the brain. These categories can be linked to *a priori* probabilities which themselves are attractors.

Starting out from Nicolis and Tsuda's scheme we would like to delineate a possible continuous description of brain dynamics. The model is based on chaos control mechanisms [14, 15, 16]. Assume $\mathbf{x}$ and $\mathbf{x}'$ to be the states of two dynamical systems of the same dimension n and the same dynamics $\mathbf{f}$ which are given by the differential equations

$$\begin{array}{rclrcl} \dot{\mathbf{x}} &=& \mathbf{f}(\mathbf{x};\beta), & \beta &=& (\beta_1,\beta_2,\ldots,\beta_m) \\ \dot{\mathbf{x}}' &=& \mathbf{f}(\mathbf{x}';\beta'), & \beta' &=& (\beta'_1,\beta'_2,\ldots,\beta'_m) \end{array} \tag{1}$$

where β and β' are sets of fixed parameters. Assume further that one of the parameters of the unprimed system is different from the corresponding one in the primed system, $\beta_k \neq \beta'_k$, and the other ones are equal $\beta_i = \beta'_i, i \neq k$. If now the difference of at least one pair of corresponding variables (say the first) multiplied by a factor K is added to the unprimed system

$$\begin{array}{rcl} \dot{x}_1 &=& f_1(x_1,x_2,\ldots,x_n;\beta) + K(x'_1 - x_1) \\ \dot{x}_2 &=& f_2(x_1,x_2,\ldots,x_n;\beta) \\ &\vdots& \\ \dot{x}_n &=& f_n(x_1,x_2,\ldots,x_n;\beta) \end{array} \tag{2}$$

the unprimed system is forced to the dynamics of the primed controlling system. If the difference of the system parameters is not too large, the value of the control parameter K is negligible. This is the usual implementation of Pyragas' control mechanism [14].

If K is sufficiently large one can even set $f_1 = f_2 = \ldots = f_n = 0$ to force x_1 to the dynamics of x'_1. Assume the oversimplified case

$$\begin{array}{rcl} \dot{x}_1 &=& \beta_1 x_2 + (x'_1 - x_1) \\ \dot{x}_2 &=& \beta_2 x_1, \end{array} \tag{3}$$

where initially $\beta_1 = 0$ and $\beta_2 = \beta'_2$. The dynamics of the external control system $\dot{\mathbf{x}}'$ is given by

$$\begin{array}{rcl} \dot{x}'_1 &=& \beta'_1 x'_2 \\ \dot{x}'_2 &=& \beta'_2 x'_1, \end{array} \tag{4}$$

with fixed parameters β'_1 and β'_2. In this trivial case β_1 can be estimated by

$$\beta_1 = \frac{\dot{x}'_1}{x_2}, \tag{5}$$

as long as $x_2 \neq 0$. For a continuous (adaptive) approach it would be preferable to treat β_1 as time dependent. Taking the derivative of the first equation of Eqs. 3 yields

$$\dot{\beta}_1 = \frac{1}{x_2}\left(\ddot{x}_1 - \beta_1\beta_2 x_1 - \dot{x}'_1 + \beta_1 x_2\right), \tag{6}$$

as long as $x_2 \neq 0$. The parameter β_1, thereby, is driven to a value so that $\mathbf{x}$ mimics the external dynamics of $\mathbf{x}'$ after a while. This approximately holds true even when $\mathbf{x}$ is decoupled from $\mathbf{x}'$ after a sufficently long time – the controlled system starts to simulate.

To construct a continuous neural network on that basis is very complicated. The network $\mathbf{x}$ has to be large enough and one perhaps has to add nonlinear terms in order to be able to resemble complicated external dynamics. In such a case, the parameters β can no longer be estimated by means of writing down the corresponding differential equation which leads to an adaptation of β. Rather, time consuming and complicated optimization routines have to be used. Additionally, the optimization of β may become non-unique. The more the values of the parameters β are in the vicinity of the "true" parameters β' the easier is the task – still tough enough.

5 Reversible control

Although the continuous neural network based on control processes is presently in a speculative phase it may be worthwhile to stick with it for several reasons explained in the following. The adaptation of the neural network may be a mixture of parameter adaptation and internal control processes within the network itself. Control processes in the brain on the basis of Pyragas' chaos control mechanism seem to be as evident [17, 15] as parameter adaptation (synaptic strengthes).

To treat the external stimuli, the excitation of the neurons, in terms of continuous control enables the network to be trained not only to static images but also to dynamics which in turn enables the brain to simulate, i.e., to anticipate, to extrapolate and to predict. An advantage of Pyragas' control mechanism is its generalizability to diffusive coupling as shown in [16]. In this paper we investigated two diffusively coupled chemical oscillators with slightly different parameters according to the scheme of Eqn. 1. However, the unidirectional control term in Eqn. 2 has been replaced by a diffusion term. If one of the reactors is much larger than the other one, it is almost not influenced. However, the smaller one is controlled by the larger one in Pyragas' sense. Interestingly, when varying the fraction of the reactors sizes there is a relatively sharp transition of the roles of the reactors – the controlled system switches to the controlling one and vice versa.

Clearly, an observation is an interaction between the observer and the observed object. In the macroscopic range this interaction has negligible impact on the object. However, is it allowed to treat an observational process as an unidirectional one in any case? In the microscopic realm the reversible control may become important and support the link for the understanding of the observation process in quantum mechanics.

A special and philosophically most interesting case of observation is the visual observation. To see an object clearly means to receive photons which stem from the object. Brillouin in 1951 published an interesting treatise on Maxwell's demon [5] in which he assumed a totally isolated chamber with molecules at a certain temperature in it. If the chamber is left alone the molecules and the radiation are in equilibrium according to Planck's law of radiation. Brillouin argued that a demon who's task is to separate fast from slow molecules has to observe the molecules, thus absorbing photons. To take photons out of the system drives it away from equilibrium.

Although there are some doubts whether Brillouin's estimations are complete he recognized a very important point concerning observation. If one extrapolates his thermodynamic approach one has to take into account that observers (even if an apparatus is inbetween) are themselves dissipative thermodynamical objects. The ability and efficiency to absorb photons depends on their thermodynamical state with respect to the environment. If one treats the Universe as a hollow chamber there is no need to mention that the existence of an absorber does not change any macrospopic feature. But again, the microscopic realm is addressed here. It is the microscopic realm where a systemic approach of the observation process may be fruitful.

A scheme for cognition based on "controlling" may also provide a link of dynamical system theory to the theory of formal concepts as described by Y. Gunji et al. on page 111. As they correctly point out, macroscopic dynamical systems usually lack what is sometimes called the "second cybernetics", i.e., they do not evolve. A 3-dimensional differential equation can generate a point attractor, a perodic or a chaotic attractor, depending on the parameter values. However, it never can show hyperchaos. To this end, the system itself has to undergo an "evolutionary hyperdynamics". A neural network as sketched above defines a kind of "potential wholeness" through its size and other entities. The "actual wholeness" is given by what has been already "switched on" via the adaptation to the externally presented dynamics (stimuli). In the simulation state of the network, internal control may lead to an extension of the actual wholeness where new dynamics ("ideas") are created. Such a process has some similarity to the *Bayesian learning*. However, in our example the "unknown hypotheses" also have a small but finite apriori probability, so to say, that may increase when the network again is coupled to the external reality.

6 Entropy Flow Between Multi-Component Systems

The "second cybernetics" may be a useless notion from a puristic microscopic viewpoint, at least, if one deals with a Hamiltonian Universe. However, the construction of a Hamiltonian Universe means to construct a reality from which we experience only the "eigenstates", in this case, the macroscopic features. This construction makes sense, unless it produces inconsistencies. Therefore, the micro-macro transition is a crucial point in studying the interface, maybe the most important one. The micro-macro-transition is closely related to the exo-endo-transition as already made evident above through the discussion of Laplace' demon. As a consequence, a crucial step to understand the interface is to fully understand thermodynamics.

The interaction of an observer with an object not only means that something material or photons are transmitted. The observation leads to a gain of knowledge on the object. Information, or the related entropy, is transported from the object to the observer. Information is a subtle term still controversially debated. Szilard [4] for the first time introduced the term information in a technical sense in his 1929 paper in which he analysed "the entropy decrease in a thermodynamical system by the interference of an intelligent being". Later, Shannon and Weaver introduced the mathematical theory of communication based on Szilard's work. However, the observational roots have been suppressed or avoided. Brillouin was one of the first authors who reanimated the linkage to the observation in his 1951 paper [5].

The puzzling problem is how to link syntax and semantics. For a most promising approach please confer the paper by Gunji et al. on formal concepts (page 111). But even if one sticks with a purely syntactical definition of information and entropy one is confronted with basically two different concepts: the Boltzmannian approach and the Gibbsian one. The latter one has been termed an anthropomorphic concept by E.T. Jaynes [18]. It depends on the knowledge of the observer which Gibbs-entropy the observed system has. Boltzmann's concept can be seen as the entropy of a system with respect to Laplace's demon. Since the demon exactly knows the microstates of a gas, for example, he easily can compute the entropy as a functional of that microstates in a deterministic way. That is why Boltzmann's entropy is quite frequently used in molecular dynamics simulations, where the programmer is a kind of non-relational demon, so to say, since his knowledge has no impact on the simulated system. Of course, the computer and the monitor has to dissipate energy to supply the demiurge of the simulated Universe with information. But this, unfortunately, is seldom taken into account and analysed.

In 1997 we introduced a deterministic time dependent entropy formula based on the instantaneous occupied phase space volume [19]. This entropy, on the one hand, preserves all the deterministic features of Boltzmann's entropy, and, on the other hand, takes into account the full arrangement of particles in the phase space as the Gibb's entropy does. For an N-particle gas, this entropy reads

$$S\left[\gamma(t)\right] = k \left\{ \ln\left(N\right) + \frac{1}{N(N-1)} \left[\sum_{i=1}^{N} \sum_{\substack{j=1 \\ j \neq i}}^{N} \ln\left(\frac{1}{6}\pi^3 \gamma_{ij}^6(t)\right) \right] \right\}, \tag{7}$$

where γ_{ij} is the normalized distance of particles i and j in the 6-dimensional 1-particle phase space. For technical details, please confer [19, 20]. In the following we would like to give the reader a hint of the meaning of the entropy in Eqn. 7 by means of an heuristic argument.

Assume given an N-particle gas consisting of shapeless point-particles. Each particle is thus described by 6 coordinates – 3 spatial coordinates and 3 components of velocity – which mark a point in the corresponding 6-dimensional phase space. Now we draw the state of each of the other particles into the same phase space, which leads to a cloud of points. The distribution (density) of this cloud is part of the entropic measure. In a high entropy state, i.e. in a relaxed state near equilibrium, the particles have large mutual distances which leads to a less dense cloud of points. Boltzmann's entropy builds on that distribution in the 1-particle phase space.

The full phase has 6N dimensions spanned by all 3N spatial and all 3N velocity components. The momentary state of the N-particle gas marks a single point in that high-dimensional phase space. In order to compute an entropy, one has to integrate over time, i.e., to follow up the point along the trajectory. This trajectory smears out the full phase space more or less dense at different locations which in turn is a measure for entropy – the Gibbs entropy. However, transient states can not be captured with Gibbs entropy. It works only near equilibrium or near invariant subspaces (like attractors in dissipative systems). Gibbs' entropy is time-independent.

The weak point of Boltzmann's entropy is that it does not capture the full arrangement of the particles since only local densities are taken into account. However, the above introduced entropy (Eqn. 7) does and, additionally, is still deterministic.

A further advantage of the entropy in Eqn. 7 is that mutual entropies can be formulated as partial sums over the particle numbers of interest. Due to the deterministic features this mutual entropies differ from the usual concept of mutual entropies based on Gibbs' entropy. We, therefore, prefer to call it *partial entropies*. The time dependency allows in an easy manner to follow up partial entropies in its time course. The entropy changes can be interpreted as entropy flows. Such entropy flows between well defined compartments or subsystems have been investigated in a recently published paper [6]. The main results are depicted in Fig. 1. Please confer the original paper for technical details.

The system under investigation consisted of two parts. The first part was made up of 99 point-particles bound within a cube. The particles interact with each other through a repelling Coulomb-like potential $\frac{\epsilon}{r_{ij}}$, where r_{ij} is the distance of particles i and j. This mimics an electron gas. Outside the cube, a single particle with the same potential is moved slowly from a huge distance to the vicinity of the cube. This is the usual introduction of the electrostatic potential, whereby in this traditional case the first system is defined by a single electron. Here, we would like to stress the fact, that in the many-particle case not only the potential energy changes but

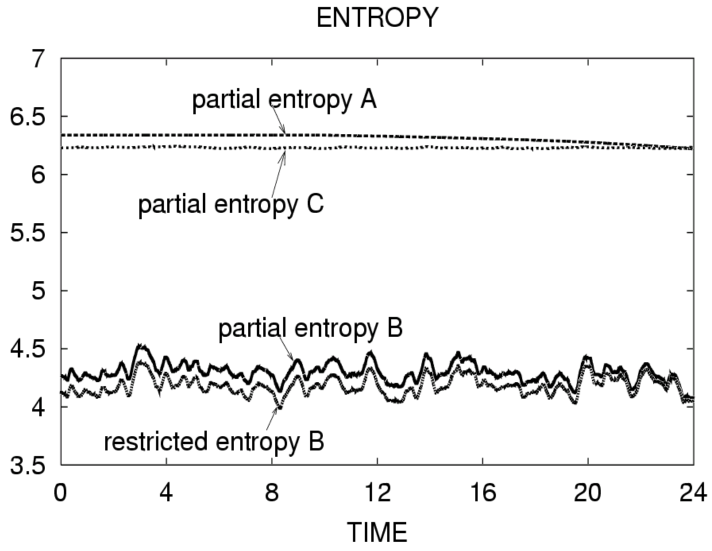

Figure 1: *Entropy flow between two components of a composed system.*

also the arrangement of the 99 particles in the cube, i.e., entropy. This is a very rough and priliminary step towards an observational situation.

As already mentioned, above entropy formula allows for the computation of entropy flows. Figure 1 shows the result. The upper pair of graphs are the entropies seen from the "outside particle" (upper curve) and an arbitrary "inside particle" (lower curve), respectively. Within 24 time units the outside particle is moved towards the cube ending up in an entropic state that is close to that of the inside particle. The difference can be interpreted as entropy flow mediated through the interaction. The lower pair of graphs show the partial entropy of the 99-particle system (upper curve) and the restricted entropy of that system (lower curve), respectively. The restricted entropy is defined as the entropy of the 99-particle system that neglects the existence of the outside particle. With a grain of salt, this corresponds to the usual neglection of the observers impact on the observed object. Roughly, this neglection corresponds to the neglection of entropy flow mediated through the interaction. Please confer also the contribution by D. Janzing (page 89) who shows closely related results within the fields of quantum computing. You have to substitute his cooling apparatus by an observer.

To rephrase the findings in a heuristic way: Observation leads to a gain of knowledge on a system that is no longer in that state which corresponds to the information. If the observational interaction is such strong that we gain all information available, than the system is totally destroyed and the information becomes useless. Compare with the observation of a photon which no longer exists after observation. Thus, we have to be contended with an incomplete knowledge in order not to perturb the object too strongly and rely on statistics. In the case of photons, we can use statistics to say something about the photons that have not been observed (destroyed). That is the price of being an intrinsic part of the Universe.

7 A First Working Approach to a Continuous Neural Network

Figure 2 shows a screenshot of a simulation of a two-dimensional array of $n \times m$ coupled excitable oscillators – a rough model for a continuous neural network [21]. The dynamics of

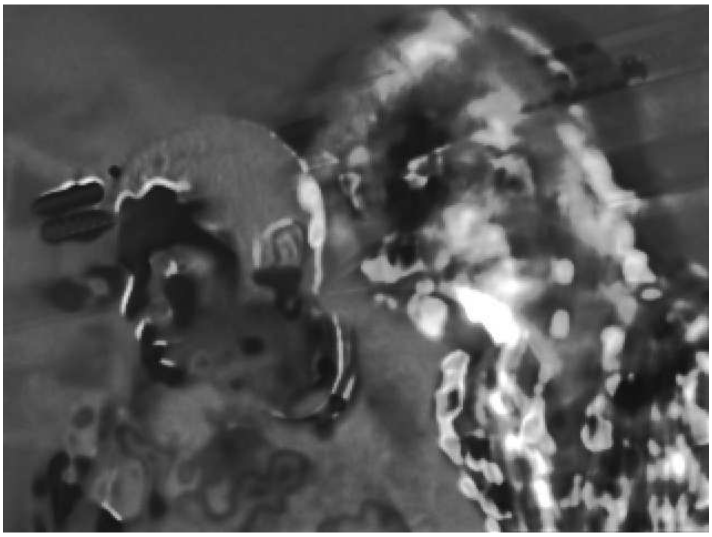

Figure 2: *The values of the pixels of a live video (of the authors) have been used to excite the simulated two-dimensional array of coupled oscillators. The dynamics of each oscillator is similar to the Hodgkin-Huxley equation for neurons. The live video emerges in the simulated neural network superimposed by its internal dynamics. Parameter values:* $a = 0.056, b = 0.12, c_1 = 0.5, c_2 = 0.1, D_x = 0.1, D_y = 0.03$.

each oscillator is very similar to the Hodgkin-Huxley equation for neurons. Each oscillator is coupled with its neighbors according to the following set of differential equations:

$$\begin{aligned} \dot{x}_{i,j} &= a + x_{i,j}y_{i,j} - \tfrac{c_1 x_{i,j}}{c_2 + x_{i,j}} + D_x Diff^x_{i,j} - Video_{i,j} \\ \dot{y}_{i,j} &= b - \dot{x}_{i,j}y_{i,j} + D_y Diff^y_{i,j}. \end{aligned} \tag{8}$$

Thereby, zero-flux boundary conditions for the diffusion $Diff^\xi$ have been used:

$$\begin{aligned} Diff^\xi_{i,j} &= \left\{ \begin{array}{rcl} \xi_{i+1,j} + \xi_{i-1,j} + \xi_{i,j+1} + \xi_{i,j-1} - 4\xi_{i,j} & : & 1 < i < n; \quad 1 < j < m, \\ \xi_{i+1,j} + \xi_{i,j+1} + \xi_{i,j-1} - 3\xi_{i,j} & : & i = 1; \quad 1 < j < m, \\ \xi_{i-1,j} + \xi_{i,j+1} + \xi_{i,j-1} - 3\xi_{i,j} & : & i = n; \quad 1 < j < m, \\ \xi_{i+1,j} + \xi_{i-1,j} + \xi_{i,j+1} - 3\xi_{i,j} & : & 1 < i < n; \quad j = 1, \\ \xi_{i+1,j} + \xi_{i-1,j} + \xi_{i,j-1} - 3\xi_{i,j} & : & 1 < i < n; \quad j = m, \\ \xi_{i+1,j} + \xi_{i,j+1} - 2\xi_{i,j} & : & i = 1; \quad j = 1, \\ \xi_{i-1,j} + \xi_{i,j-1} - 2\xi_{i,j} & : & i = n; \quad j = m, \\ \xi_{i-1,j} + \xi_{i,j+1} - 2\xi_{i,j} & : & i = n; \quad j = 1, \\ \xi_{i+1,j} + \xi_{i,j-1} - 2\xi_{i,j} & : & i = 1; \quad j = m, \end{array} \right. \\ \xi &\in \{x, y\}. \end{aligned} \tag{9}$$

The parameters a, b, c_1, c_2, D_x and D_y are constants. The size of the array is 160×100 which is the number of pixels of the used video signal. We used the values of the pixels of a live video to excite the neurons given by the term $Video_{i,j}$ in Eqn. 8. Concretely, in Fig. 2 the difference of two subsequent video frames have been used: $Video_{i,j}(t) = pixel_{i,j}(t) - pixel_{i,j}(t-1)$. In other words, only motion in the external world leads to a stimulation of the network.

After a couple of seconds the live video image emerges in the simulation of the neural network superimposed by its internal dynamics. If decoupled from the stimulus the network slowly relaxes to an equilibrium state of random oscillations, since so far no parameter adaptations are implemented.

There is a huge range of influence of the parameters on the behavior of the network, the transient time, for example, which is related to "echo effects" of the "virtual reality". Parameter adaptations may lead to a "dynamical simulation" of "reality" for a certain time duration. As mentioned above, control and parameter adaptation via control is a complicated and thus time consuming computational process. It so far disables a live performance of the network. The future task is to search for quick and practical working implementations.

8 Conclusions

As a quintessence, we consider the brain as an "hermeneutic engine" driven by the leitmotif "consistency". Our recipe for an actual implementation are control processes. Thereby, we distinguish between internal and external control whereby in each case parameter adaptations are included. External control corresponds to perception and the internal control corresponds to simulation. Both, internal and external control lead to a processual augmentation – the hermeneutic cycle – through their entanglement.

An important step towards the investigation of the interface would be to design adequate experiments. As immanently made clear in the previous sections one important tool is the computer since an indirect approch to endophysics is given by simulations of "Universes" of which we, the programmers, are the demiurge and have a priviledged perspective such as Laplace's demon. In a previous work we derived an algorithm free of dissipation for consistency reasons [22]. In fact, the study of entropy flows described above has been carried out using this consistent algorithm.

Since there exist clear analytical limits of investigating dynamical systems, "computer experiments" are meanwhile established as essential tools in dynamics studies. Nevertheless, a "real experiment" would be an augmentation. From our example of a continuous neural network it follows a mechanism for the coupling of model networks with "reality". In combination with bio-feedback mechanisms (cf. H. Prehn, page 202, and T. Hinterberger et al., page 232) this enables the coupling of "real" and "artifical" brains [23] from which we expect new concrete results for the understanding of the interface.

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The Art of Interface Technology

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1 Introduction

This paper is about the art of interface technology, projecting the future of the image technology. I focus on the physics of the image. From the physics of computation, as we have learned it from the work of Fredkin and Feynman, I sketch a forecast of the future of the image.

2 Observation of Observation

Firstly, I will describe some of my own work, dating from about thirty years ago, to formulate the problem. The first video that I show has been produced for the Austrian Television. It was broadcasted in 1970. It is called "The Endless Sandwich" [1]. It contains already the model of multi-universes, or as Otto Rössler formulated: The boy in the bubble. Here we have many boys in bubbles, a little bit like a Russian doll. You also see a cascade of observers.

Twenty years later, Niklas Luhmann started the discussion on "the observer of first or second or third order etc" [2]. In my own work I already investigated the idea what happens if one observer observes another observer. Imagine that this was broadcasted in real television, which means that you will find a real person at the end of the chain of mutual observers.

An error happens in the first Universe. The person has to get up to correct the error, and while he does so, it jumps to the next Universe. In the end, each Austrian TV viewer had to get up to readjust his own TV. So this is one of the first models of Multi-universes and how the information exchange and transformation works. You can see very clearly that the TV is treated as a kind of interface.

Another work I did in 1973 was called "The Observation of Observation – Uncertainty" [3]. It was a closed-circuit video installation. Somebody was watching himself, but due to the installation of cameras and monitors, he could only see himself from the back, not, as he was expecting, from the front. Watching oneself in such a way destroys one's identity. Like in quantum physics observation is an act that influences the information we get. Already in the beginning of the seventies I saw a correspondence between quantum theory and media theory, respectively image theory. The correspondence centred around the function of the observer, as well as in quantum mechanics as in interactive video-based and computer-based installations.

3 Theory comes before Experience

I would like to call back to your minds that Heinrich Hertz did his famous experiments in 1886 and 1889 in Karlsruhe. As you know, in his laboratory he generated for the first time electric waves and showed that these electric waves are identical to optical waves. Thereby he proved first of all the existence of electric waves and secondly that Maxwell's equation from 1873 had

Figure 1: *Screenshot of the Video "The endless Sandwich".*

been right. This for me is the beginning of a new era, because it shows that theory comes before experience. Before, physics and philosophy relied on the primacy of experience, on which the theories were modelled. In the case of Hertz' derivations, for the first time, theory was much ahead of experience. Experience was exchanged by what we call experiments.

Everybody accepts that you need a lot of theory in the natural sciences. The new era, the new world is theory dependent. However, an interesting point is: the only field in which people usually do not accept the dependency on theory is art. They want to understand art immediately. If an artist argues that you need explanations, that you cannot look on art without theory, as is the case, with abstract paintings, he usually is attacked, because such an artwork is regarded as too dependent on theory.

There is a book in America called "The painted word" [4], and the author, Tom Wolfe, is blaming modern art, e.g., the abstract expressionism of New York, exactely because of this. He says that this art is only valuable because of the many written commentaries added to these artwork. My suspicion is that people that refuse art that depends on theory want to exclude art from the modern world. What we do in art nowadays is like in science to formulate theories and then we make experiments to prove them. Only art of this kind is art as a part of modern times.

In the nineties I focused in my work and philosophy of the image on the virtual image in computer based interactive installations. I discovered three steps defining the new virtual or algorithmic image. First the virtuality of the information storage. The next step is the

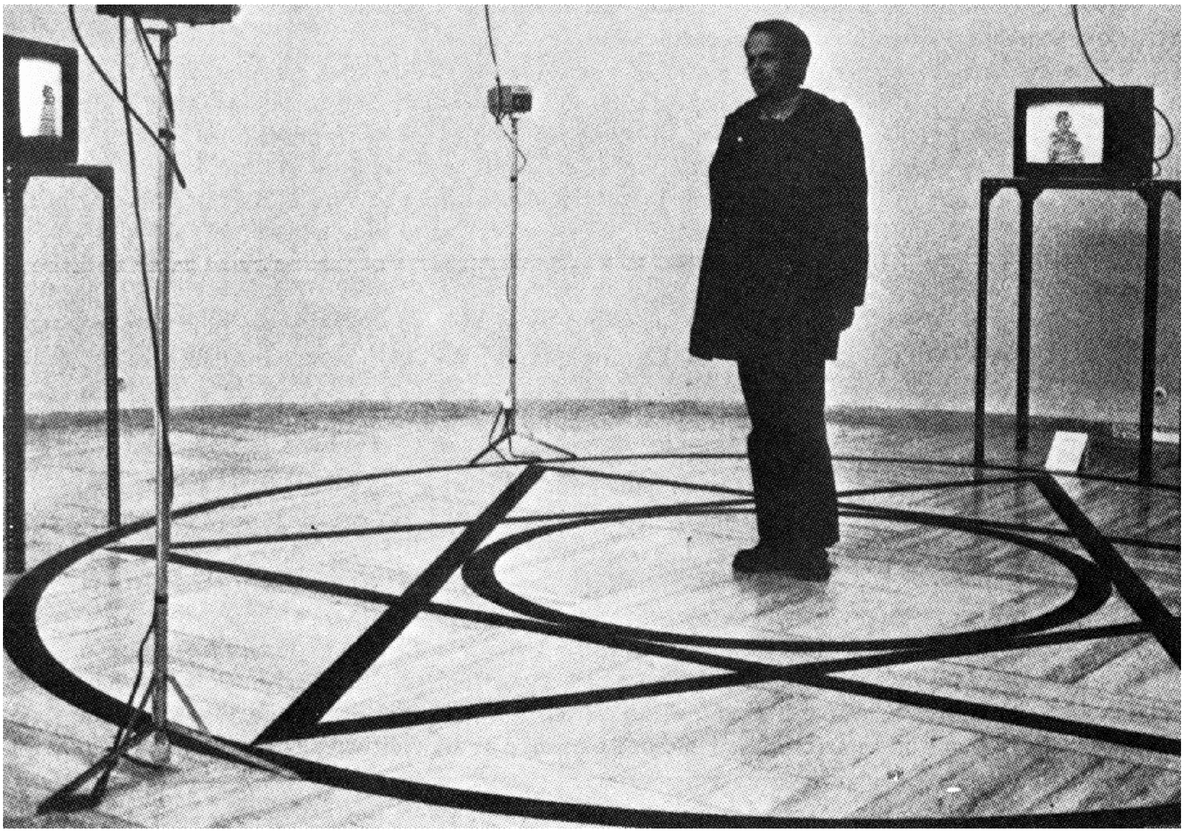

Figure 2: *"The Observation of Observation – Uncertainty", a closed-circuit video installation.*

variability of the image contents. Finally, when an image is just a set of variables which can vary at any moment, this image becomes a system which has a lifelike behaviour. We then speak about the viability of the image behavior. What do we have to expect for the next decade?

4 Distinction Constitutes the Interface

To approach to the idea of an interface consider two states, state A and state B, respectively, and that the interaction between these states is not restricted to one direction, but takes place in two directions. In a sense, this bidirectional interaction is reversible, if you accept for a moment this expression. Between these two states, a transformation of information takes place correlating cause and effect. If you have a cause here, you have an effect there. Normally this happened in a local horizon. The interaction in a computer based installation is locally bound. In net-based installations the interaction is not longer locally bound. The interaction is reversible and approaches the simulation of what in quantum physics is called "entanglement". A cause in one point of the universe has an effect on one point beyond the local horizon.

What I would like to do now is to outline the steps that we have to make according to this definition. It is a kind of differentiation which leads to the idea of an interface. For example, Ivan E. Sutherland wrote in 1963 his famous Ph.D. thesis He defines a tablet as an interface to the machine. "Sketchpad: A Man-machine Graphical Communications System" [5]. A change in the tablet (state A) results in a change on the computer screen (state B). But the question is now: Is the machine the interface, as suggested by Sutherland's title, or is the alphabet already an interface and the machine just a physical implementation of a formalism?

What we have to do here is in fact to create a difference. George Spencer Brown wrote a book in 1969 called "Laws of Form" [6], and his first sentence was: "What you have to do whenever you create a system, whenever you look at the world, you have to draw a distinction". Draw a distinction between you and the world, between your body and your soul. Whenever you make an observation, you draw a distinction. This is his basic theory.

The point is now that whenever you draw a distinction, like here in Sutherland, you can also, in a further step, erase a distinction. You will then find a new distinction. In fact, when you erase an old distinction, you are going on to construct a new one. The idea behind the distinction is equal to the idea of an interface. We define interfaces, then we erase them to construct new ones. In fact, I could call Sutherlands interface not a man-machine interface, but also a machine-machine interface, because both tablet and screen are machines. However, then I could say: here is my hand as an interface. Sutherland may say we have a hand, an interface and a machine, which is already a cascade of interfaces. People have normally the tendency to say that the hand is not an interface. But if you draw a distinction between your consciousness and your body, you realise that your hand is also an interface.

Adopting the title of the famous article by Warren McCulloch "What the Frog's Eye Tells the Frog's Brain" [7] the frog's eye actually can be seen as an interface to the frog's brain, because the frog's brain tells the frog's eye what to do. Thus, I, or speaking with rational psychology, my brain can tell my hand what to do and then my hand acts as an interface to this tablet which activates the machine.

So what follows from this: we construct a distinction, and a distinction is in fact a regulator on a relative scale. You have a set of variables and a scale of differences and then you take a regulator and draw the distinction – in this case between my hand and this tablet. I could just as well say that I draw the distinction between this tablet and the screen, or between the alphabet and my consciousness. In my opinion, the alphabet already is the first interface.

5 Interface Between Real and Virtual World

In 1991 I did one of the first interactive computer assisted installations [8]. I used buttons on the floor that activated letters when being stepped on. The installation was endowed with specific functions which allowed to write big or small letters etc. In addition, a memory function had been used that kept each phase of the motion memorized.

The point is now that you can also switch between different worlds. I made four different worlds available. The buttons are an alphabet for different worlds. There is a world of architecture, a world of objects, a world of letters and a world of gas clouds. The objects can be rotated, changed in color, texture, size etc. There is only one code, one interface, one set of buttons, but you can enter at the same time four different worlds. This is the idea of the Pluriversum or the Multiversum. You have access to four different virtual worlds. One could even think of thousands of different virtual worlds if we had the computers to make the calculations. Probabely we need quantum computers that enable us to make reversible communication between this massively parallel virtual worlds possible.

Here many people can walk around on an interface modelled after our alphabet and thereby create different vitual worlds. In the fourth world we find, as already mentioned, gas clouds. They are the first artificial creatures, because they have a lifespan of approximately 10 seconds, they are looking around to find others of the same color to copulate and create offspring, and if they find somebody with a different color they try to eat him to prolong their own lifespan. They were relatively autonomous, so here we have one of the first works with autonomous

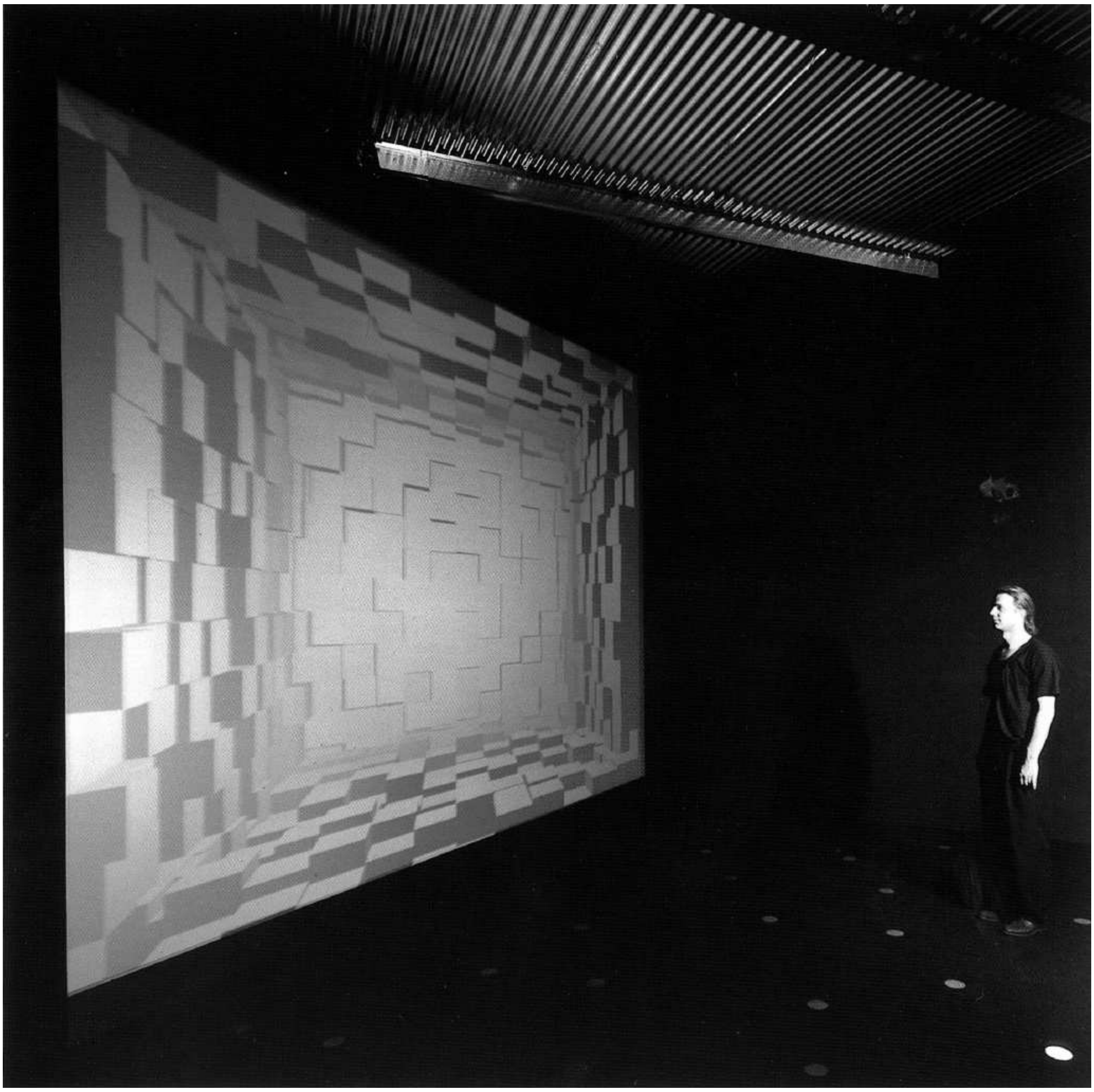

Figure 3: *Interactive computer-assisted installation.*

intelligent agents. It is a simple model of Darwinian evolution.

Now it becomes clearer what I mean if I say that an image has a lifelike behavior. It is important to realise that the interface is a regulator on a scale of distinctions. We can make different definitions. So we have in fact a hierarchy of interfaces.

The classical world just accepts an interface between two points of the real world. If we think again of those states A and B, then we accept naturally that these states are two states of the real world. In art, the idea of the hierarchy of interfaces enables us to have representational states in the real world or in the symbolic world like language or images. For example, a telephone is an interface in the classical world. It is an interface between two space-time points in the real world, e.g., from Karlsruhe to Sydney. There is an exchange of information in both ways. However, in the non-classical world we have different possibilities. Of course, there is also the possibility to connect two points in the real world, but as I have shown in my work, it is also possible to create an interface between the real and the so-called virtual world. It is yet another distinction as when using the interface of language, as we have seen before.

6 Bidirectional Interfaces

Whithin the range of computer assisted installations, we find an expanded set of interfaces, such as bicycles or plants, for example. All this installations deal with an exchange of information, however, they are still locally bound and not “reversible”. When you are riding on the bicycle [1] [9], the image has still the same local horizon and the image has no effect back to you. Or, when you touch the plants [2] [9], it triggers the growth of plants in the simulation, but again, this has no effect back to the the real plants.

What we have to look for in the coming decades are transformations that are bidirectional. From the virtual world, something has to go back to the real world. We have also to overcome what I would like to call the locally bound situation of a computer installation or a video installation. To give a concrete example, assume a net-based installation by which one has the possibility to send a ping-signal to a server in Vancouver that activates it without the knowledge of the owner and that in turn sends back another ping-signal to your server here in Karlsruhe causing it to create images. Such a net-based installation offers for the first time the possibility of a non-local activity. This is, of course, just a simulation, and thus not fully comparable with non-locality in quantum physics. Rather, we here jump out of one local horizon into an image.

If I speak about an image, I do it in a non-classical way, as explained before. The image can be regarded as an information space. The possibilities we have now are activities in a remote information space and that this activities have an effect in the real local world, thus it is “reversible”, so to say. Ralph Hollis’ “Flotor” [10], as an other example, is an interface beyond the telephone, because it connects virtual and real worlds. With the “Flotor” one can activate and move around virtual objects. When the object falls down in the virtual world, it makes a sound, but you do not feel it. You could lift a weight of several thousand pound but do not feel it. Precisely this is what we are looking for at the moment – interfaces that are bidirectional or reversible between multiple virtual worlds or virtual worlds and the real world.

The next step therefore is to create interfaces between virtual worlds. If you have one image here and another image remotely, there is at the moment no possibility to exchange information between these two virtual worlds. Concerning the realization of interfaces between virtual worlds I rely in the skillfullness of the engineers to solve these problems. But the main problem in fact is, as I mentioned, if you regard the interface as a regulator on a scale of distinctions, to find an interface that regulates the information exchange between two virtual worlds. These different virtual worlds are called multi-user environments, or more precisely, multi-user virtual environments.

To explain this, let me give you an example. Assume two persons playing an online game. They sit each in front of their own computer screens, but in the game they enter the same virtual castle and meet. Now both person 1 and person 2 are facing a little monster, but in reality, there are two players, two real persons behind those monsters. These net games cannot be played without real persons, which is the main difference to standard computer or video games. You play remotely with other persons who are resided at different places. Each of those many users has a subjective point of view. If person 1 walks down a staircase and sees a monster coming up, which is person 2, then person 2, while walking up the staircase, sees a monster coming down which is person 1. What is this situation about? Are they entering a common visual space or even a common screen? No, this meeting is not a portal to a common

[1]of Jeffrey Shaws “Legible City” (1988–91)

[2]of Christa Sommerer’s and Laurent Mignonneau’s “The Interactive Plant Growing (1992)”

screen, but each screen is a window to a virtual environment that is not ubiquitous, but that in fact is multi-local. It is different from the cinema. The cinema is locally bound, which means that many persons are all in the same space.

7 Multi-local Structures of Communication

What we are entering now with the net is a multi-local structure of communication. This multi-local structure of communication gives us access to virtual environments. Looking back in the history of cinema from about 1820 to 1896, you can see that it took seventy years to develop the basics of cinema. Cinema was invented in the 19th century, but it was only in the 20th century that it has been developed for mass reception. In the beginning, due to technical restrictions, only a single person watched one film at one place at one time.

The beginning of virtual reality can be credited to Hugo Gernsbach, the editor of a famous science-fiction magazine. He was the first who developed an idea of virtual environments. He mentioned the idea of building VR machines. I myself tried to construct such a machine in 1966 [11]. It was a very primitive model, more or less an illusion. It is a helmet with a TV inside and some devices to regulate what you want to see. One year later, my friend Walter Pichler developed a media suit, combining radio and TV [12].

Out of these ideas, as you know, were born the famous head-mounted displays. These are not yet designed for multi-user capability, and in fact, here we are in the same situation as the cinema was in the 19th century – one person looks at one image at one time in one place. That is a single experience. The cinema was revolutionized in 1896 by the invention of the projector. Now many persons could look at one film in one place at one time. The single experience was turned to a collective experience. TV later on had a complete different structure, collective, but distributed or multi-local. Now many persons at different places could watch one film at one time.

Now, with video, many persons at different places can watch different films at different times. Here we have for the first time the idea of parallel communication. People sitting and watching TV can not communicate. The TV is not interactive. In virtual reality, as I said before, we started, as in cinema, having one person at one place seeing one image at one time. In contrast, with the mobile phone, we repeat for the first time the distributive collective structure of television. Many people at any time in any place can communicate. We have here for the first time an interactive multi-local communication structure.

Naturally, the same happens with the Net [13]. What the projector was for the cinema, the net is for the idea of multi-user virtual environments. Now anybody at any time can see anything anywhere. The crucial point is in fact that the net is a multi-local communication channel.

We are now capable to distribute interactive activity from the locally bound to the non-locally bound simulation of different virtual worlds. The net for the first time shows the possibility of interacting between real and virtual worlds and, additionally, on a "reversible" scale. What is not possible at the moment is interaction between two virtual worlds. How can we continue this research?

8 Multi-User Online Environments

Recently, I talked to Fredkin, who has already been working on these ideas for a long time. He told me what topics he is working on at the moment. Imagine a cinema situation with four different viewers looking at four different films on the same screen. It is still locally bound, but four users are looking at the same time into different worlds. What you need to achieve this are special projection lenses (Fresnell-lenses), an eye-tracking-system to know exactly where the person is looking at, an LCD-display and a projector that moves and rotates in a way that the beam is focused directly to the eye.

Finkelstein already in 1983 has written an article about computer interactivity simulating quantum complementarity [14]. Otto Rössler and myself announced at the documenta X 1998, that electronic media, as a part of physics, show parallelisms to quantum mechanics on different levels. For example, closed-circuit installations are just realistic implementations of the observer problem. When we go onward to the models used by Everett and DeWitt, we are already close to the ideas of Fredkin and others.

What we are searching for is to look into one window, however, not only seeing one, but several virtual worlds. These parallel virtual worlds are non-local, they are distributed through the net. There is a work by David Deutsch [15] who established the idea of quantum parallelism, which is the basis for parallel quantum computation and therefore the basis for the possibility of parallel virtual worlds. Today we have just multi-user online games, but the idea would be to develop multi-user online environments that people can enter.

The objective will be to make it possible to enter different parallel virtual worlds and communicate between them. The effect of this would be philosophically interesting. When you are able to make an interface between virtual worlds that are the same as between real ones, these virtual worlds become an ontological equivalent of real worlds.

When Fredkin, Landauer and Toffoli organized in 1981 at the MIT a conference called the physics of computation [16], there was a famous lecture by Richard Feynman "Simulating physics with computers" [17]. He refers to ideas he got from Fredkin 1975 and says: "Nature is not classical, and if you want to make a simulation of nature, you better make it quantum mechanical". This is also valid for the future of the non-classical image. For many people the ideas of quantum mechanics and quantum computing sound crazy, but I think they are the basis for the future of the physics of the image – multi-user virtual environments.

9 Neurocinema

One last idea: The interface of the new cinema will not be the eye. Since J. E. Marey and Peter Mark Roget who discovered the "laziness of the retina" (persistence of vision), the role of the 19th century physiology has been turned over to neurophysiology. What was done in physics, from Ernst Mach to Farraday, is done by quantum physics today. The idea of neurocinema was already developed in the 19th century. Poisot, a forgotten inventor, had the idea of producing electricity with the brain and feeding it to a lamp. From this, naturally, it was not far to the idea of a kind of cinema which does not need the eye any more. There is a book by Mass and Bishop entitled "Pulsed neural networks ", [18] which shows precisely that the pulse-based firing of neuro-spikes is how we see. We do not see spatially, but by means of a temporal code. Now we have to construct nano-machines that help to control the activation of one spike. If we would be able to simulate the activities of the spikes, we were able to create images without the eye. At the moment, the eye delivers some 15% of the information that we need to see something. I always say that the eye is nothing else than the doorkeeper at an hotel. A doorkeeper only sees what the director tells him to see. The most important information comes from the brain, why not simulate the firing of spikes and forget about the rest?

This step forward to neurocinema is already shown to us by a film called "Strange Days" [19], directed by Kathryn Bigelow and the scenario written by James Cameron. Cameron did his homework very well when he wrote the scenario. In this film from 1995, you see people with a strange net on the head. With this device you go around to film something when somebody falls down a building, another one rapes a woman. The point is that you get an experienced view of what happens. You can then buy these digital films and with your own net on your head, you can see with the eyes of somebody else. The cinema of the 21st century will make it possible to see the world with different eyes. Imagine that your wive is on holidays and you just switch some channels in your neuromachines to be able to see what she sees. One can imagine such a device like the windscreen of a car, where the images are superimposed over your own perception.

Of course, you can also regulate these images to see only the ones of your wife or you can switch them off altogether. In the film, the net was called a "squid". The film critics thought of course that this was just a fancy name for a funny machine, but in fact James Cameron had done his homework. "Squid" is the abbreviation of superconducting quantum interference device and is used in magnetoencephalography (MEG) for neuro-imaging. It is, though in fiction, one of the first realizations of quantum computing. It is the idea of neurochips that could be the basis of the future cinema stimulating the brain, not stimulating the eyes. The classical world of images was a trompe l'oeuil-technology, the new world of images is a trompe le cerveau-technology.

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On the Difficulty to Think Twofold in One

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I

Usually, we academics speak in public about what we have already done. This is safe territory. Today, I want to talk about something that I would like to do because I think it is both meaningful and necessary. However, so far I have neither found enough time nor the requisite concentration to follow it through. Therefore what I am going to put before you now must be understood as a very rough draft. Preliminary Sketch of a "Short Organon" for the Interface.

To make it clear what this is about, a few prefatory remarks are necessary.

1. Art which is expressed via media is becoming more and more the art of the interface. Theory of media seems to become theory of the interface. This statement reflects in a very specific way/in a particular phenomenon what the computer is or can be: It is, first and foremost, a machine for measuring, monitoring, controlling and connecting. It is not a machine for creating individual/single realities but one for guiding sequences/processes/time and combinations of heterogeneous fields of knowledge or activities; of scattered/distributed actors, machines, and programmes; combinations of different forms of expression and drawing materials: text, image, sound, haptic, etc.

   In short: I wish to treat the question of the medium as a question about the IN BETWEEN. Computers – and to an ever greater extent – computers in networks are intermediate machines: machines and programmes that operate in between various time processes and realities.

   It is quite possible that this will facilitate our approach to the question, which is of great concern to us from an artistic perspective, namely, the question of subjectivity. It is easier to formulate this than the question of what happens in the cut, in the difference.

   When German Romanticism was in full flower, Novalis complained that "Everywhere we seek the absolute but find only things." Two hundred years later if we turn this around it makes sense as a question: Why don't we seek the absolute in and between the things/singularities, by observing/respecting them?

2. Etymological Excursion.

   In engineering "interface" denotes the connection between various machine processes and sub-processes for controlling and moving and for time processing, including the processes in which man-machine relations play an important role.

   German (Schnittstelle): clearly marks the place in between different realities; as separation, as a dramatic place where it is not possible to rest.

English: face; the two meanings of face and surface. Interface; the meeting of two faces/surfaces, "the surface forming a common boundary of two bodies, spaces, or phases; the place at which independent and often unrelated systems meet and act on or communicate with each other." (Webster's Collegiate Dictionary)

"THE PRINCIPAL SIDE PRESENTED BY AN OBJECT".

"The facade of a building".

"The active, striking, or working surface or edge of implements or tools like the sharp side of a knife (opposite the back)".

There we are again, a dramatic place at which it is not possible to rest or stay.

3. What Was/Is the Interface in the Older Arts?

   Cinema: The apparatus in the widest sense of the term (basic apparatus, Baudry), that is, everything in which the concept of the film-maker/author is realised as a film in the cinema (shooting, cut, sound, montage, etc.)

   Theatre: Analogous to cinema – dramaturgy, direction of actors, scenography, stage sets, architecture, music, etc.

4. At the present time the dominant trend is toward humanisation of the interface as a special variant of the humanisation of work and the work-place. This expresses very clearly the human longing for standardisation, for the "universal". At issue is the "humanisation of areas that are not yet humanised" with a view to appropriating them (Bruno Schulz, Die Republik der Träume).

Reference to those, who once took or still take the risk to explore the other side:
The importance of experiment (with Klossowski, Die lebende Mnze):

"In the meantime, the manufacture of appliances itself has become acquainted with temporary infertility. This is becoming ever more apparent because the accelerated rhythm of manufacture forces it incessantly to prevent inefficiency (in the products) – it has no other possibility except to resort to wastefulness/extravagance. The experiment, which is the condition preceding efficiency, presupposes wasteful errors. To test experimentally what can be manufactured with regard to profitable operation leads to elimination of the risk of an infertile product at the price of squandering material and human energy." (Pierre Klossowski, Die lebende Münze, Kadmos: Berlin 1999, p. 10-11.)

My experiment tonight is (at least for me) a risky one. I have taken a text which at the moment belongs to the forgotten ones, totally unfashionable, dusty, more than half a century old, Bertolt Brecht's "Kleines Organon für das Theater" (Short Organon . . .) and I try to read through it the questions I have regarding the Interface.

The short Organon was written as a wonderful polemic against the laziness and satiation of established classical theatre. But it is much more than that. It was also written in a cultural situation, when industry took over the new media of Brecht's time, – radio, cinema, and already television, - and, moreover, in the same year that Turing wrote his text on "intelligent machines".

"With my father I had already talked from continent to continent, but together with my son I saw the moving images of the explosion in Hiroshima." (end of item 16)

Furthermore, it was written already to oppose the attempts by the new rulers in the East, to use Brecht's theatre as a service for their ideology. "Theatre has to stay something luxurious, which then means that one lives for luxury. Pleasures need defence less than anything else." (item 3)

So, let us explore some details:
7 points (as usual):

1. and regarding the most important and general point: The Aristotelian concepts of empathy (Einfühlung) and purification versus the epic concepts of pleasurable learning and thought that intervenes (eingreifen). Not constructed as a dualism, but a tension. No contradiction between crying and counting or laughing and calculating (Brecht: on the relationship of reason/rational logic and feelings, particularly the first sections of the Organon)

   The aim is not to replace entertainment but to implement a position (intervene) within it. At the beginning of the Organon Brecht writes something rather strange: "Let us cause general dismay by revoking our decision to emigrate from the domain of the merely pleasant, and even more general dismay by announcing our decision to take up lodgings there. Let us treat the theatre as a place of entertainment, as is proper in an aesthetic discussion, and try to discover which type of entertainment suits us best". (Vorrede)

   A harsh critique against those adepts and critiques of Brecht, who wanted to put him completely outside of the process by making him a god of the avantgarde, a fetishist of theory and dry scientific thinking. Those people, as he writes elsewhere, who were applauding him by saying, "yes, you are right, I agree, 2 + 2 = 5". The imperfectly understood "Lehrstck" (didactic drama). This – for me – involves a critique of the fetishisation of the ASCII-file and the written algorithm as the worship of idols. (Kittler, but more his adepts.)

2. Free interchange/transparency (the most difficult of all) toward the users on the one side, and to the machines and programmes on the other. It must be made apparent that the dramatic construction is something that has been produced, is something that is synthetic, and not the iconographic plastering over of the two sides. WIMP. Brecht: if the actor does not aspire to being either a parrot or an ape (item 55)

3. The gesture of showing something and, at the same time, showing that you are showing something, Kronos and Kairos , the programming of two different kinds of time, or better: to programme time from two different points of view: the time that is portrayed and the point in time from which the first kind of time is programmed. Dual data processing, the date of the original event and the date of its actual reproduction. (See also the invention of non-Euclidean geometry in the second half of the 19th century by leading Russian mathematicians, artists, and charlatans. The dynamisation of an infinite number of lines runing through one point opposite to a given line, that do not intersect with the given one.

   Brecht has tried to make this necessity of double data processing clear by developing the idea of an actress, who is not a parrot or a monkey, but who is able to play something which has happened from the perspective of actuality, as the auspicious moment.

   "Important is, what has become important. Such a Verfremdung (alienation) of a person as exactly this person and exactly this person now, is only possible if the following illusion is not created: the actress must be the figure, and the play should be the event." (item 51)

4. "We need a theatre that not only enables feelings, insights, and impulses, which are allowed by the current historical field of human relationships on which the activities (Handlungen) take place, but we need a theatre that uses and generates ideas and emotions, which play a role in the change of the field itself." (item 35).

I am trying to make a connection here with what has been discussed yesterday: what Maurizio Lazzarato calls "immaterial labour" and what some thirty years ago has been called "control labor", control of automatons/machines or Metätigkeit. What kind of aesthetical strategies do we need, if we want to respond to or even interfere in such processes?

What kinds of thoughts and feelings play a role in the changeof the field of networking itself?

Arguing against the ranting and pretentious German classical stage, Brecht wrote: "With us, everything slips easily into the insubstantial and unapproachable, and we begin to talk of Weltanschauung/world view when the world in question has already dissolved. Even materialism is little more than an idea with us. With us, sexual pleasure turns into marital duty, the delights of art subserve education, and by learning we understand not an enjoyable process of finding out but the forcible shoving of one's nose into things. What we are doing has nothing of an enjoyable Sich-Umtun, and to prove ourselves we do not say how much pleasure we had with something, but how much sweat it cost us to do it." (item 75)

5. Montage: shortage and glut. Montage originated from a situation where there was an acute shortage of material. What kind of strategies are feasible in dealing with a situation where there is an over-abundance of material? Can one even still practise montage with a glut of material or are not reduction, cuts and omissions called for?

   And how could this reduction look like in a networked permanent production of glut/over-abundance?

6. The Alienation Effect itself.

   Alienation as a concept to be posed against the imitation that is everywhere? Amongst other things, investigation of filmic strategies like, for example, the jump cut for digital design work. Irritate the simulation of continuity through the intervention of the machine itself.

   "The new alienations should only take away the stamp of the familiar of the social influencable processes, which today protects them from interventions." (item 43)

   Or: Guy Debord

7. Very complicated because: computers are very unstable systems and so, too, is network communication. Therefore, as I am dealing with extremely unstable systems, might not the creation of stability be a subversive tactic?

   Strengthening of local elements?

   "As we cannot invite the public to fling itself into the story as if it were a river and let itself be swept vaguely to and fro, the individual events have to **be knotted together in such a way that the knots are easily seen. The events must not succeed one another as indistinguishable but must give us a chance to interpose our judgement." (item 67)**

Conclusion (again, Klossowski)

Industry claims as the actual principle of all its initiatives that all human phenomena – and each and every natural phenomenon as well – are eminently suitable to be treated as exploitable material and, consequently, all variations in value and all uncertainties of experimental experience are subject to this. The case is the same with the both spiritual and animal character of erotic emotions which are valued essentially as a power of suggestion. (P.K. p. 20-21)

PALINDROME

This is a work by Cerith Wyn Evans (a compatriot of Keith Griffiths, obviously!) in the Galerie Neu in Berlin: a red neon band floats on the air, circling, with the text "In girum imus nocte et consumimur igni"

"We wander around in circles in the night and are consumed by fire" pax et amor.

II

The relationship of media to interfaces is dialogic. The understanding of this dialogical relationship is a result of an interpretation of the Cartesian dream. It stands against a background of "contra-modernism"despair at the lack of purity of linguistic communication. Dialogical philosophy formulates an ethical claim which, according to Otto Rössler's reading of Descartes, is prefigured in the Meditations. The precondition of dialogical thinking is that the relationship of the ego to the person opposite is only held to be a community if both parties accept each other, without reservation.

día

The proverbial Cartesian doubt and the prefix "día" have a common linguistic root, traceable to the Greek syllable "días" which means twofold, in two, asunder [1]. The assumption of an initial unity, which supposedly preceded the twofold, is problematic. There is no etymological evidence to support this assumption; rather, its antithesis suggests itself: unity is the result and synthesis of the twofold and manifold. The possibility "to think the twofold in one" rests on the premise of the twofold and manifold. The linguistic researcher, Wilhelm von Humboldt, has pointed out that at earlier stages in the history of language, the special character of the twofold was emphasised through the fact that it had its own word class, the dual [2]. The dual makes it possible to denote objects that appear in twofold form in such a way that allows their essential difference from things that are single or manifold to be signalised. The dual makes it possible for the "other", which faces the"one", to be described in its otherness and not as a mere doubling of one's own ego: The "You" is not of the same kind as the "I" but confronts it as its opposite, as "Not-I". The "second person" emerges, not by simple repetition of the unity but relates to it as the qualitative other [3, p.208].

The history of philosophy permits a relativisation of the notion of unity. Unity first began to engage European thought when the cities of ancient Greece found themselves confronted by a superior enemy power that was completely different to themselves, the empire of the Persian king Kyros [4, p.12]. However, it is problematic to analyse the relationship of the twofold to the onefold as a hostile conflict. This analysis can, in agreement with Marshall McLuhan, be construed as an effect of the media technique of writing, which has fundamentally changed the minds of the ancient Greeks. The violent changeover from an oral to a written culture was heightened, according to McLuhan, by the invention of the printing press with its movable type and this led to the mechanical age of the division of labour and industrialisation. In modern science, the written word and letterpress printing have resulted in extreme specialisation and fragmentation of knowledge [5]. It is this fragmentation that determines the relationship of the onefold to the other and it is a common prejudice that it was the concepts of Descartes' modern philosophy which systematically accelerated this fragmentation and splitting up of given entities into ever more divisible elements [6, p.24]. In the history of the reception of Descartes' philosophy, both monological and dialogical approaches can be found that attempt to piece the fragments together. Those that argue from the side of the Cartesisan ego and postulate its claim to knowledge as absolute can be termed monological; dialogical are the approaches that take the other in order to reflect on a rapprochement between the one and the other. Therefore at the heart of the Cartesian ego, an interface, and thus a dialogical principle, is revealed.

Descartes

Descartes' *Meditations* appear in the "fair" perspective, as does the "twofoldness" of his thought. According to Otto Rössler's reading, Descartes can be liberated from the veil of mechanical prejudices and the reputation of mere fragmentation [7]. Here, Descartes' concept of the ego is seen as something that operates at the dividing line between God and the world. It operates in such a way that the other is accepted as free and independent of principles which limit it. Otto Rössler understands the Cartesian "self" as occupying an intermediate position between the empirical and transcendental realm. Descartes doubts whether it is possible to distinguish between dream and reality. While asleep, he sees a book in which his future life is set down. When he wakes up, the book is not there. He falls asleep a second time and sees the book again but this time the page about his future is missing. Descartes concludes that it is not possible for both of the dreams to be true. Either there is a book in the world of dreams containing important information or this book does not exist in the world of dreams. The two dreams do not tally. They are contradictory. They cannot be understood in their contradiction in one and the same world. The Cartesian ego can thus certainly assume that the world seen in dreams is contradictory. This is a decisive difference to the world that the Cartesian ego perceives in the waking state. Statements can be made about the world experienced in the waking state that concur. One can assume that it is formed according to reliable laws; in short, this world is determined.

Determination implies the possibility of taking hostages in a double sense. Determinism is at the same time of this double kind [7, p.15]. For on the one hand, the ego can assume that its own perceptions are determined. This raises the question of how these determinations are formed, or to use a modern idiom, programmed. On the other hand, the ego can assume that the surrounding world is also determined and consists of machines. Again the question is raised about how these machines are programmed. The answer to both questions depends on one and the same position of the Cartesian ego.

Descartes assumes that an omnipotent programmer has set up the determinations. However, the quality of the programme can be determined by the ego. Descartes understands by "quality" an answer to the binary question, whether the programme was set up with intent to deceive or not. Is the world a hostage of the programme? The Cartesian ego receives an answer through an astonishing twist. It decides to regard the surrounding world – and in particular the humans in this environment as free beings and not as programmed machines. On the basis of this decision the question is thus also decided as to whether the transcendental programmer designed the world with intent to deceive or not.

Through its own decision the Cartesian ego arrives at an answer about the structure of the world. This decision prefigures dialogical thinking, namely, that concedes freedom to the other and, proceeding from the assumption of this freedom, constructs a common stock of meaning of the world. The Cartesian ego is at the interface between the transcendental world of the Great Programmer and the empirical world.

The ego is double-sided. One side faces the surrounding world of machines and the other the supernatural world of God. Descartes discovered two things: first, that this ego can manipulate both of these sides and second, that the manipulations of one side have consequences for the other. Both sides are connected via the interface. If the switch is set to "mistrust", then God not only becomes the culprit who alone deceives the Cartesian ego, but inevitably the worldly side becomes a questionable machine that is subjugated to the will of the programmer. However, if the switch is on "fairness", then God is the benevolent and great Other and, at the same time, the creatures in the world perceived by the senses are magnificent in their diversity. The Cartesian ego thus becomes a manipulable medium, and the opposite of pure. The Cartesian medium is, in Rössler's interpretation, an impure medium of change which consciously slides in between the divine light and the diversity of the world that it illuminates. The Cartesian ego can regard itself as an interface and thus manipulate. It can switch back and forth between a fair view and and mistrustful view vis à vis God and the world. In both cases the interface changes the incoming and outgoing information, like through smoked or crystal-clear glass. Thus the Cartesian interface is never a pure medium: it either dims or illuminates. For Rössler, the interface is a paradise machine. It is driven by fair decisions.

Media Science

At this point the use of the word medium demands further explanation in the context of current debates in media science. The editors of *Kursbuch Medien* [8, p.10] decline to ascribe a historically solid and substantial meaning to the media. I am fully in agreement and would like to support this with a brief look back at the etymology under the presumption that etymology will clarify the relationship between "media" and "interfaces".

The word "medium" has its roots in Greek and Latin. It described a spatio-temporal position, for example, the space between above and below, between the rising and the setting sun, and also referred to a public meeting place. Since early modern times, it is customary to understand a medium also as an incorporeal context in which something may take place. The definition of this in the Oxford English Dictionary reads: "Any intervening substance through which a force acts on objects at a distance or through which impressions are conveyed to the senses: applied to the air, the ether, or any substance considered with regard to its properties as a vehicle of light and sound". This usage led to the definition of medium as it is used in the natural sciences. In the methodological discussion of media science, Friedrich Knilli has drawn our attention to the fact that the definition of "medium" as it is used in physical science – "an intermediate agency continuously pervading space" [9, p.230].

At the beginning of the twentieth century the relation to etymology became more lax. Two competing epistemological opinions on the relationship between media, consciousness and the world evolved – one connective and one divisive. The philosopher Ernst Cassirer understood media as symbolic forms that build a bridge between consciousness and the world, whereas the mathematician Hermann Weyl stresses the distance between symbols and consciousness on the one hand and the world on the other. Cassirer's reflections are based on the premise that the world is only given in human consciousness in the medium of symbols, which he disccusses in its historical differentiation in his *Philosophy of Symbolic Forms* [3]. The symbols used by humans are a medium in which consciousness and the world reach a synthesis. Cassirer makes a distinction between the media of mythical figurative expression and the medium of linguistic articulation and between both of these and the abstract use of symbols in science. Each medium forms the perception of the world and demands examination of what is considered to be true or false in accordance with the media.

Interestingly, Cassirer only began to use the word medium in methodological discussions in 1923. Two years before that, Hermann Weyl had published an article on the renewed crisis in mathematics [10] where he used the expression "Medium des freien Werdens" [medium of freely coming into being] to describe the continuum of real numbers. Weyl's argument rests on the assumption of a fundamental split between consciousness and the world. In contrast to Cassirer, he does not regard symbols as mediating bridges. Symbols and combinations of symbols are separate from reality. A further contrast to Cassirer is that Weyl speculates about a reality behind the familiar world which is accessible through mathematics and physics. One might say that the familiar world lies between mathematical consciousness and the true world. The different epistemological positions of Weyl and Cassirer result in two different notions of media. For Cassirer, media are forms in which syntheses between consciousness and the world can arise. Media are thus meta-forms. For Weyl, media are indicators of a fundamental cut between consciousness and the world. This cut is a possibility for determining the more real reality behind the visible world.

Cassirer and Weyl were familiar with the other's publications. Their differences – between a mathematician and a philosopher – are an indication of the function that media science might possibly have. Cassirer's lifes work is the "heroic" attempt of a philosophical observer to keep abreast with developments in the natural sciences. In 1921 he published an account of relativity theory, which was read through by Albert Einstein before it went to press, and on the day that he died, he wrote an essay on the debate on causality in the reception of quantum mechanics. Hermann Weyl acknowledged Cassirer's achievements and expressed his admiration during a speech given at Columbia University, New York, in 1954 while emphasising that his own position was a different one. Weyl did not share the opinion that one can speak of a uniform development in the way that humans utilise symbols. In his *Philosophy Of Mathematics and Science* [11], Weyl stresses the differences and makes it abundantly clear that the "heroic" age of Leibniz, where philosophy and mathematics cross-fertilised, is now over. Weyl's recognition and emphasis of the fundamental difference between philosophical concepts and mathematical symbols in his philosphy lays the foundation for a new dialogue. He distinguishes between two types of philosophy. First, there is the historical account of the foundations of modern science and Cassirer's work is his first example. Second, there is the "independent" thinking of philosophers such as Fichte, Schelling, and Husserl who arrived at questions that modern science also poses, for example, the position of the human subject between finite empiricism and speculations about infinity, between determination and freedom. Weyl both stressed the difference between philosophical metaphysical thought and constructive scientific laws but never tired of calling for science to retain metaphysical belief.

For Peter Weibel and Otto Rössler, natural science is media science. This is plausible if one shares the opinion that the place formerly occupied by philosophy as mediator and communicator of scientific results is vacant. Weyl argues that philosophy asks the same questions as science but in a different way and, therefore, cannot mediate and communicate dialogically as long as generally (following the above argument, monologically) the pre-condition is to gain an overview of mathematics. Weyl questions whether it is in fact possible for a mathematician or a philosopher to take up a position above the other's discipline. Media science cannot judge per se from a superordinate position, for it is bound to the "in between" of the positions. Research on media obliges one to think in terms of relationships. This ranges from spatial and temporal relationships to relationships between disciplines and relationships between humans, machines, and the world. The starting point of media theory is the point where a relationship between discrete objects is assumed. Proceeding from this assumption, it examines the construction of the relationship whereby the interface is of paramount importance. I call this relationship a medium in which the interface decides between the "one" and the "Other". The medium only becomes visible through differences. (In my opinion, this definition is already implicit in Weyl's understanding of the continuum although it is generally ascribed to Luhmann's systems theory.) The differentiations are grounded in the dialogic principle. As long as the other or the diverse is not assumed to be the basis of the established relationship, the discourse of media science remains empty. In Rössler's interpretation, the Cartesian ego only succeeds in producing a consistent world-view when it recognises that it can only think of the world of humans and the world of God as consistent and inter-related if it takes an ethical decision. On the cut between a "fair" and a "deceptive" world, which the Cartesian subject can make, depends the form that the relationship between world, transcendence, and subject will take. Before, the relationship existed only as an abstraction, as a simple medium of possible decisions. Through the decision, the medium is either illuminated or obscured, that is, it is perceptible to a greater or lesser degree.

Paradise Machine Lampsakus

Computers and telecommunications allow us to communicate with other people. However, the myriad of possible connections remain "empty" if contact is not made. Vilém Flusser, who like Rössler acknowledges his debt to the dialogical philosophy of Martin Buber, illustrates this with the example of a chess player. If you have played chess with someone who lives thousands of miles away, then the possibility is always given that the other can enter into your life again and ask you to play. One must reckon with the entrance of the other without being able to count on it. The unexpected entrance of the other becomes a possibility that is always given. In Flusser's view, when it does enter, God also enters. The entrance of God – here the last piece falls into place between Descartes and the modern era – is always the entrance into the world and thus the chance to escape from self-referentiality.

Here there is an important distinction between media theory and media praxis. For Rössler, the interface becomes a paradise machine if it is set to fairness, that is, when the interface colours the centre between the worlds so decisively that the world appears as free and not as contradictory at the same time. It follows that the interface can be programmed by ethical choices. The interface set to fairness can, for example, be controlled in such a way that the ancient city of Lampsakus is rebuilt on the Internet. What we know of the original Lampsakus can be extended and expanded. Up to now, all that is known about this digital Lampsakus is that there information and knowledge can be obtained for free in a sunny place. To date, Lampsakus is a possibility for gaining knowledge in a tranquil and orderly fashion. The possibility exists to South-Americanize Lampsakus. However, if we can entertain the thought that knowledge cannot only be obtained in libraries but also through dance and rhythmic forms, then there is a great chance that image-makers, dancers and others who have overcome their obligations to the alphabet will help to build Lampsakus with their arts and skills. It is with this hope that I dedicate this chapter to José-Carlos Mariategui, mediator to the Peruvian supporters of Lampsakus.

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On Friendship. Philosophical Reflections on an Economy of Giving and a Style of Expenditure

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Figure 1: *Laughing human face and mechanistic schematic of an unsmiling face. Document form applied science, March 2000.*

Handshake between friends: A flaming heart from out of the clouds – *VERA AMICITIA* ([2], columne 1013).

For Otto Rössler, a smile possesses a unique power which, amongst other things, enables it to irritate the authority of evil. A smile shimmers and shifts between joy and kindness. It delineates itself as a relationship to the world to which the world may respond or remain silent The dignity of its existence is not dependent on such reactions. It reveals that which it enables from out of itself. It remains a secret and, because of its specific nature, it embodies a special image of what is human. One thing is certain: it is not yet possible to simulate smile.

Hands entwined across a table with a salt-cellar. SAL VITAE: Salt of life: whereas bad and harmful friendship is fruitless and devoid of substance, true friendship based on virtue grows into a delightful and pure treasure. That is why it is called the salt of life: it makes this arduous *life palatable. With friendship there are no sorrows and entanglements; without it, there is neither good nor contentment.* ([2] column 1016).

The philosophy of Otto Rössler is a far-reaching and deep, always noble and restrained draft of friendship. Its essence combines joy and kindness. It carries its decision as decisiveness within itself. It frees itself from Nietzsche's curses of a love that has degenerated into desire. The shackles of desire come off under its sign for they recognise that love not only means to respect but also to insist upon the release, both of the loved one and the one who loves, from the misunderstandings that life brings with it. Friendship relates to a higher idea than desire could ever describe. Friendship goes beyond the ontology of solitude and thus philosophical solipsism as well. Through a smile shines that which can only be experienced inadequately in solipsistic argument. Like the supposition of consistency, the inadequacy of the ontology of solitude is the concern of intuition or the sensory perception of evidence. The development of interfaces, with which the forms of exchange of the living, living beings, – and nothing else – are designed artificially, is dependent on the insight into the existence of disparate, different, many and diverse elements. The question, whether the quality of being human is limited to human empiricism or whether it includes relations between humans and machines, proves to be only secondary when confronted with the richness of the quality thus described. Who would be able, prospectively, to decide or prescribe this? Who would even be interested and what could it look like, what would it intend to mean, what could it mean? One only has to think of the subtle relationships that certain people – for example, Otto Rössler and his profound admiration for the whales – are able to establish with certain animals. Theoretically, condiderations of such phenomena cannot be advanced that remain within these relationships but only against the background of particlular world-views, that is, the particular philosophical ideas that inform the respective constructions of the world.

The parrot fish (scarus) helps conspecifics to escape from fish-traps. ADVERSIS NON DEESE DECET. In adversity, one must not be absent. Behold how the prarrot-fish get their brothers out of the willow fish-traps in which they were ensnared. In truth, this is a symbol of true friendship. ([2], columns 721f.)

Whatever the constructive intervention of an engineer or a aprogramme transmits of qualities that go beyond the ontology of solitude – which the traditional view of the intelligence of machines, regressively, time and again endeavours to measure: intelligence as problem-solving that flows out into a box (or a tank), individual self–assertion, presents itself, makes references to earlier cultivation of friendship in symbols and images, ideas and phraseology. In this respect, the handbooks on emblemes have offered rich nourishment since the 16th century, both positive and negative. Under the sign of true or false friendship, what is ultimately at issue are the conditions for a smile which one can interpret as a non-solitary gift of the secret. With regard to Emmanuel Lévinas, whose ontology of alterity – and thus also the logic of non-solitude – is cited frequently by Otto Rössler, this is easy to understand. However, in this context "understand" does not mean analysis, argument, and proof but, again, the experience of evidence which guarantees the feeling of consistency while permitting sceptical argument at any time. I am a living beeing by virtue of what is not me, and what I am not – what the other is, for itself, and about myself. Thus suicide is, obviously, logically and in effect imposible. It cannot succeed and represents neither a goal nor an option. It is always the other through whom I am. The "I" is nothing other than the perception of the power of this other with respect to and within myself. Such an ethics of alterity balances the reflexive self-alienation, which is only a shield, and which in all self-reflection of the individual from the perspective of being actually split off, divisible, is anavoidable. The self and the entire discourse centred upon it prove to be fatal mystifications which merely express a recoil from recognition of the secret. For me, the friend, this secret does not exist at all. The secret, which the friendship of the other represents for me, does not require revelation because it exists in the friendship which is manifestly given to me. The love and friendship that I show to another are not decisions but a gift, one of life's gift. This is also how love and friendship that another shows me appear to me. This stable symmetry thus exeeds the dual and also symmetrical form of friend-enemy relationship. The gift that is kept alive by this symmetry is therefore not a model for politics because there power always turns out to be asymmetrical and is thus the priority of the enemy. However, this gift that is expressed in friendship, can become a model of economy: the art of extravagance, expenditure and unreserved loss. Friendship cannot lose anything for it is boundless and generous. This generosity is not subject to any calculation or negotiation. That is why loss is always constitutive for it and, to be precise, in the form of unreserved expenditure. Friendship settles, designs itself, is alive as that which it experiences throught itself. Friendship is decisiveness that needs no decision. It exists beyond decisions which all force splitting-off, duality and opposition. Incontestably, for friendship as for love, it is axiomatic – and exemplary for the entire problematic of the consistent world – that they are dependent on the fact that they reveal themselves. There is no love or friendship whithout knowledge of them. Friendship lives from expenditure. To describe this as "loss" is legitimate in a particular respect if the loss and the expenditure always remain prerequisite. Loss is only possible in reality or, more pointedly, irreversible, because it is the way generosity expends itself and is therein inexhaustible.

Figure 2: *Hans Holbein, The Ambassadors, 1533.*

At this point it is appropriate to call to mind an old master in which the staging of friendship and the picture's spectators are handled in a special way: Hans Holbein's painting "Jean de Dinteville and Georges de Selve" ["The Ambassadors"] (1533). It is an image of friendship which has many branchings, nuances, narratives. In connection with what concerns us here, I should like to mention the following selected elements. The figure of the left is Jean de Dinteville, ambassador of Francis I of France. De Dinteville was in London from February to November, 1533. The figure on the right is de Dinteville's friend, Bishop George de Selve, who visited him in London in April/May of that year. The artist's signature is in the area of shadow at the bottom left of the painting: IOANNES HOLBEIN/PIGEBAT/1533. De Dinteville wears the Order of St. Michael around his neck and the hilt of his dagger bears the inscription AET SVAE

/ 29. A badge depicting a skull – it is not the only one in the painting – adorns his hat. De Selve's right arm rests upon a book with the lettering AETAT / IS SVAE 25. The mosaic floor is a copy of the Cosmati pavement in the sanctuary of Westminster Abbey which was laid in the Italian craftsmen. The terrestrial globe on the lower shelf of the table is a copy of one made in 1523 by Johann Schöner of Nürnberg, who corresponded with Copernicus. The half-open book on the left is identifiable as an artihmetic book for merchants by Peter Apian (Petrus Apianius), published in Ingolstadt in 1527. It is open at a page of the chapter that deals with division. The book on the right is a Lutheran hymnal, Johan Walther's "Geystliches Gesangbüchlein", first published in Wittenberg in 1524. This book is open at two hymns in German by Martin Luther on facing pages which symbolize an idea of ecumenical Christianity and are traditional anthems of the Catholic church: "Veni Sancte Spiritus"and "Mensch willt leben seliglich". The lute with a broken string (a symbol found already in Andrea Alciati's "Emblemata", first published in 1531 in Holbein's native city, Augsburg) is a motif that possessed many emblematic meanings for this period. Amongst others, it is a metaphor for the disruption of harmony and thus it symbolises that understanding and diplomacy are in jeopardy. On the table, which is covered with what has come to be known as a "Holbein carpet", are various mathematical and scientific instruments of the age including a celestial globe, a compass, a polyhedral sundial, a cylindrical dial, a plumb-rule, a pair of dividers, and a quadrant. At the bottom of the painting, in the centre, is a striking anamorphosis.

The interpretation of the painting's various layers of meaning, particularly the precise interplay iconographic and dynamic elements, is a subject for intense speculation and discussion which is still not exhausted today. We do know that it is a double protrait of two friends. Further, we know the location for which it was painted, the perspectives and the intention it followed vis à vis the onlooker. Originally, it was hung on the back wall of a long room. Anyone entering the room faced the painting. On the side of the room facing the painting, there was a staircase on the right-hand side leading down. If one descended this staircase and, on the landing, turned back to look at the picture the previous was reversed: the anamorphic object was revealed undistorted and the rest of the picture appeared to be a distortion. From this point, it could be seen that the anamorphosis is a skull. The import of this constellation is that the painting was designed for successive reception, for contemplation in rhythmised temporal stages. Although it is materialised spatially, it possesses a chrono-topographical dynamic, to employ an expression of M. Bachtin's. It is spatio-temporal and goes far beyond art history's fixation with an allegorical stereoscopic picture. This painting puts the spectator "in the picture" in a two-fold manner: first, the onlooker decodes the messages and second, looks back and sees the memonto mori. However, this is not a simple case of one of the usual allegorical representations of "living life whilst remembering that you must die". Rather, a temporal process of looking back is the determining factor which intertwines "having been born" with "will be dead one day" – actually physically and metaphorically transposed at the same time. The most crucial element of the painting is found at the top on the far left: the brocade curtain is pulled aside fractionally and behind it is a crucifix on the wall, nearly but not quite hidden by the curtain.

This is the level of the picture, the deepest layer, so to speak, which incorporates the authority of transcendence. Here stands the symbolic proof of life and death in an exclusive, doctrine of salvation frame of reference. Or at least this accentuation has been inferred as compelling. In the name of friendship, I should like to reverse this hierarchical tangled web between transcendence and empiricism: crucial is the kind of friendship from whose focus the barrier-crossing transcendent derives its vitality in the first place, the proof of its evidence – as a reflection of life and life-style, as the ethos of the historic which has to prove itself through human actions and through these, to stand the test of time.

Figure 3: *Hans Holbein, The Ambassadors, 1533, detail in upper left corner: the crucifix.*

Being superseeded and preserved ("aufgehoben") in the transcendent is not decisive but rather the challenging question of whether this has occurred under the sign of friendship or whether this only represents an instrument of the authoritarian enforcement of superordinate purposes for a world that has been made consistent by force, levelled, unified, and formed. Events shift – thus taking the provocation of the transcendent seriously – to the level of construction of a concept of the world that coincides with the construction of the "world" in general. Thus, following this argument, the idea of a single, unified world is a phantasm. Potently influential to the point of being pathological, at the same time it represends paradoxically a vanishing point for all who allow themselves to be fascinated by the energies of the chaotic, the random, or disorder. That the world is consistent is a philosphical postulate. That the world might, at some time, prove to be inconsistent remains a suggestion, at once enticing and threatening. On closer scrutiny, talk of "one world" proves to be obscuring. Time and again the claim has been argued vehemently that "the world" is subjected to a single order. The intensity of the living, of life forms, and the idea of an infinite number of worlds are highly compatible. For wherever the formation of connections is enabled, disparate elements must have been able to exist previously.

By contrast, the demand for globalisation which is currently rampant favours the forced shrinking of temporal and spatial distances. It is grounded in conditions characterised by force that strives to commit us to abstractions. For the coherence of a miniaturised world reduced to a uniform One that it aprises to, there is apparently nothing more desirable than a perfectly controllable accumulation, analysis and evalutation of so-called knowledge and facts by members of competent elites. In accordance with a world levelled to a globe, this kind of pragmatism is revealed at the present time to be a forced prescription of self-relief from the burden of reflection and experiment. But one world is not enough: on a course diametrical to the claustrophobia of a world rendered manageable and calculable, innumerable non-contemporanities still run. Insisting on other dimensions, layers, and modi operandi, the discourse of plural "worlds" ranges from micro-spheres and sections to definite largescale open macro-designs which foster the complexity of localities and singularities, the movements of the nomadic and the extravagant, that are not subject to any dual-oppositional logic. For this reason, the question as to the construction of the world or worlds is a question of friendship, its substance, precision and reliabiliy or, put it differently, its courage. Thus each and every interface depents on the capacity for friendship.

Friendship is a third, unique quality and form that is not definable through desire nor the fusion of identities that love promises – constant recognition of the disparate and the fact that one world does not suffice. Just as love cannot tolerate any kind of contractual agreement, friendship would be impaired even by the temptation to reinforce it with an agreemeent, of no matter what kind. Friendship as a way of life does not lead to a particular type of ethics or culture. It does not culminate in a self which it enables to appear but without being able ever to attain. It is the reason for a certain way of life, it is the condition for the ethics which lead up to it and which it comprises, both determining and effecting, invisible and intangible. As Derrida remarked with reference to Aristotle, friendship belongs in the same configuration as knowledge and death, namely, in tableau of effective forces. It is a condition of possibility and, therefore, of transcendental provenance.

Friendship is a design in which self-contemplation experiences that which does not result from the "self" as causal. It is apparent that it will not suffice merely to perform deconstructivistic deletions on the instance of the self which in the end – particularly when the self's absence is invoked – always triumphantly serve to enhance the self. Friendship is a challenge to all-embracing that is founded on the secret of a smile and it reiterates this secret without commiting itself to the well-known paradoxes of disinterested pleasure or the longing to be free of desires.

The crocodile sheds tears for its victims. DEVORAT ET PLORAT. It decours them and weeps. Truly, to mistrust the word of a fair-weather friend is as natural for me as to mistrust your tears, crocodile. ([2], columns 672f.)

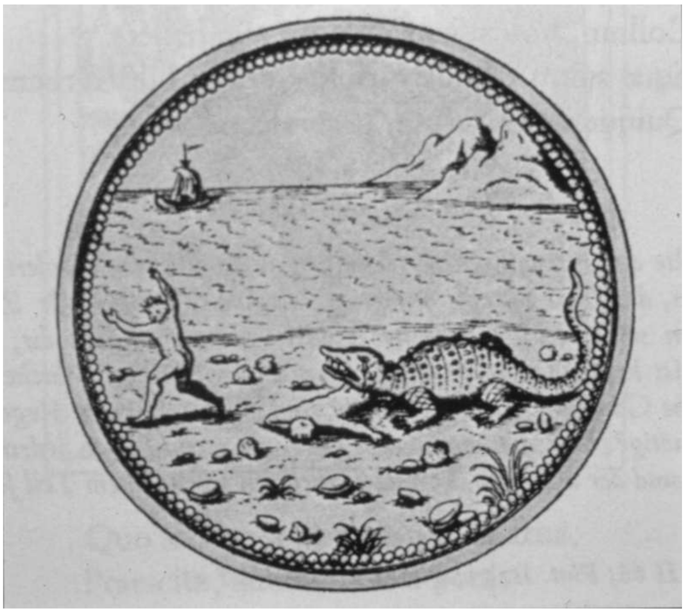

Figure 4: *Example of 16th and 17th century friendship emblemes.*

The crocodile sheds tears for its victims. INVERSUS CROCODILIS AMOR. The crocodile is the opposite of Amor. It is said that it is the crocodile's nature to weep while it kills and devours its victims. By contrast, Amor does the opposite, for he laughs while suffering the *lovers be destroyed.* ([2], column 673.)

Is it not so, that the discourse of betrayal and the notion of a foe who virtually lies dormant in a friend, is based on insurmountable mistrust which, from Aristotle to Montaigne to Derrida, has been expressed in the formula, “Oh friends, I have not got a friend”? For are not the friends of enemies especially bad enemies? Is it, therefore, unavoidable to see in a friend a possible enemy, the only true and dangerous one? Are these merely paradoxes of the theory of categories which make their impression on the semantics of out surroundings or do they express, conversely, grudging acceptance and the older and wiser realisation that the most perfidious betrayal of all is only possible between – former – friends. In any case, one is led to suppose that once the dual aporia of the friend-foe pattern, i.e., the primacy of the political, is set up, it is no longer possible to evade the compulsion to suspect: consequently, a friend is a potential foe and the enemy, depending on the tactical situation and on a case-by-case basis, has to be made into a friend, at least for a time. There is no way out of this trap. Yet it is obvious that there are no strong reasons for accepting such a trap. There are innumerable attempts at an explanation of this problem of a – foolishly – recognised asymmetry which represents a sudden chage into the opposite. The most radical and sober analysis stems from the 19th century: the embodiment of evil. Edgar Allan Poe’s “imp of the perverse” renders most appositely what can change wanton love into its most absurd inflection. Only the worst possible turn of events, according to Friedrich Dürrenmatt, characterises the dramaturgy of the real which cannot invent a reality for itself that will not be drastically outdone in this principle by the real, i.e., by itself. Something similar may apply to the aporetic involvement of a friendship that is under suspicion. Only when the real has taken the worst possible turn is the truth of its existence fulfilled. The embodiment of evil as self-realization of this counter-factual evidence – compliant self-encounter of reason – is also what takes effect as the hostile principle in suspect friendship. This is dependent on – and this cannot be emphasised enough – the pre-supposition that friendship is not absolute but can and must be placed under suspicion, that is, conceived of as both relative and relational. This is what the friendship discourse, from Aristotle to Derrida, suffers from for this sides completely with normative ontology. It believes, in its purportedly humanising scepticism, that it must confront an image which it is able to produce for the sake of protection against the real but which comprises a moral decision against the real understood as absolute – this it prevents and disallows categorically. In this way, the idea destroys itself nuance-wise which, in fact produces that which its scepticism claims to protect it against: lack of independence, betrayal and mistrust. However, friendship cannot endure any kind of prejudice or the calculation that it might be advantageous to seek, offer or accept friendship as protection.

Clam and crab in symbiosis. ALTERIUS INDIGENS PERPETUA OPE. Needing the constant help of another. A person who is constantly obliged to make use of the vigilant advice and admonitions of another and does not take care of their own affairs, glorious classical antiquity compared to the clam. For when the clam is hungry, it opens its shell in order to catch a small fish or (other) prey. However, the insensible clam does not sense when it has caught something and close its shell unless the crab admonishes it with its sharp claw to close quickly and hold fast to the prey which is welcome to them both. The best man is one who attends to his affairs himself but a man will not be despised for listening to his friends after soliciting their counsel. However, someone who despises both courses is hated by all and you should avoid such a man. ([2], column 729.)

Diogenes Laertius describes a symbol of false friendship under the motto “in amicitiam simulatum” and outlines how a handshake with clasping fingers leads to an expression of transgression. Later this took the visual form of the right hand offering bread while the left hand concealed a stone. Asymmetry and furtiveness, insincerity and evil intent are expressed trough

Figure 5: *Example of 16th and 17th century friendship emblemes.*

the fact that someone keeps something a secret from someone else. But friendship is that which has no secrets, which cannot be analysed further. Both a goal and an ideal, friendship is the prerequisite for the ontology of the social as well as of the political. Jacques Derrida's "Politiques de l'amitié" (Paris 1994) demonstrates with great insistency that the secret cannot be analysed; indeed, does not need to be, Derrida does not substantiate this for such proof lies beyond arguments. For friendship constitutes itself through itself, as trust and all-embracing quality of love, but not through logic. Derridas attempt only play on friendship indirectly because he is not willing to accept the absolute. He fails – albeit most impressively – because he attempts to mistrust friendship, although he knows that it is precisely friendship that is rooted in non-provable evidence and that there are no limits and no conditions for the trust that makes friendship possible. I am not raising an objection to Derrida's observations but rather pointing out the inadequacy of the assumptions that he permits himself (and into which he attempts to fit himself like a frame that is too small). Further, it is to urge a different reading of his book, not only with regard to the mistrust that is forced upon friendship by the relationship to the enemy: to read it as an encirclement of that which still remains convincing when all arguments referring to political discourse fail. Political discourse is always a discourse of betrayal.

A rapier with a resilient blade. NI SE QVIEBRA NI SE QVEDA. It does not break nor remain bent. Put your true friend to the test when you are in difficulties or when fate has thrown you from the right to the insignificant left side (of life). If he who was your friend when you were at the height of fortune is still your fiend when you are plunged into the depths and stands by you in both situations, then he resembles a precious and finely wrought rapier that does not break or alter shape when it is bent. ([2], column 1504.)

Life is always "life with". Between friends, there is no form of address of solitude. In the West, friendship has always been philosophy/been referred to philosophy. There is no true philosophy without friendship which does not exist as a constant expenditure of generosity. To what extent is this a question of style? What should be understood by "style" in this connection? To make this clearer, I shall first take a circuitous route via some general, non-specific comments that can make lasting an independent reference to the style of friendship

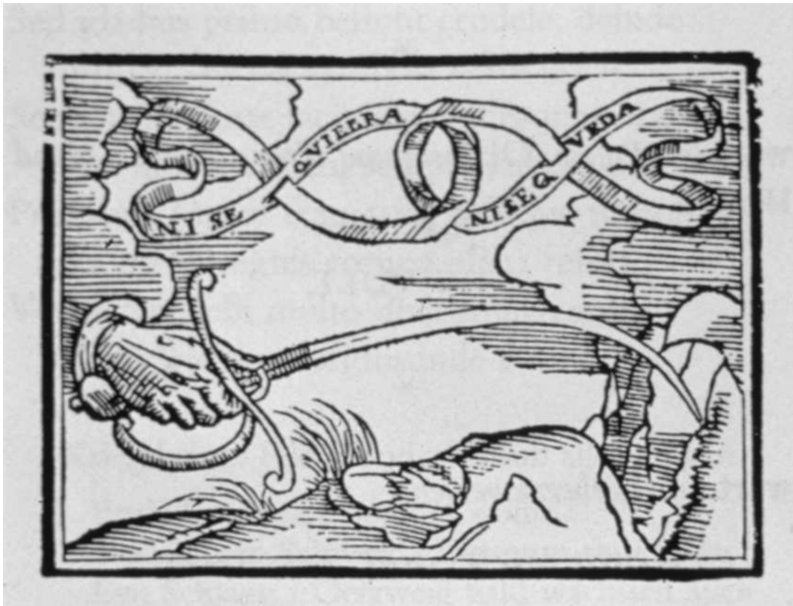

Figure 6: *Example of 16th and 17th century friendship emblemes.*

which is not style in the usual sense nor indeed a usual style. Perhaps these general remarks will provide some applicable and adaptable insights.

Style is a synonym for order. It both realises and describes the successful application of a concept which does not represent the subjective culture of an individual person but instead – in contrast to “maniera”, handwriting – constitutes the wider context and, therefore, a non-personally controllable objectification. This attests to a profound familiarity with a metaphorical mode of expression, a psychological substitute for the coming into being of style as an order of events which can be in accord with inner dispositions that have not yet become conscious ones. That which is termed identity can be understood by imagining an order that is not without a rest of comprehensible inner mechanisms. All conceptions of formable style that comprise salvationist and redemptionist yearnings are examples of such inner dispositions for style. The conception of a world in which all people use the same, right, universal things is a well-known variant of this. And why should they want any “wrong” things; why should they prefer the unfinished to the perfect? There can only be one conceivable reason for this: because they know that their lives are essentially bound up not with the solving of problems but with the unsolvable. Paradisiacal notions of immortality and effortlessness involve the implication that things fall to one and that they do so because they are universal, i.e., they are true. In this case, “true” expresses self-referentiality, not a relation into which intermedia can insert themselves.

Thus the context of the definitions of style and these themselves obviously concern the relation of the One to the Other, of what is other peoples and what is one’s own. Style refers to the process of its development. It is not an entity but a procedure with which its many and varied aspects can be fixed with reference to a non-material system and it always culminates in recognition or esteem. The style characterisation, which refers to aspects, becomes a component of a wider context. It is for this reason that a style certainly does not go beyond a normative claim but rather proves itself in the constant strength of high esteem. This is why it can be regarded as an essential category of friendship.

If pure style is the right one, what shall we do with the deviations? Specifically, in the case where we know that the forms are the results of a selection process operating with binary codable exclusions? One unsatisfactory answer is given by the instrumentalisation of style as a way to salvation. This is a universal concept which forcibly subsumes disparate forms and diversity and is not without reductive consequences. Its content depends on the idea of a continuum, a serial order that is contrived by the constants of a linear logic, i.e., by an order within a continuum, which is binding for elements that were previously dispersed when these elements arrive from the outside as new elements. The change of attractors in the gravitational field of stylistic forms can also be viewed as a change in the energies that support them, affinity and friendship.

The salvationist components of the expectations placed on style are that the identification of style as perfection of life and of life's context are understood in the sense of asummation of cultural goods. Evidently, in the unity of a style, its conception of the consistency of things, ideas from the philosophy of history are effective. Their historical origins lie in industrial activities, the growth of technology, experimental test apparatus, the civilisation of the emotions, a final verification by the subjective consciousness of people who conceive of themselves as the subjects of crisis in that they think that their consciousness can do without all external or transcendental verification. As is well known, the result is both devastating and salutary: from being the subject of the crisis, the enlightened consciousness changes into being the crisis of the subject (the best way to date this conception of the subject of the crisis is still through Philipp Moritz's "Anton Reiser", published in 1785).

After due consideration, it is clear that the phenomenon of style is deeply rooted, namely, in the conviction of an epistemological realism which has erected a dual structure between consciousness and reality coordinated by equality of structure. Western ontology has drawn its most enduring convictions from the idea that true thought adapts itself to the real. Thus the origins of the vigorous historical development of a secular awareness of empowerment lie elsewhere: in the fact that the supposed triumphant progress of the world-historical individual, the powerful historical consciousness of a person and the entrance of teleological thinking into the orientation of the consciousness of Western man are not only a consciousness of crisis but also simply establish consciousness as a crisis. The supposed power of thought, according to the philosophy of history, is always poised on the brink of a threat to its very existence: namely, that the consciousness of power is shattered by the crisis of the real and, worn down by contradictions an made insecure in its fear, is driven towards self-disintegration. Together with consciousness based on the philosophy of history, fundamental doubts about the power of reality arise which even the most emphatic hopes cannot simply pass over. That which formerly was preordained security, because it derived its identity in a First and a Last, is now made over to salvation-history: but the kind which cannot conceal that its secular import/meaning stems exclusively from the break-up of all foregoing a priori safeguards. With René Descartes, the security of consciousness thus becomes emphatically a breeding-ground for strong doubt which can be systematised but never overcome. However, it was a long time after Descartes, in the epoch of Positivism, when the crisis of history as subjective consciousness became converted into a salvation-historically corrected idea of a history that is makeable, or at least influencable to a high degree. Here one may easily overlook the point that it is precisely not identity but rather a fundamental brokenness that forces consciousness to a powerful over-identification of its designs with the structures of the real. What results from this assimilation of structures is the claim to supremacy of technology. Its power leads to crisis; the crisis demands self-reflection. Could style – and particularly the style of friendship – be capable of making good this loss or at least of making up for it?

Evidently, the crisis of historical consciousness as a crisis of power is also a crisis of the functions with consciousness, as active agent, commits the environment to memory. And the poverty of all types of functionalism – from design to the natural sciences – derives from their foundations in a philosophy of history that is inadequate to cope with the reality of the crisis – the only thing that makes meaning possible. The mythos of modern production does not consist in an external form but in disregard for the critical value of historical consciousness. The clandestine positivism of functional theories invents for itself a style concept that requires an empty, homogeneous structure of time and subordinates freedom to a serial, continuous order. Science and technology fail to recognise that non-knowledge is increased by knowledge, exponentially. However, as long as science does nothing to oppose the delusion that the whole of nature is the expression of a secret which, in the name of knowledge, should finally be disclosed, the style of this knowledge will not be sustained by friendship but by violence and subordination. Whereby especially friendship, as mentioned above, is a phenomenon that entertains exceptionally subtle relations to the realm of the secret, the clandestine in general. Friendship is founded in a secret that is without secrets. For this reason, a secret must not be disclosed in, through and as friendship. Friendship creates intimate knowledge about the evidence of the secret of all life, the living, which does not become a form of experience in friendship. Put more pointedly: friendship is the expression of the secret in the state of awareness (awareness facilitation, capability of being in mind) of its secretlessness.

As a friend, it must be reiterated, one cannot have secrets, because only through friendship can one experience that one is the secret oneself and only friendship allows one to accept such a secret without having to utter it with dire consequences or disclose it. Friendship is sustained by the effect of the secret above all violence or possible betrayal. This is accomplished for oneself as throught and for other. The other is not a secret to oneself. For this reason, the secret sustains all but does not appear as such. The issue is not the secret but the evidence which it enables, whithout ever being a problem or having to initiate disclosure.

Figure 7: *Example of 16th and 17th century friendship emblemes.*

An anvil on which a sword shatters. There is a danger that a sword will shatter if it is brought down on an anvil with too much force. Love, too, breaks up if one is foolish enough to force oneself upon a friend too vehemently. Whoever acts in this way will suddenly lose that which was precious and should have been preserved. Beware of such misuse for which this is a warning example. You must not proceed in such a forcible manner: if you continually impose *upon your friend, then you will lose him.* ([2], column 1408.)

Friendship as a gift – as its expression, its prerequisite, the condition of its possibility – stands in contrast to the present economy of deficiency with its extremely violent effects. All things social in the European modern age have thus far been dominated by a catastrophic economy of deficiency, which makes itself felt as a mania of production and as the violence of labour. By contrast, to reflect on the riches of friendship leads directly to an economy of expenditure and extravagance; a different economy that cannot be conceived of without critiquing the values and the economy which produces a surplus from all reified labour, core of all management as reinforcement of deficiency.

The most radical critique of the hitherto economic theory of values and metaphysics of labour for the exclusive creation of value was advanced by Georges Bataille and formulated following the remote and twisted paths of his theory of religion and cosmology. Betailles's model of an economy confronts the hopeless dialectic of deficit and extravagance, where extravagance is conceived of as the boudary of the world of productivity, seen only as the prerogative of the few or as an inconceivable instance of negative destruction. Against such negative power, Bataille posits the elementary assumption that labour, since long before the developement of captitalism, is constrained by a double deficiency: the withdrawal of energies that are released from the surplus, and the lack of a productive destruction of value, which the surplus in fact makes imperative. Both forms of deficiency are incorporated as labour. In Bataille's view, work that is capable of being wasted must be organised discontinuously. The goal is to transform the labour capability, that results in objects and value, into an art of improductive expenditure and extravagance. This is the art of voluntary loss instead of the projected complete reification of living energy in object-like values.

Continuity, the formatting compulsion of blindly reified labour is, in fact, what the inevitable surplus of energy of the living cannot endure. Far from viewing the struggle for employment and subsistence as the expression of a natural history of deficiency and as the evolution of facilitation through technical means, Bataille sees the malady of the world as stemming from its wealth. This is wealth of a specific kind, which becomes established cosmologically as a wastage of energy at a particular moment in time (not long-term lavishing in the sense of entropy) and its anthropological manifestation is that humankind is the result of the surplus energy: "It is above all the extreme richness of its higher activities that can be defined as the magnificent release of the surplus. The free energy blossoms and florishes in them and demonstrates incessantly its useless splendour." ([1]

Economy is thus no longer the regulation of the materialisation of living activity, but instead designs a form of time in which this extravagance is conceivable. Labour, time, and wealth are for Bataille different forms of expression of the same energy. All systems produce more energy than they can expend if they merely concentrate on the value-optimising organisation of the products they produce themeselves. If the system does not organise any forms of productive destruction of value, then the inevitable surplus of the materialisations force it to self-destruction and this has unfiltered repercussions on the basis of the system – in the form of violence, as raging abstraction, historically, usually as war. By contrast, surplus is loss without calculation or service in return – and it is precisely this which creates its art with reference to the gifts of friendship. A living system can only develop or expend itself without reason. Needless extravagance is a goal for controlled loss, which humankind can assign to its surplus in order to avoid this changing completely into the basal organisation of deficiency through devastating destruction.

The constraint on all growth is what is possible; the further dimension is the consciousness of the world, which is what gives the world its framework in the first place. With regard to the possible and the gift as the art of friendship, it is manifest that consciousness is greater than the world. To make the surplus into liquid assets in order to keep realities virtual, as the difference of themselves, an art of the possible is needed which is not conceived of in terms of property, constancy, and preservation. It cannot and will not leave acts of destruction to the dysfunctions of a system any longer. As all systems, from a certain size, are not able to maintain, form, or convert their energy, they have to expend it. Often, this may take place as the destruction of produced object values. However, what is decisive is that expenditure is always a form of giving back, of returning time and energy to the enabling and providing forces.

Beyond all calculations, such a gift becomes not only an act of extravagance but above all an act of returning. Expenditure as the consciousness of time articulates itself in this ethos in this specific way because the uncontrollable process of energy surpluses takes as its starting point natural wastage, the overproductive power of all living systems. Thus it is not an issue of abstract or principle extravagance for this is unspecific and has always existed throughout evolution. Rather, it concerns the type of gift which is a return gift and as such must represent explicit, additional expenditure – a merry riddance of energy surpluses that otherwise would grow into an overwhelming potential for destruction. This ethos of giving back can be described with the forms of pausing, stopping for a moment, or of wasteful intensity. The return gift no longer has the form of productive continuity or continual productivity. To put it another way, on no account does it have the form of labour. It can no longer be converted into time or systemic subsistence for these deny perpetually all successful wastage of wealth in order to maintain their own impulse which is the objectification of labour in material values.

In principle, expenditure and waste are an integral part of human existence. By contrast, labour that increases productivity has no awareness whatsoever of the return gift, its forms and expressions. Only a deep feeling for its time – an intuitively perceived proof of its proximity – can form the natural evolutionary energy surplus which until now has been clearly obstructed by this type of labour. Bataille's conclusion clearly alludes to this: "A living organism receives, thanks to the energetic play of forces on the earth's surface, more energy than is strictly necessary to sustain life. The surplus energy (wealth) can be utilised for the growth of a system (for example, of an organism). However, if the system cannot grow further and the surplus energy cannot be completely absorbed by growth, it must be wasted lost without profit, deliberately or not, in a glorious or in a catastrophic form." ([1], p.45)

Labour as the producer of abstract bodies of values can never attain the liberating consciousness of that shadow which has threatend it in the form of improductive expenditure long before human cultures began to form labour as the measure of time. Only a position that opposes the optimum calculation of nature can give wide-ranging expenditure and the art of giving through friendship an economic consciousness. This is clearly apparent in the present epoch which has proven completely incapable of developing labour in this way, as pausing and giving back, as a transformation of itself.

AMICITIAE BONVM: The keystone that locks all the other pieces in place (Fig. 8). The sign of the achway – an emblem that motivates the foundation through the final element which carries the entire structure. The keystone as the property of friendship. (cf. [2], column 1235.) Friendship ensures that nothing comes too late.

Oil poured in a lamp. SERO NON FRUSTRA: Late, but not in vain. If a man needs the light of a lamp, he pours oil into it and takes care that it does not go out during the night. No man is so happy that a cruel fate will not deal him a heavy blow; no man is so clever that he cannot make a bad mistake. Therefore, the duke should seek loyal friends in good time, so that he has their support when a difficult situation arises. So that they do not forsake him, he must keep them through gifts and kindness. He who achieves wisdom late, will not be wise in vain. ([1], column 1381.)

Figure 8: *Example of 16th and 17th century friendship emblemes.*

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The Art of Interfacing: Senses, Sense and the Discipline of Playing Interfaces

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Abstract

The world of music is full of “interfaces”, of instruments, which mediate between the human body and its faculties on the one side and complex invisible and time dependent events on the other. Musical instruments can be described as “time critical, feedback controlled excitation mechanisms for interpretative cultural frameworks”. The science of interfaces could learn by looking at the tradition of musical instruments. But the inherent property of the digital world, that is the arbitrary mapping of control parameters between the physical action of a human and a programmed environment within the computer, leaves us with the most important issue: how do we create sense with our senses – what are the connections between sensing and making sense.

A brief overview will give some indications about the complexity of traditional instruments and how we can generate highly complex results with rather few control parameters. The controlled complexity is defined by the ear as sense, the mind as interpreter and the body as actor. The second part will discuss eyes and ears under a specific perspective: The closer a sense is linked to “survival”, the more difficult it is addressed by new impressions on a differentiating level. The farther a sense is removed from the necessity of fast reactions, the easier it can be opened for new contexts. Wit these criteria, we can define a hierarchy of our senses and within the events for each sense a hierarchy of their properties. The description of such hierarchies has direct consequences for creating and interpreting art – and for the usefulness of interfaces.

The world of music is full of “interfaces”, of instruments, which mediate between the human body and its faculties on the one side and complex invisible and time dependent events on the other. “Complex”, “time dependent”, and “invisible” sounds like attributes to computer processes. But any, even traditional musical instruments can be described as time critical, feedback controlled excitation mechanisms for interpretative cultural frameworks.

This talk is going to investigate two perspectives of interfaces. First, I will present a few musical instruments as interfaces. In the second part I will discuss eyes and ears as interfaces and the hierarchical structures of these analog senses.

Figure 1:

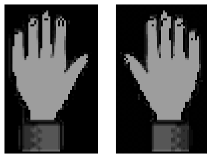


Figure 2:

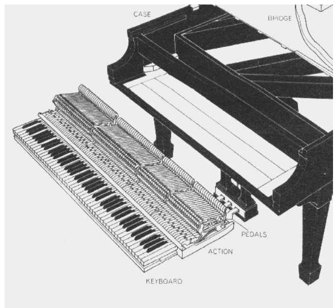


Figure 3:

I.

Let us look at a few interfaces. Figure 1 shows a keyboard . It is the first complex digital interface. As you know, "digital" stems from the Latin "digitus", which means "finger" (cf. Fig. 2). This keyboard provides many discrete keys for one finger each, so it is digital.

The most prominent property of our fingers is that we have ten of them and that they are discrete (as for instance opposed to our skin). Between two fingers you do not have another finger, but the analog space of "no finger". The definition of "digital" thus means: no matter how many fingers or "digits" you take there will always be a gap between any two adjacent fingers or digits. The digital keyboard for musical instruments has been in existence for some 2000 years. Over the past few centuries many humans dedicated their whole life to master this keyboard.

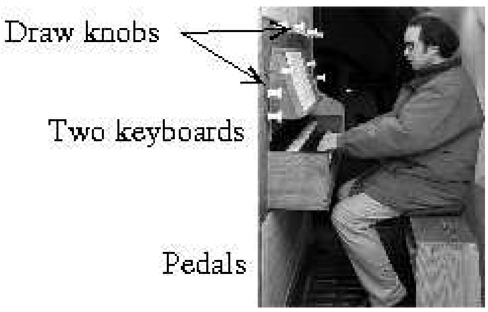
The piano keyboard of today (Fig. 3) usually has 88 keys (and let us neglect the pedals for the moment). The player has only three choices: which key to hit, how hard, and when. That's all. There is no control over the hammer, once a key has been pressed. You may say that piano playing is like dropping lead weights at a given time onto specific keys. Why can someone enchant us by dropping weights on keys? As soon as we listen to a piano piece under this perspective, we find the answer: the result depends totally on "which key" and "how hard" being functions of time. The relationship between different pitches and the relationship of different levels of loudness are coming to life through their temporal evolvement. The control of micro- and macro-temporal relationships between a few keys and a few levels of loudness result in an impressive appreciated complexity.

Let's move on to another instrument, which is even more reduced in its parameters for immediate playing: only pitch and time can be differentiated through the keyboard.
The organ is the oldest keyboard instrument. Sometimes an organ had only a few keys, like 3 or 5. This young man (Fig. 4) has two keyboards available and his two feet add two more "digits": the pedal. As you know, once a key is pressed the pipe or pipes associated with that key get wind and start to sound. The draw knobs can be pulled to select which of the sets of pipes are to be connected to the keys. The sets of pipes being connected to the keys define the timbre and the loudness of the played sounds. In contrast to the piano we do not have immediate control over loudness but we gain a different kind of complexity for timbre.

In the course of time, the cockpit of an organ player grew.

With the advent of pneumatic technology and electricity the previously mechanical functionality could be extended. Electric stop pads can take the place of draw knobs (Fig. 5).

A swell pedal opens or closes a case with sets of pipes and allows a specific kind of louder and softer (Fig. 6). A crescendo pedal can control the incremental addition or subtraction of



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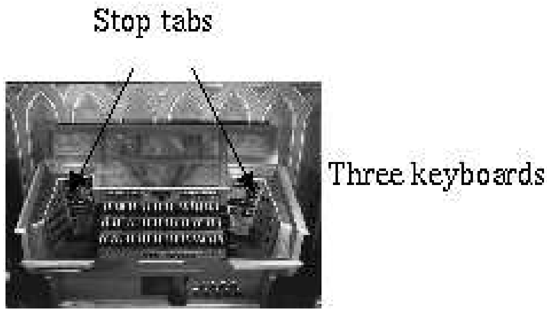

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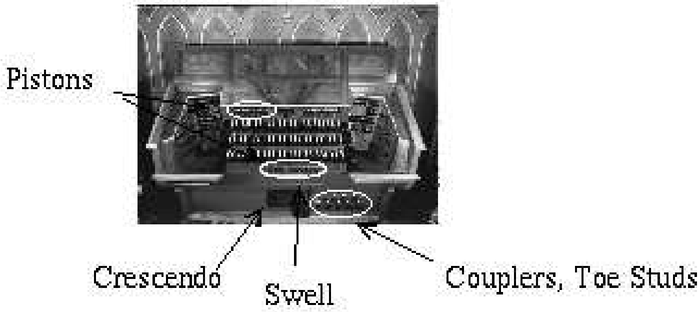

Figure 6:

sets of pipes. And pistons and toe studs are freely programmable to switch to complex pre-sets for the combination of pipes in the middle of a piece without loosing much time.

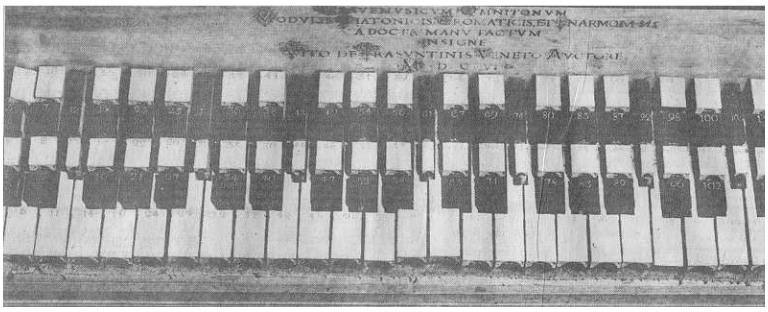

Figure 7:

There is one major difference to the cockpit of a plane: life does not depend on any button or key being pressed correctly. Or to put in other words: the events, resulting from operating this interface, are open to any kind of interpretation.

The ancient design of a multilayered keyboard shown in Fig. 7 puts 31 keys into the space of previously 12 keys. The accordion (Fig. 8) is a hand held organ. The keys have mutated to small buttons.

In Figure 9 we see another sort of keyboard. This is Douglas C. Engelbart of the Stanford Research Institute. On December 9, 1968 his “Augmentation Research Center” presented publicly their developments including hypertext and object addressing. On this picture, Engelbart

Figure 8:

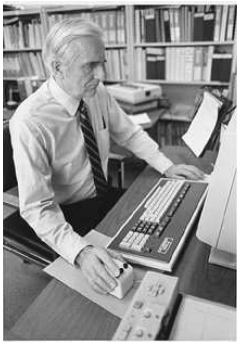

Figure 9:

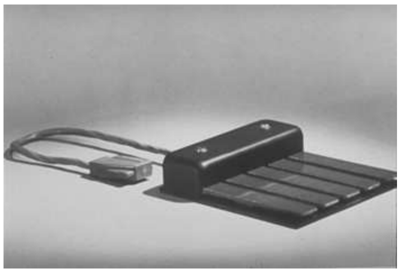

Figure 10:

is not touching the regular keyboard. His hands are busy with something else. His right hand is playing the mouse, which was presented to the public for the first time. It is a three button mouse (Fig. 10), ergonomically perfectly designed: thumb and small finger can move the device in x and y directions and the three middle fingers can press the buttons. As you see, Engelbart is not a musician: he is playing the three buttons only with his index finger which is over the button actually intended for the ring finger. So this picture already implies the future reduction to the one button mouse. His left hand is busy with some another "augmentation", with the "Chord Key Set".

The name makes a reference to music: a chord is more than two pitches being played at the same time. This keyboard allows "playing the bits". We see five keys spaced in such a way that five fingers can play them. Five keys allow 31 different combinations to be pressed. This keyboard allows "playing up to five pitches" at a time in any combination. It is a direct descendent of a musical keyboard. If you have one for each hand you could press 1023 different combinations many more than any conventional computer keyboard provides. But you would have to practice like a musician to master the instrument - with one advantage: time does not matter so much.

If we position this Chord Key Set into a line with the piano and the organ keyboard, we can see that all but one parameter have been dropped. Only "pitch" is left, that is, which key is pressed, which bit is addressed. Time, as a constitutive element has been totally omitted. Keyboards divide the audible range of frequencies into discrete steps. I would like to discuss briefly a group of musical instruments that are not limited to discrete events but put the whole range of what our ear can hear and our mind can "digest" into our hands.

Figure 11:

String instruments like the double bass on Fig. 11 offer continuos frequency space within the limits of their construction. The left hand presses the strings at any point down and the right hand sets the shortened string with a bow into motion. The left hand determines the pitch. It can move freely along the strings. The player develops with his fingers and his whole body a map where to put which finger in order to produce which pitch. But the ear exerts the top-level control. It tells the fingers precisely if the desired spot on the string has been reached. But not only the spot itself is of interest (like the key on a piano), but also how to move in between spots in such a way that continuously changing frequencies are added to the performance.

The right hand moves the bow. This requires also an extremely refined technique to control pressure, position and the speed of movement. The bow controls the onset of the sound, the loudness plus the coloration of the sound as a function of time. And again, all these are governed by the ear with a feedback between what is intended, what is heard and how the body has to act to produce the intended sounds. In comparison to the piano, this is a far higher complexity of controlled parameters. As "trade-off", usually only one pitch at a time is played.

Here we have an interface, which takes full advantage of several senses in order to control and shape events that are addressing all aspects of one sense, in this case the ear. The range of events the ear can receive is fully utilized by musical instruments as a continuum within the psychophysical limits of the ear.

This brief overview might have given some indication about the complexity of traditional interfaces and how we can generate highly complex results with rather few control parameters. The controlled complexity is defined by the ear as sense, the mind as interpreter and the body as actor.

II

The properties of digital technology differ from any set of properties ever associated with any other technology or tool. The properties of digital technology are the result of an interpretative act as opposed to the properties of analog technologies.

The properties of analog tools are the result of goals and means. The goals always arise out of needs. These needs might be primarily rooted in the physical world surrounding us or in the imagination within us. To meet these needs may secure survival, compensate deficiencies, provide luxury, yield new insights or fulfill a dream. For these purposes we design tools which can be controlled by our physical presence in this world. The development of all these tools from a hammer up to chemical factories and the atomic bomb can be seen as continuos bottom-up processes. Analog tools can be *conceived* in a topdown way, but can only be *put into the physical world* in a bottom-up engineering strategy. And their effects or outputs are always directly related to this bottom-up construction.

The goals for making analog tools are “thought of” and imply an interpretation of ourselves, but the means of matter are controlled by our senses, by our “interfaces” between “outside” and “inside”. The speed of thought, the flash of a vision, the flight of mind, the fantasy of happiness or megalomania have to pass through the time-tunnel of our senses. It takes time to kill millions of people, to watch a video, to write, to harvest crops, to paint, to repair and research, to listen to music or to read a book. As we have found out we are able to move matter faster and faster, to kill faster, to harvest faster, to find information faster or to accelerate research. But we cannot speed up equally watching a film, giving a kiss or beating someone up, talking and listening.

So one sort of time is defined by the speed at which we can move matter (including ourselves), but time as the basis for communication is defined by the speed of our senses.

A “pre-digital” definition of interface is “a surface that forms the common boundary between two parts of matter or space”. This definition of interface fits perfectly our senses: Our senses are surfaces that form a common boundary between our internal part of matter and space and the external part of matter and space. The surfaces of our senses are active and allow transgressions between “internal matter and space” and “external matter and space”. Time is then the domain necessary to pass through the surfaces of our senses.

Let me jump onto another thesis: The closer a sense is linked to “survival”, the more difficult it is addressed by new impressions on a differentiating level. The farther a sense is removed from the necessity of fast reactions, the easier it can be opened for new contexts. Wit these criteria, we can define a hierarchy of our senses and within the events for each sense a hierarchy of their properties. The description of such hierarchies has direct consequences for creating and interpreting art and for the usefulness of interfaces.

Let us focus on our most refined interfaces, on eyes and ears.

Our ears receive audio signals from all around us independent from the direction of our nose. With our ears we monitor the whole environment which is not in direct physical touch with our body. Without having to turn our head we are able to tell with quite high accuracy how much a sounds comes from left or right. We may say that our ears survey a sphere around us up to quite a large distance, even around corners and through walls.

The ear watches over us while we are asleep. It discriminates between well-known sounds (and let's us sleep) and unknown ones (and wakes us up). It is very easy to enter into our heads through the ears independent of what we are currently doing. If we do not want to hear we have to use our hands and cover the ears.

Within the first few milliseconds we can determine where a sounds come from. This is important because if there is some danger, we know which direction we should run into and which not. Only later after we have realized the direction we can differentiate if the sound is higher or lower or what kind of sound it is. The ear is *not* good in judging distances in exact quantities like meters. It is very good in telling *differences* of distances. Our ears measure quite small frames of time, between $2ms$ and $200ms$ are sufficient. A sound is gone once it reached our ears, we cannot go back in time and listen to the same event again.

Our field of vision always depends on the direction of our nose. We have to turn our head to look to the right or to the left, up or down. The eyes are good at quantifying space; we can judge distances quite accurately with our eyes. Our eyes allow us to order visible objects in very refined spatial relationships to each other. The eye can find very fine details if the object we see does not move fast. In order to gain all information about a visual object in all its dimensions, we have to move around the object while moving the eyes up and down, left and right. If we want to confirm what we saw or if we want to find out more details, we may go back in space. Our mind will put the information together, which we obtain while *we* are moving in space. The most detailed information for the eyes is obtained if we can forget time and consider space as time-independent.

Our mind will *synthesize* the visual properties of an object from the information we gather while moving our eyes or our whole body. The ear works the opposite. The ear's most common mode is analysis of the fast moving sounds. It has to regroup the audible information in order to identify different sound sources. For instance, when we listen to an orchestra, our ear can differentiate between the violins and the trumpets playing together even though all information reaches our ears in one "wave".

This means, seeing and hearing have two completely opposite basic modes of "reading reality". Visual objects have to be synthesized by us in order to be able to obtain an image of what is around us. Auditory events have to be analyzed by us in order to distinguish different sources. Visual objects have boundaries of their own; they are mostly delimited from each other. Auditory events on the other hand reach us as a mixture of all soundings at once and have to be taken apart in order to identify individual events.

As a conclusion we can say that the *ears* have the primary task of securing everything around us, which is not touching us and which we do not see. And the *eyes* have the primary task of positioning ourselves in space. The synthetic mapping of what we see takes more time than the analytical process of the ears.

The temporal reaction of the eyes in life-threatening situations is slower than that of the ears. So for the context of this discussion on the hierarchy of senses this means that the sense of seeing is "higher up" than the sense of hearing.

In aesthetic terms looking at our willingness to adopt to changes in what we are used to can exemplify this. To accept new worlds for the eye is a constant necessity. We are much more reluctant to accept challenges in the auditory world. The eyes are geared towards synthesizing ever-new environments; the ears are best at analyzing known patterns. The arts in the 20th century have made it clear that people are more ready to accept new directions in the visual arts than in music.

For the discussion of "The Art of Interfacing" we can note at this point:

Eyes and ears are non-redundant. The ears are omnidirectional; the eyes have a limited field of vision. The basic mode of the ears is analysis and that of the eyes synthesis. The ears are best fit for shortest time-intervals, the eyes for shortest spatial intervals. For survival, the ears are more directly linked to reactions than the eyes. The eyes adopt easier new environments.

I mentioned that the discussion of hierarchies could not only be applied to the senses but also to the parameters of each sense. I would like to take you "one level down" for auditory events.

Events we can hear can be parameterized in following categories: frequency, spectrum, energy, direction, and duration. To keep things simple I will ignore many details. Let frequency equal "pitch". If you hear a trumpet play a melody, you may also sing it or repeat it on a piano with the same pitches. The properties of the spectrum may be called "timbre". The same pitch played on a trumpet or on a piano has two different timbres. "Aaaa" and "oooh" can be sung on the same pitch and still sound differently. Energy translates into, how loud we perceive a sound. The determination of the direction a sound comes from is actually quite complex, let's call it "localization". And duration has two faces: that of relative and of absolute time.

The hierarchy under the criteria of "survival" looks like this:

Localization loudness duration pitch timbre.

The localization of a sound is detected fastest. In principal we can detect within the first few milliseconds the direction a sounds reaches us from. Imagine you are hearing a roaring sound from behind you to the left. It is not important to be able to tell if it is a Mercedes or a BMW approaching you. It is of primary importance to notice direction, distance and speed of the moving sound and which direction *not* to run into ... The ear is very good at letting us know changes in distance and direction. For musical purposes, one to four different directions are sufficient for the vast majority of pieces.

Levels of loudness are very important for determining the distance of a sound source. How sensitive our ear is for loudness over the audible frequency range defines how good our ear can serve the purpose of monitoring our environment. Our ear can receive sound pressures from the softest sound we can detect to more than 10 million times the energy of this softest level. Again the ear is very good at discriminating small *differences* of loudness, but it is not good at judging absolute levels of loudness. The musical terms pianissimo, piano, mezzoforte, forte, fortissimo are relative terms. It is doubtful if we can discriminate more than 6 distinct levels of loudness within the time window in which we remember this parameter accurately.

Duration can be discussed on three different levels: in a musical context we are concerned about relative durations, for instance short - short - (twice as) long / short short (twice as) long. Another level would be absolute time. Within certain limits we can map durations onto a gesture: we hear a sound for about 3 seconds - and we can reconstruct the duration for instance by an arc movement of our arm. I believe that this way of remembering absolute time is for untrained persons accurate up to 5 seconds. The shortest temporal discrimination of the ear is around 2 ms. And when musicians play together, a difference of 10 ms may be felt as "not together". In music, durations are mostly used on a level of small integer proportions. In our western culture a maximum of 5 or 6 such different proportions are sufficient for most pieces. Once we are outside of these ratios - like in some contemporary music , we may "appreciate" such complex durations by for instance connecting them to gestures or imagined images or verbal descriptions.

Some people have "absolute pitch", they can tell in absolute terms which pitch was played to them. The majority of people are not capable of doing so. Again, all of us are able to finely discriminate *differences* of frequencies, with frequencies ranging up to about $20.000 Hertz$. Within this range, the art music of the Western culture uses approximately 100 different pitches. The average pop-music piece may utilize about 20 to 30 of these pitches; all of Mozart's pieces add up to maybe 50 or 60 pitches. This does not sound like very many but if you compare it to 5 or 6 proportional durations, it is already quite an increase.

And now we take a giant step to timbre. We have unending capacities to identify "sound colors" on an absolut level. We accumulate a large "dictionary" of timbres over the period of our life. To identify a sonic quality takes much longer than to identify localization or pitch. On the mere physiological level, $200ms$ are enough to identify a sound with all its properties. $200ms$ are the temporal integration time of our ear.

The "official" definition of timbre says that this parameter enables us to judge differences between complex sounds having the same pitch, loudness and duration. Let me demonstrate that first as a series of distinct different timbres: a-e-i-o-ä-ü (spoken on same pitch). And now with interpolation: a-e-i-o-u-i-ä-a (sung on same pitch with continuos interpolation). I sang the same pitch with about the same loudness, but you heard different and changing sounds. To make it short: Speech is the crucial channel to establish and maintain socio-cultural communication and survival. Our ear is best at differentiating timbre.

Timbre can be shaped in the most complex way of all parameters for auditory events. Timbre has always been the widest varied parameter in music.

I tried to exemplify that also within one sense inherent parameters are hierarchically determined by their proximity to survival. The farther a parameter is removed from time-critical, immediate needs for survival, the more complex it can be shaped in cultural contexts.

To phrase it in the context of this conference: the farther an interface is removed from immediate survival, the higher the potential for complex interactions. The farther the parameter of a sense addressed as interface has been developed as a cultural tool, the better it can be employed for complex evaluation and action.

Musical instruments can be looked at as paradigmatic examples for interfaces in general. They mediate between the physical world and a radically constructed world of meaning outside the realm of semantics.

The science of interfaces could learn by looking at the tradition of musical instruments. But the inherent property of the digital world, that is the arbitrary mapping of control parameters between the physical action of a human and a programmed environment within the computer, leaves us with the most important issue: how do we create sense with our senses what are the connections between sensing and making sense.

Out of this dilemma, some take the approach, to analyze senses, meaning, mind and soul as basically digital domains. The price being paid is a reductionistic model of human capacities. Because the arts have always been part of life-extending luxury, the arts have always seen humans as non-reducible. The arts have always strived for integrating senses and sense. The discipline of playing interfaces is a highly appreciated art in the field of music. Maybe, some day we will have equally complex interfaces connecting to the digital computer and played by interface players practicing with great discipline and satisfaction. One step might be to look for more refined mapping strategies between the digital computing environments, our senses and sense. For this, the arts may provide valuable aspects, models and experience.

Let me finish with a final thesis:

The only way we have to interpret the output of a computer is by converting it to light, sound or whatever our body can perceive. The digital world without valid links to our analog senses which allow us to create sense is void.

Everett's Observer: A New Rational Psychology?

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Ever since Hugh Everett [1, 2] proposed his no-collapse formulation of quantum mechanics in 1957, it has fascinated commentators for its mathematical elegance but also raised the suspicion that it cannot explain why the world of our experience has a definite physical state and history. In this paper, I will sketch an argument for the empirical adequacy of Everett's formulation of quantum mechanics that I have proposed recently [3, 4] and discuss some consequences of this claim.

Everett's formulation rests on the fundamental assumption that quantum mechanics is linear. This claim can be analyzed into three logically dependent postulates:

1. The state space of quantum mechanics (the Hilbert space) is linear, this means that for any two states $|a\rangle$, $|b\rangle$, any linear combination $c_1 |a\rangle + c_2 |b\rangle$ (called a superposition) of the two states is an element of the state space, too.

2. Any physical process is characterized by a linear operator U on this state space.

3. Any physical property is characterized by a linear operator. This means: if $|a\rangle$ and $|b\rangle$ both have the property P, then any $c_1 |a\rangle + c_2 |b\rangle$ also has the property P. But it also implies that if $|a\rangle$ has a property P and $|b\rangle$ has property $not - P$, then any superposition of the two states cannot have either property P or property $not - P$.

The linearity of quantum mechanics offers powerful tools for the solution of physical problems, but it is also the reason for a perplexing puzzle that has beset quantum mechanics since its inception: the measurement problem. Any measurement implies an interaction between an object and a measuring apparatus. But this means that if the initial state of the measuring apparatus is $|w\rangle$ and the initial state of the object is $|a\rangle$, there will be (according to postulate 2) a linear operator that describes the process of the observation as follows:

$$|a\rangle\,|w\rangle \to U\,|a\rangle\,|w\rangle = |a'\rangle\,|w_a\rangle \tag{1}$$

where $|a'\rangle$ is some state of the object and $|w_a\rangle$ a state of the apparatus that describes its having measured $|a\rangle$.

Then the linearity of U tells us that the evolution of a superposition of two states will be the following:

$$(c_1\,|a\rangle + c_2\,|b\rangle)\,|w\rangle \to c_1 U\,|a\rangle\,|w\rangle + c_2 U\,|b\rangle\,|w\rangle = c_1\,|a'\rangle\,|w_a\rangle + c_2\,|b'\rangle\,|w_b\rangle \tag{2}$$

But postulate 3 tells us that the outcome state can have no property that distinguishes $|w_a\rangle$ from $|w_b\rangle$. This statement is obvious conflict with the common sense demand that at the end of a measurement process there should be an unambiguous matter of fact about the state of the measuring apparatus reflecting an outcome $|w_a\rangle$ or $|w_b\rangle$.

Everett's formulation of quantum mechanics accepts this theoretical prediction: the final state of a measurement interaction is really the state given by equation (2). Every physical system (including ourselves as observers) really is in superposed states and there is no objective matter of fact about those properties that should be definite at the end of a measurement.

But, as Everett says: "...we do not do justice to the theory of pure wave mechanics until we have investigated what the theory itself says about the appearance of phenomena to observers ...". This means: Although observers as physical systems are in a superposed state like (2), it will *appear* to them as if they were in a definite state like (1).

Everett's proposed solution has often caused puzzlement. There are two questions that immediately come to mind: first of all, how can the world be like that? Or, for that matter, how can we be like that? How could it be that a physical system like a measuring apparatus or a human observer is in a superposition of states? This is what I will call the ontological question. Secondly, how can it be that we don't notice that the world is like that? Can we give an argument for Everett's claim that appearances can be saved in a world that is so radically different from our preconceived ideas? I will call this the epistemological question. The first question has preoccupied most commentators of Everett almost exclusively. It has given rise to a variety of interpretations, such as the many-worlds, many-minds, and the various modal interpretations, which I believe obscure the fundamental point that an interpretation of Everett has to make: namely, answering the second question, that is, explaining why Everett's formulation is an empirically adequate representation of quantum mechanics.

The basic ontological assumption of Everett's formulation can be most neutrally characterized in the following way: unlike classical states which are given by points in the state space, quantum mechanical states have an extension in state space. Therefore they do not correspond to single propositions but ensembles of such propositions. These ensembles can be understood as ensembles of possible propositions, not defining single objectively real facts but describing a set of possible facts. Probabilities can then simply be understood as an objective measure on the state space given by a quantum mechanical state. The difference to classical probabilities (as for example in statistical mechanics) is that the coexisting possible states in Everett's formulation can interact and give rise to the interference effects characteristic for quantum mechanics.

To return to our second question: if there is no single objective reality but rather a set of possible facts about the world, why does it appear to us that we live in a world of definite facts? In a many-worlds interpretation, this question is answered by fiat: since the different possible states are understood as states of different worlds, it is assumed that an observer inhabiting one of these worlds cannot be conscious of the others. But if we are not willing to make an ad hoc ontological assumption of this kind, we have to be able to give an argument which answers this question if Everett's formulation is to be a satisfactory account of the phenomena.

My claim is that such argument can be given and while I will not lay out its details here, I will mention the necessary assumptions and main points of the argument. For the sake of connecting subjective appearances to the quantum mechanical description of physical processes, some assumptions have to be made about their relation:

- **Supervenience**: Any phenomenal quality that a mental state might have (e.g. being an experience of seeing something red) corresponds to a set of physical properties of the underlying system (brain). Conscious processes are physical processes as described by quantum mechanics.

- **Decoherence**, i.e. the disappearance of quantum mechanical interference effects in most circumstances through interaction with the environment and the emergence of a single stable preferred basis for the state space that allows an approximately classical description. Especially, this assumption applies to the physiological states that underlie our experience (brain states).

It follows from these two assumptions that all functionally relevant mental states will supervene over states of the physically given decoherence basis. From this and the linearity of quantum mechanics it can be argued that a conscious observer cannot be conscious of being in a superposition. She will always only be conscious of one component of the superposition. I call this component the phenomenal or subjective state of the observer. So far the argument was only concerned with our consciousness of the present. It still needs to be shown that Everett's formulation can account for our belief in a definite past and our successful predictions of the future. This does not follow immediately, since quantum mechanics itself does not give any correlations between components of the state across time. The argument for this claim relies on a third assumption that already Everett made explicit:

- **Memory**: Conscious beliefs about the past supervene on quantum mechanical states of a physical memory, i.e. a subsystem of the brain that maintains stable records of past events.

From this assumption it can be explained why we have definite beliefs about our past and why these beliefs enable us to give successful predictions of the future.

While the argument so far gives an account of subjective beliefs, it does not address the question how these beliefs relate to an external reality. If one interprets reality as the objective quantum mechanical state of the universe, one has to admit that the subjective states do not represent this reality. It seems as if Everett's formulation forces us to accept a radical solipsism and skepticism. This worry can be addressed by a "Kantian" argument: The unobservable objective quantum mechanical state is not what we mean with reality. Everett's formulation allows us to introduce a phenomenal concept of reality, described by what Everett called the *relative state*. For any subjective state of an observer, a corresponding state of her environment can be defined. This state does not simply represent the beliefs of the observer (she can be wrong in her beliefs), but gives the state of the environment conditional on the beliefs of the observer. Therefore it can be understood as a description of empirical reality. This empirical reality is an appearance in the Kantian sense, i.e. not absolutely objective, but it is not an illusion, because it is stable, lawful, and empirically adequate. It can be shown that the evolution of the relative state is just the evolution of a quantum mechanical state in traditional quantum mechanics with collapse: it evolves deterministically as long as the observer does not interact with the environment; when an interaction occurs, the relative state evolves indeterministically with probabilities given by the Born rule. This completes the argument for the empirical adequacy of Everett's formulation of quantum mechanics.

I will finish by giving a brief outlook on the consequences of this interpretation of Everett. Obviously, the consequences for physics are not very radical: we are justified in using standard quantum mechanics in our everyday experience, but the model removes the measurement problem and the difficulties of introducing relativistically noncovariant processes or entities such as a collapse of the wave function or Bohmian hidden variables. The true importance of this interpretation lies in its consequences for metaphysics and the philosophy of mind: Obviously, the interpretation forces us to accept are radically new picture of the ontology of the physical world. But even more importantly, quantum mechanics plays a central role in the theoretical model of mental processes even though they are not quantum mechanical processes in the traditional sense (there are no quantum mechanical interference phenomena). This has momentous consequences for most of the traditional questions in philosophy of mind. I will only hint at some issues in metaphysics and philosophy of mind that will be appear in a new light in this interpretation:

- **Time**: the interpretation gives a basis for the distinction of an objective coordinate time defined in a relativistic block universe and a subjective "flowing" time with a definite direction defined on the succession of subjective states.
- **Modality**: the modal realism of the interpretation allows a realist account of counterfactual statements in the interpretation of causality and natural laws.
- **Intentionality**: the relative state formalism gives a physical basis to the notion of intentionality of mental states.
- **Choice**: the interpretation breaks the ancient dilemma of determinism versus indeterminism in the theory of action. It allows for a more satisfying account of free choice of conscious agents.

One of the great hopes of traditional metaphysics was the formulation of a rational psychology, a theory of the mind based on fundamental metaphysical principles. Ever since Hume and Kant this hope has commonly been thought in vain: there are no deep psychological laws, only phenomenal regularities that can be observed empirically. This is possibly the most exciting consequence of the interpretation of quantum mechanics sketched here: it might yield a new fundamental theory of the mind that gives us more powerful principles for psychology than we had hoped for. Unlike the old rational psychology it is not based in a priori metaphysics, but in an "empirical metaphysics": the fundamental insights into the structure of nature that we can gain from quantum mechanics.

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Interface Psychology

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Abstract

If we take the findings of interface theories (from Constructivism and Endophysics) seriously, we must give up the traditional idea that all our knowledge is identical with our reality. To look at the world through someone else's eyes means to change the interface and to dive into another psychological reality. But in this way psychology loses its character of objectivity, because if the world is as tight as a swimming-dress it provides space only for the own subject. Psychology becomes objectively subjective or observer-relative – it thus becomes Interface Psychology.

The aim of this Interface Psychology is to explicitly integrate the observer-relativity into the methodology, results and interpretations of psychological research. In this way it becomes possible to investigate the process mechanisms of the interface. Observer-relativity is the reason why investigators themselves move more and more into the center of their own investigations. They must learn to distinguish between the dynamics of the interface and the dynamics of the environment in which this interface is located.

1 Introduction

In this paper a psychology of the observer is outlined in accordance with micro- and macro-constructivism. This is an attempt to fulfil the demand by von Foerster [1], who sees an epistemological necessity in making the observer's position explicit. Particularly in psychology as a science of humans this should be an urgent demand. Being a human, the scientist herself/himself is already included a priori in psychological research as its object, namely humans. With regard to the result, the test subject and the experiment leader must be in the centre of psychological research as well. What connects them both is what separates them at the same time the interface between the endo- and the exo-perspective. Therefore I will briefly outline the basic characteristics of Interface Psychology as well as its theoretical and methodical implications, starting with the epistemological roots.

2 Epistemological roots

Macro-Constructivism

With the concept of Macro-Constructivism I refer primarily to the findings of radical Constructivism [2, 3, 4]. From the viewpoint of macro-constructivism, we gather special experiences through sensomotoric feedback interactions with the environment and other systems in the course of our childlike development. These experiences in turn lead to cognitive constructions of objects, of space and time, of movement, of causality and also of the observer herself/himself. In the course of our further socialization these cognitive constructions undergo a stabilization process and are then interpreted as if they were "adequate to reality" [5]. Macro-constructivism postulates two worlds with that: a constructed cognitive reality and an ontological reality according to Kant, which we can experience because we live in it, but which we can perceive only distortedly through the interface of our senses. The interface of the senses thus becomes the division line between knowledge on the one hand and the ontological reality on the other.

Micro-Constructivism

With micro-constructivism I refer to the findings and postulates of endophysics [6, 7, 8, 9, 10, 11]. This starts out from the physical assumption that the microscopic inner movements of the observer transform her/his reality in ever new ways. Through this, every form of objectivity becomes an observer relativity. "Therefore the manifestation of the world must change just as quickly as the inner movements [of the observer] do" (cf. [8], p.128). At any present moment a perfect world, including past and future, is represented by the micro-interface. The recognizable world thus becomes as tight as a swimming dress and therefore may be possessed only by the observer alone.

The starting point is a many-worlds-theory, in which at least three worlds can be distinguished between: a world of the internal observer (endoreality), a world of the external observer (exoreality) and an absolute reality (ontological reality). The world as an interface becomes the division line between endo-knowledge and exo-knowledge.

Endophysics suggests a computer-simulated world-modelling as a method of research with which it is attempted to reach at least indirectly the dynamics of the interface which are in principle unrecognizable from our endo-perspective. In this way it becomes possible, at least at a model level, to generate an internal and external observer.

3 Interface psychology

If we take the findings of these two interface theories (Radical Constructivism and Endophysics) seriously, we must give up the traditional idea that all our knowledge is identical with our reality. To look at the world through someone else's eyes means to change the interface and to dive into another psychological reality. But in this way psychology loses its character of objectivity, because its not possible to be in more then in one own subjective world. Psychology becomes objectively subjective or observer-relative it thus becomes Interface Psychology.

The aim of this Interface Psychology is to explicitly integrate the observer relativity and thus the observer as well into the methodology, results and interpretations of psychological research.

To reach this, Interface Psychology starts out from the cognitive area (from an explicit endo-perspective) to approach the limits of the cognitively constructed world and with that the structural features of the interface.

From this follows a shift of the attention: away from the phenomena and from the objects of cognition in the direction of the cognition process of the cognition objects, viz. the observer herself/himself. Observer relativity means to investigate the process mechanisms of the dynamics which is decisive for which world appears real to the observer this means that the interface of the observer herself/himself is made the object of investigation. If we concentrate on the interface process, the flow of observation and action need not be interrupted.

What now does interface psychological research look like in concrete terms?

In Social Psychology, for example, there is the theory of social perception [12]. It has been proven experimentally that if a person is in a happy condition, the world also appears as beautiful and worth living and vice versa: The environment appears hurtful, inhospitable and unjust if the person is in a bad condition. The theory of social perception shows that the person's own inner state influences the outside world. In constructivistic terms: The inner condition changes some parameters of the interface and "another" world then appears on it. Such an Interface Psychology which wants to examine the process mechanisms of the interface must ask "how?" (that is directed towards observer relativity and the dynamic process) and not "why?" (i.e. ask for causality and static cause) (cf. [13]). It is always interesting how a person manages to change not only her/his own view of the world (this is a statement from an external observer position) but also the world itself (endoperspective).

From the internal perspective of this person the world is either objectively good or bad. This question "how?" directs the attention towards those structural qualities of the interface which produce a particular world. It is important to find out how a depressive person, a priest, or a criminal e.g. gain the impression that the world is as they perceive it. In the case of a person with severe depressions one would not search for the cause or the situation that triggered the depressions but one would try to find out how the person manages to generate these particular symptoms again and again every day.

How is it possible to reach the interface from the inside?

1. The central starting-point for this is the *thinking process* itself, which means our own cognitions. Though it may seem paradox in the first moment to attempt to look behind the thinking process with the thinking, this process is described in a Hindu metaphor: The thinking process is like wood in the fire. It nourishes the fire first and then it is transformed by the fire [14]. So its the centrale hope for Interface Psychology.

2. It is essential that thinking in this case is classified as a process and not as a thing or a substance. A process cannot be reflected timelessly like an object in thinking but time is constitutive in the grasping of processes. Processes are described as temporal sequences of objective circumstances, thus they are objects plus time. In the course of time the movement of thinking escapes from its fixation as an object [15]. This finding is essential to generate an observer in the flow of the observation (observation process). Analogous to the quantum measuring process where a defined condition is fixed by observing a variety of possible quantum levels, the observation also interrupts the flow at phenomenal level and prepares an object. "If we replace the observer by the privy, the 'con' of consciousness, the 'I' of the 'I know', we direct the attention away from the objects to action unities or action shapes" (Ruhnau, 1995 p. 209 [15]); and with that on the observer herself/himself (cf. [16], p.104).

3. Due to the fact that our sensory systems are not only perception organs but also cognitive representation systems we have access to the interface. I.e. the cognitively generated reality is exclusively structured by sense-specific modalities: seeing, hearing, smelling, tasting and feeling. We cannot think in other ways than in these modalities. These representation systems make it possible to perceive the world and to transform the perceived objects into ideas. Something seen and heard for example is mentally represented in visual and acoustic ideas. We get information about the basic elements of the observation

and experience generating process via the representation systems. The important thing is that it happens at a formal, content-free level [17].

4. The key access is formed by the *submodalities*. These are the fine and subtle distinctions which can be found in every representation system. If, e.g., one mentions the word spider in presence of a man with arachnophobia, then this man's body will perhaps become cramped perceptibly. If we ask him how he manages to generate a cramp only by hearing the word spider, then we would perhaps find out that he sees a picture (visual representation system) of a spider inwardly. For example, if we ask further what exactly his inner picture looks like, he might describe it as a big black spider that is moving very near before a black and white background. The submodalities of the visual sense specified here refer to the categories: size, colour, distance and movement. If we suggest to this person to make the picture of the spider smaller or to push it further away from him, or to stop the movement, or to paint it all yellow, then often astonishing changes in the personal experience may be noted only by changing submodalities. Submodalities are the difference which make the difference. They determine the quality of every subjective experience [18]. Experience is not understood as something that happened in the past but as a perceiving, interpreting and constructing process in the present.

5. However, not only microscopic changes of submodalities cause a change in the experience of the observer but also macroscopic movement changes can change submodalities. In the field of NLP (neuro-linguistic programming) a basic distinction between *three mental perception positions* was developed by DeLozier and Grinder [13]. These perception positions as illustrated in Fig. 1 demonstrate the influence of perspectives on the experience. Perspective means perception from an internal or external observation (endo- and exo-perspective). It has to be noted that perspective and experiences represent purely subjective (interface) phenomena.

Kutschera [19] and Weerth [17] regard the three perception positions as basic variables of the personality and think they are based on the basic submodal ability of association and dissociation. The perspective under which a definite position is perceived is essential for any later interpretation (Fig. 1).

The first position is the viewpoint of the person herself/himself, where the world is looked at exclusively in a completely associated state from the viewpoint of the own inner reality (endoperspective of first position) .

The second position is defined as the view of the other person who is in the relationship. Here it is pretended to be in the body of the other person in an associated state and perceive oneself in a dissociated state in the first position. The intention is to perceive the situation from the viewpoint of the other person (exoperspective of first position).

The third position corresponds to the view of a non-involved observer who stands outside the situation as a completely independent observer without any personal involvement in the situation. It is possible only from this point of view to perceive the relations or deceptions between the first and second positions (exoperspective to first and second positions = metaperspective).

In NLP these three perception positions are considered very helpful [19] to describe a situation in its completeness and to make clear that we cannot be looked at as separated individuals, because we are always in interaction with our tasks and relationships and we are influenced by them. The perception position which we now take in a situation determines the depth and intensity of our feelings and with that of our inner state. This shows that in the first position feelings are experienced more intensively than in the second position and least in the third position.

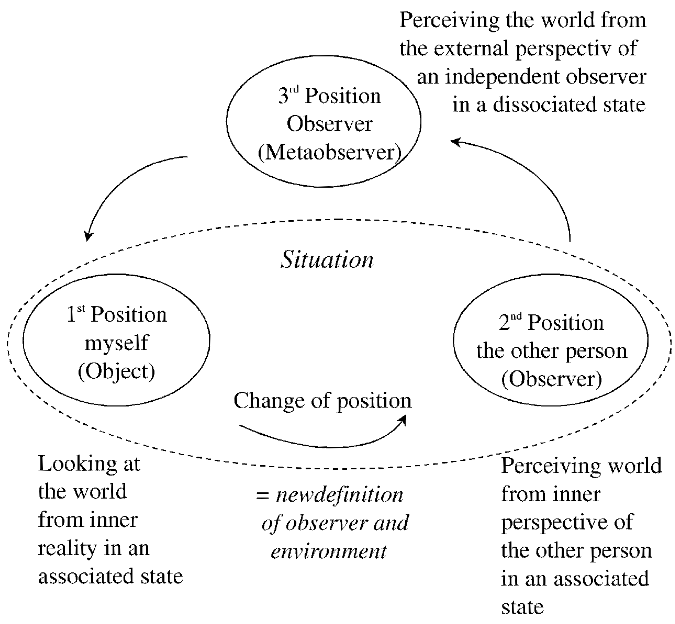

Figure 1: *The three perception positions in the process of a new definition of the environment and the observer.*

This model illustrates the effects of changing positions on subjective experiences. With every change into another position one's own identity remains unchanged, and only the distance of the identity and of the self-perception to the current event changes. Every change of one's position is a change of one's interface. By taking another position a new definition of the environment and observer takes place. The interface thus represents another observer objective world. For this it is enough to perform a conscious cognitive act of distinction between the first, second and third position as demonstrated in NLP.

Although from an epistemological perspective this change of perspective is always carried out only by an internal observer, the varying perspectives and changes of submodalities bring about an expansion of the knowledge regarding the current situation. This enriches the epistemological perspective in psychological research. The psychological model outlined here offers the possibility of research on the observer during the process of generating subjective knowledge and subjective experience. Furthermore it creates a structure to put the world representations perceived by the observer in an explicit relationship with his/her point of view (endo- or exo-perspective) and to describe them.

Let me emphasise again that Interface Psychology sees itself as a model of psychological research and thus does not describe a absolute reality or truth. It understands itself as one of many possibilities for investigating the interface structure. Interface Psychology takes available scientific knowledge and simulates with it various model worlds with external and internal observers. In this way, scientific research becomes a creative game during which the players curiously try to find out how the game changes depending on changes of co-players, new findings, new rules of the game, etc. It is aimed at finding out which structural qualities of the interface remain consistent over all cognitive realities and modes of playing. Representation systems and submodalities seem to be such basic structural parameters of our cognitive interface. Any change of the smallest (microscopic) structural features, viz. the submodalities, causes a change of subjective experience at macroscopic level.

Starting application areas for interface psychology

- Of course the focal point of Interface Psychology is oriented towards psychological interface phenomena. The limits of a phenomenon-oriented science become apparent in particular in *parapsychological* research or other *border sciences* because it deals with phenomena which frequently run contrary to everyday understanding and the laws of nature. In this case, the withdrawal from the pure phenomenon-orientation to the person- or observer-orientation would open up new research tracks. One of these could be to investigate which structural dynamics of the interface become effective so that paranormal phenomena become "reality" in the world of a person. Another way could be to ask how a cognitive world representation can be generated in whose world "extra-sensory" phenomena are "normal". The answer lies probably hidden in the world of the interface.

- But interesting application fields can be found also in the area of *sexuality*. For instance: Where are the observer-relative or cognitive-emotional differences between sex with oneself (masturbation), sex with another person, telephone-sex and cyber-sex? It is especially in the field of sexual therapy that very many wrong expectations, fears, taboos or also violence all of which are linked to the interface play a role and the interface principle could be helpful there. One ideal research area to examine the interface between biological sex and subjectively experienced sex would be *transsexuality*. Perhaps the great uncertainty in the field of sexuality could be reduced to the relative uncertainty of the interface principle itself.

- Also in *developmental psychology*, the interface approach could be one possibility for making it clear to our children where the virtual reality of a computer game or video ends and where reality begins. Interface Psychology could provide criteria and values to learn that the consequences of one's own actions could be very different from one reality to another. What are the interface limits between killing a man in their computer-game world or their teacher in their school world? This is an important aspect in the discussion on violence of children and young people.

- Due to constant progress being made in the field of computer technology new media have developed. Cyberspace, Virtual Reality and Artificial Life are the new keywords. These new media in connection with the above-mentioned world simulation model could revolutionize tests, questionnaires and therefore the complete area of *psychological diagnostics*. One way could be to lead test subjects into various virtual worlds and then let them reflect on their subjective experience with the model of the three perception positions. In this way we could get access to the perhaps most basic human ability and a personality variable which has been neglected until now to produce cognitive worlds of reality (personality psychology).

4 Epistemological implications

Logical level

The inclusion of observer relativity and, therefore, of the observer with the aim of obtaining a scientific result changes and enriches scientific findings regarding the research object and thus also the researcher since both of them are parts of the examination process. Particularly cognitive emotional modelling processes, such as the 3-positions-model presented above, enlarge the reflection possibilities of research results and their epistemological value.

Meditative level

The suggested methods leads to selfreflecting and inside observation. The observer becomes an observer during her/his observation. In this way, meditation become part of scientists research.

The micro-constructivistic observer-relativity is based on the assumption that at any given moment we are aware only of the difference between the own inner state of motion and the state of motion of the environment. In physical epistemological terms this leads to the paradoxical circumstance that, if the difference is at a maximum - i.e. a counter-movement or the observer and the world are most different -, cognition on the world is also at a maximum. In the reverse case the state of motion of the observer agrees with the one of the world, both are in resonance and because of that there is no difference, the recognizability of the world is zero at this moment.

The more I am in harmony with the world, the more it is unrecognizable for me; the more I differ from the world, the more it becomes recognizable. *But what is this knowledge then worth anyway?*

At the same time a second access possibility to the world and to the observer opens up. If observer and world are in resonance and in harmony, then the observer disappears and then the world disappears. Me and the world are one. Like a single water-drop that falls into the sea. Does not this remind us of millennium old stories of enlightenment and mystic experiences? Of many an enlightened person it is said that they did live in the world, but the world nevertheless did not live in them. The separated until now,, meets together and becomes to an associating observer. *Has such a person become the interface itself?*

This is an very interesting but open question. It is also doubtful to me if, out of the last mentioned micro-constructivistic finding, the search for new cognitive knowledge really brings us nearer to the knowledge of the essential. In this way I suggest, that scientific research must enlarge its analzing methods whith holistic methods which involves experiences of the whole being.

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Audio Collage: Sciences of the Interface
A Tribute to Otto Rössler

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1 Prelude

With great interest, I listened to the talks and presentations given at the ZKM Symposion "Sciences of the Interface", which took place in Karlsruhe in May 2000. Out of the recorded audio material I created an audio collage which is presented as track 1 on the enclosed CD.

This short additional text is written in the hope that it can provide some assistance in understanding the ideas and structure of the collage.

To succeed in this I start with some technical and theoretical information on how the material looked and how I actually did work with the material. In a second step I present an extract of my working script in order to show how the theoretical ideas connect with the practical work. The last part of this text presents questions with which I struggeled during my research and suggests directions that my work will go in the future.

2 Background

The audio collage is the result of an attempt to connect documentary and artistic elements. The material is structured along five parameters:

1. A walk through the ZKM exhibition represented by various sound fragments.
2. A Rössler attractor set to three musical versions. The compositional work restricts itself to the following interventions:
   (a) Choice of instruments,
   (b) cuts and multification of individual sections and
   (c) orchestration.
3. Talks given by the participants.
4. Excerpts from abstracts of the symposion program read by a computer generated reader.
5. Selected quotes from sections 3 and 4 set to music.

A short extract of the script clarifies my procedure. This extract plays a central role in the audio collage, since in it Author and Virtual communicate as well in their documented conversation as in their discurse converted into music. This section is preceded and followed by tractor-converted music.

3 Extract from audio collage: "Sciences of the interface"

Plot
fade in *music*: attractor; crossfade to *sound*: dolphins (Mayer-Kress)
Reader (Siegfried Zielinski)
"The interface concerns what is inbetween."
Michael Klein
"There is something like a recursive zone where the interaction and the feedback takes place. It seems to be this space – or space probably is not the right word – between the virtual and the real world."
Reader (Siegfried Zielinski)
"Inbetween is the place where doubt is at home."
Plot
crossfade to *place*: exhibition
Virtual
"Talk with me!"
Author
"Hello. What is your name? I do talk to you! You don't have a name?"
Virtual
"I am a virtual."
Author
"Oh! I am real. How is it to be a virtual?
No? So talk to me! I am talking to you!"

"Now you are looking sad. Are you sad?"
"Yes! Why? What happened?"
(Author to Ralph Hollis)
"You see her? She changed somehow... the colour."
(Author to Virtual)
"What happened to you? You changed your colour!"
(Virtual laughs, Ralph Hollis and Author laugh)"
Plot
fade in *music*: virtual, fade in *music*: author; crossfade *music*: attractor
Reader (Otto Rössler)
But what is the real gain? Can we explain colour?

5 Upcoming Questions

The enclosed audio collage represents a first attempt by the author to approach the topic of interface from a scientific as well as an artistic point of view. In this respect the results are to be understood as work in progress.

What happens when various forms of speech are converted into music? How do they compare to attractor-converted music?

"In a sense you can dance to it." This remark by Gerold Baier clearly marks the intrinisic artistic quality of attractors at work. Out of the temporal sequences of different levels playful transitions result, sometimes graceful, sometimes abrupt.

This procedure can offer us, as Otto Rössler says, "...the view of the non evident. The view behind the curtain."

Can art provide us a tool to see behind the curtain?

Acknowledgements—Thanks to James Phillips for discussion and feedback.

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[1] Recorded audio material. ZKM, Karlsruhe: May, 18-21 2000.

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Instead with an epilogue we want to close with a short excerpt of the slapstick performance held as an homage to Otto Rössler by a close circle of friends of him during the final happening of the symposium. Enjoy this humorous view onto the interface after a strenuous itinerancy through the perspectives given by representatives of different disciplines.

The editors

Licking the Interface

Ladies and gentlemen, dear Otto Emanuel, we are glad to welcome you all to this symposion hosted by the “Stammtisch Unser Huhn”, this symposion on the subject of french kisses. What is a Stammtisch you may ask, and we have of course prepared some instructive slides showing confidence intervals and significance bars. Unfortunately these slides have come out flipped and upside down when we printed them out. We have several grad students investigating the question whether or not this is a good excuse for not showing them, and they’re working slow as usual. But our preliminary results indicate that indeed it is a very good excuse, so I’ll simply use it.

So we, the representatives of the Stammtisch Unser Huhn, solemnly declare, that we are in a free and independent state of joyful excitement, because we are able to honor our member and friend Otto Emanuel Rössler at this fine symposion on the meritable subject of french kisses. We are very glad to see that so many young scientists have gathered here to investigate and discuss the oft neglected french kiss. Many has been said about french kisses during the past four days, I’m sure. We today want to investigate them as interfaces, as the virtual structure that enables the cognitive systems that are the minds of man in an environment of increasing complexity and swiftness to communicate and project their elementary hedonistic necessities. So to speak.

Of course you all know that the binary human soul, the on/off of mental energy, has it’s seat in the electric undercurrents of a virtual Pentium chip sitting under the tip of your tongue. So we want you all to show, now or during our talk, your binary soul to your immediate neighbor and value their’s in exchange.

We will investigate the interfacial role of the tongue in the french kiss under special consideration of Friedrich Emanuel Nietzsche and his enormous mustache. Mustaches, as I’m sure you all know, can seriously intercept the communicative role of tongues during the interface process that is a french kiss.

We will present you with all this in German, thus enable your quantum language processors to receive the information without bias, in its pure and undisturbed form. The final question we want to present you with is “How can we kiss Nietzsche with our tongue, when he isn’t even present here”.