The "Time-Loop" Model of Visual Perception

Uwe Kämpf
Department of Psychology
Dresden University of Technology
D-01062 Dresden
+49-(0)351-46333179 (phone/fax)
uwe.kaempf@psychologie.tu-dresden.de

Abstract
As an introspective observer, we are aware of an outlook from the cockpit of our ego into a spatially extended holistic visual-world representation with *simultaneous* awareness of all visible parts of the perceived environment. However, the neuronal network transforms spatial extension into temporally extended codes, being registered, e.g., as an oscillatory EEG pattern of *successive* phases or stages of brain activation. Since the temporal extension of perceptual processing is in a rather fundamental conflict with the internal psychophysics of real-time comprehension of ongoing events, the hypothesis of a "time-loop" model of visual perception is presented in order to handle the contradiction. Thus, the visual signal's recurrent processing is argued to be critically dependent on advanced anticipations of the next input in order to adjust its timing aspects in a way which stabilizes the equilibration of non-linear brain dynamics. In order to account for the coherence e.g. of binocular stereo vision, a synchronous visual flow in both left and right brain hemispheres is needed for. Thus, the temporally delayed information of the both eyes left and right visual hemi-fields, which are processed in different hemispheres, should be integrated with anticipated versions of their complements in order to close the time gap. Departing from the standard computational approach to anticipation, our "time-loop" model is argued to account for some of the mentioned phenomena by a possible quantum-entanglement effect. From this point of view, the issues of visual processing under discussion may be reinterpreted based on the Wheeler-Feynman absorber approach. In line with the hypothesis of a transactional interpretation of quantum brain dynamics, we apply an anticipative resonance coupling approach to aspects of cortical synchronisation and recurrent ideomotor visual action control. In light of our hypothesis, recent findings about so-called mirror neurons in the brain cortex are suggested to be associated with temporal rather than spatial mirror functions of visual processing in phase conjugate adaptive resonance, known from non-linear optics. Therefore, it is proposed to consider the registered coherence patterns of neuronal synfire chains' discharge streams (which should be related to the EEG brain wave patterns of, e.g., evoked potentials after visual stimulation etc.) not only as a result of retarded brain communication processes. Rather they are suggested to be components of a standing-waves system. The latter might be generated in the counterbalance of a "time loop" between the actual input's delayed bottom-up data streams and advanced anticipative signals from mirror neurons taking part in top-down recurrent processing.
Keywords: transactional interpretation of quantum brain dynamics, cortical synchronisation, idemotor approach, inter-hemispheric communication, amblyopia

1. Kant's Challenge and the Psychophysics of Quantum Brain Dynamics

Imagine, you were the creator, and you had no space at all, only time and no more than just one single point to manipulate – what would you do? In other words: How would you manage to transform time into space? And why should you do so in the first place? And finally, what does this space-time transform have to do with the topic of this paper, namely, the hypothesis of a "time-loop" model of visual space perception?

Subsequently, we try to answer these questions consecutively, one by one. To begin with: In fact, our issues in question were mainly inspired, in view of the actuality of an envisaged new psychophysics of quantum brain dynamics [34, 43], by an argument, which had been originally proposed more than two centuries ago by the German transcendental philosopher Immanuel Kant. If we took all material objects away from the world, leaving only empty space and time, according to Kant, these two categories, cannot be understood as referring to basic properties of an objective external reality. Rather they should be understood as internal sensory "qualia" of our "interface" to the world, hiding the "thing in itself" (*Ding an sich*), whose intrinsic properties, which exist behind the perceptual surface, probably, are not fundamentally anchored in our usual realm of space and time.

In the last decades, Kant's argument received striking experimental support by the apparently „timeless" and/or „spaceless" instantaneous non-local correlations between distant subatomic "twin" particles under certain quantum-observational conditions. Initially obtained by Alain Aspect and his collegues [3], the subatomic non-locality effects have also been termed quantum teleportation [42], or the Einstein-Podolsky-Rosen (EPR) paradox [10]. Strangely, this paradox has been named after the gedanken experiment of a man who did not even believe in the experimental reality of this phenomenon. Einstein initially proposed it as an argument against the absurdity of the consequences of quantum mechanics. He aimed to rule out such "spooky" instantaneous action at distance, resulting in a "collapsing" wave function of one of two "twin" particles whose quantum state is correlated (entangled) to the state of its partner being subject to a measurement at the same time, but in a different place.

However, the nowadays experimentally verified instantaneous quantum correlations imply a Kantian challenge to Einstein's relativist approach of understanding time and space and, moreover, to the whole "realistic" and "local" worldview of science. In view of special relativity, instantaneous – superluminal – "communication at a distance" between particles in quantum entangled states, seems to imply one or both of the following conclusions: Either that spatial extension, the main property of space as a such, does not exist, at least not as an objective feature of the world outside there, but only as a subjective one: Maybe, there's no space at all behind the inside our sensory interface! Complementarily this could mean – according to the transactional interpretation of quantum mechanics [4] derived from the Wheeler-Feynman absorber theory [40], which will be sketched below – that time should be conceived to posses certain unusual features: Some kind of a "back in time" signaling must be expected to occur, as a kind of an additional "loop" contrary to the flow of causality. Thus, it appears – in line with

Kant's argument – that something might be wrong with the fundamental psychophysical assumption of an isomorphism of space and time as we ordinarily perceive them in our everyday life, as corresponding to a physical reality "out there".

2. Halfway to Kant: Subjective Space vs. Objective Time

All in all, the quantum non-locality results seem to give strong experimental support to Kant's challenge for the "objectivist" conceptions of our psychophysical, i.e. sensory connectedness to the world. Accordingly, the spatio-temporal appearance of our perceptual outlook on the world outside us should be considered to be a purely subjective construction.

Over the centuries, outstanding scientists and philosophers, following Karl Marx, have counter-argued against Kant from a rather pragmatic position. According to this position, everyday practice shows – in spite of all philosophical reasoning – space and time plus the included objects to really behave as they perceptually appear to us, namely, located outside of us, being thus part of an observer-independent reality. And as long as there were no practical reason for another view, runs the argument against Kant, there seemed to be no theoretical need to complicate our lives. Speculations about a possible conflict between the inner qualities of the perceived reality and the objective one of the outside world appeared to be useless. However, the experimental practice of quantum theory has confronted us, anew, with the challenge of Kant's original formulation of an eventually pure subjectivity of time and space as perceptual categories. Indeed, his theoretical argument is supported by the hitherto unknown experimental "practice" of quantum non-locality which is rather different from common sense physics: Space looses its most outstanding feature, namely, extension, and time is probably supposed – as it will be discussed below – to loose unidirectionality, as its most outstanding feature.

Kant's argument implies as a possible consequence of the EPR paradox that even "hard" physical science may be constrained by the limits of psychophysics as well. Speaking anachronistically, the process of scientific observation is concerned with no other reality, too, than with the "interfacial screen" of our subjective "quantum computer display": Even if we studied all the screen's spatio-temporal properties carefully, we would still not know anything about the processor's non-local reality itself[1].

Starting from Kant's challenge, we attempt to discuss in this paper the envisaged consequences of quantum non-locality for an internal psychophysics of visual time-and-space representation and cortical neuronal network synchronization. However, left with both space and time as pure subjectivity, as has been proposed by Kant, it would be hard to find a way out. From the perspective of the embedding of our discussion in the

[1] To illustrate that, think of an "ego-shooter" computer game, containing not only the outside world's environment, but also your hands with the tool and your whole body within the frames of the screenplay. Studying, thus, the architecture of your body and brain, down to the nervous cells, atoms and electrons given with no other reality than that of the interface screen would always result in still "another brick in the wall" of the pixel arrangement of the display's, but not of the processor's layout.

envisaged psychophysical framework of quantum brain dynamics [34], as has been stated, the EPR effects rather show space to be the more obsolete of the two categories, raising doubts about its most evident feature, namely the reality of spatial extension. Time appears to be the more veridical category, and only the usual assumption of an unilateral temporal flow seems to be in need of reform. Thus, the quantum non-locality results suggest space to be the best candidate for the subjective category, and so time is preserved as the objective one. In the following, a quantum non-local absorber model is proposed to handle the psychophysical representation of space by the hypothesis of a "time-loop" in so-called recurrent visual processing. It is based on the assignment of – as a working hypothesis halfway in accord and halfway departing from Kant – only one of the two categories, namely, space, to the subjective sphere, leaving the other one, time, anchored in the objective domain.

3. A "Time-Loop" in the Psychophysical Representation of Visual Space?

So, let us return to the first of our introductory questions. Really, what could we do, if we had no space at all, only time and no more than just one single point to manipulate? What we could do is to remember childhood: As small children, we used to meet on New Year's Eve to light sparklers. We were moving them around repeatedly, very fast, to and fro, over one and the same area of our visual field, oscillating them fast enough to reach a speed above the critical flicker fusion frequency (CFF). If successful, we managed the transition from a sparkling moving point to an apparently stationary bright line. Extending this childhood experience into a new gedanken experiment, we keep moving the resulting one-dimensional line orthogonally to the initial direction up and down along a second dimension, again at a speed high enough to overcome flicker fusion, we obtain a bright two-dimensional square. If, in addition, we modulated brightness and color according to a certain highly synchronized repetitive code, we would obtain a kind of stationary TV-picture. If, finally, we moved this arrangement along a third dimension, say, around us like a cocoon, we would obtain a three-dimensional spatial environment.

But stop: How could we manage to generate, by repetitive movement, a "to and fro" with our sparkler in the first place? Were we already "cheating" in the initial step of our reasoning? As a prerequisite for that movement, do we not need exactly that spatial extension we want to "create"?

No. We would not need it, if we were moving the spot forward and backward in time rather than to and fro in space. Thus, our linking hypothesis to the issue of how to generate space from time is, essentially, to include a "time loop" into the phase structure of visual representation in order to create a spatial dimension. Since this is conceived of as an oscillatory process, we obtain a kind of standing wave in time as the psychophysical basis of space perception. This idea seems to be applicable not only to the first dimension, but in form of a fractal to the second and third one too, since the orthogonal oscillatory components can be conceived to constitute several levels of "sub-loop" structures in time, being nested in one another similar to the relation between the rows' frequency and the picture-frames' frequency in an ordinary TV screen, that is, one with a cathode ray tube rather than a liquid crystal display[2]. Time, thus, is conceived of as possessing an internally fractal substructure, which is supposed, as a main hypothesis of this paper, to provide us with the basics of our ability to perceive three-dimensional space.

Note that such a model proposes an elegant explanation for the origin of dimensions, which is not accounted for in most approaches, neither in psychophysics nor in "hard" physics. Ordinary Euclidean axiomatics as well as multidimensional models – e.g., the 11-dimensional structure of superstring theory etc. – cannot really explain what a dimension is. They cannot tell "what it is made of", where it comes from; so they take their extra dimensions as an axiom, i.e. from a nowhere like a *deus ex machina*. By contrast, our time-loop approach proposes dimensions of spatial extensions to be constituted by a standing wave pattern of nested oscillations in time, every additional subcomponent of which can be generated in the form of another additional extension of a set of fractal dimensions.

4. The Absorber Approach and the Psychophysical Interface Model

Thus, the view presented here may imply the additional potential to propose more than simply an *ad hoc* speculation in order to get a handsome psychophysical model for a perceptual transformation of time into space. In fact, our hypothesis may be proposed to correspond – as a psychophysical counterpart – to Cramer's transactional interpretation of quantum mechanics [4, 5]. His model of a temporally inverted spatial transaction is rooted in the core of the Wheeler-Feynman absorber approach [40] to quantum nonlocality which had been proposed as an alternative explanation to the traditional Copenhagen interpretation. Following a proposal by John Archibald Wheeler, Richard Feynman developed this idea as the basis of his contributions to the theory of quantum electrodynamics (QED), as he tells us in an excerpt[3] of his Nobel Prize speech [31]: "One day my professor of physics, John Archibald Wheeler, called me by phone: 'Hey, Feynman, I know why all these electrons appear to be so identically exactly the same ones!' – 'Namely, why...?' – 'It's always just one and the same electron! There exists only a single one!' – 'And why do we think there are 10 powered by 80 of them or so?' – 'Very easy: It runs very often zigzag to and fro along time. Anytime it comes from the past through the present we do think it is a new electron...' – '... and then it comes from the future, we think it's a positron?' – 'Bravo, Feynman, make a theory of that!' "

Thus, the core of the absorber theory is based on the unidimensional structure of an ultra-high frequent time loop of only one individual particle, generating the illusion of

[2] Of course, this is a rather oversimplified picture, serving only for illustrative purposes. With respect to neuronal coding, the idea of a fractally organized hierarchy of spatial frequencies will be proposed as a more realistic scenario.

[3] The excerpt of Feynman's Nobel Prize speech in Stockholm has been cited from "Gehrtsen Physik", one of the most influential textbooks of German university physics.

the appearance of all other particles around us in space. In fact, a very similar time-loop assumption is also fundamental for the transactional interpretation of quantum mechanics which had been developed by Cramer [4, 5] later on, as an attempt to explain the EPR paradox in a straightforward way in contrast to the Copenhagen standard interpretation of quantum mechanics. This alternative explanation rests on the idea that a "handshake" between the ordinarily transmitted signal and an anticipative effect deeply rooted in the quantum world is a fed back from the so-called "absorber" to the "emitter" of the transmission. Coupled in between the "retarded" and "advanced" components in the collapsing wave function of a quantum event under measurement, this process appears to an external observer as a seemingly[4] time-reversed transaction. The mathematical roots of this may already be found in the standard quantum-mechanical procedure for calculating the so-called "collapse" of the wave function, by computing the square of the probability amplitude. This is done by multiplying a weighted complex number (cos t + i sin t), representing a quantum state vector, by its conjugate (cos t – i sin t). Since the angle t represents time[5], a change of the sign of the imaginary part in the complex conjugate number mirrors the angle against the real axis. The result is a change into its opposite of the time flow, which has to be identified with angular rotation direction. In a similar way, as will be discussed below, this argument has been adopted by Marcer and Schempp [28, 29, 30], using the framework of phase conjugate optics, in order to give an account of visual consciousness in terms of quantum holography.

5. Spatio-Temporal Integration of Visual Processing Streams in Light of Possible Quantum Transactional Effects in Cortical Synchronization

Returning to our main issue, we should admit that from our psychophysical interface, i.e. as introspective observers, we have a "cockpit perspective" into a spatially extended, holistic visual-world representation with simultaneous awareness of all perceived parts of the environment. Neuronal processing retransforms spatial extension into temporally extended codes, being registered, e.g., as an EEG pattern of successive phases or stages of cortical oscillations. But how are these constituents of the visual space-time representation psychophysically and neuro-cortically interconnected?

It will be shown below that this temporal extension of perceptual processing is in a fundamental conflict not only with the internal psychophysics of real-time comprehension of ongoing events but also with the need for a stable synchronization of the multitude of underlying representational brain processes. In fact, the problem of simultaneity

[4] In fact, the "back-in-time effect" is understood by the absorber model to result from an illusion from the point of view of the external observer since, in the relativist framework, the light beam from its inner aspect has zero time flow and no spatial extension. Thus, the absorber theory is an attempt to unify certain contradictions of the relativist and the quantum mechanical paradigms.

[5] More precisely, time is represented here by omega t, with omega as a constant 2Pi/T (with T as the time period measured, e.g. in msec) which transforms the temporal periodicity into the phase of an oscillatory "angular time" corresponding to circular revolutions in radiants.

and succession in vision, i.e. of the perceptual processing modes of spatial and temporal integration, is as yet unsolved, in spite of the many approaches addressing that issue.

The reader may object here: The retina consists of a spatially distributed array of receptive fields, the activation patterns of which are transferred into cortical receptive fields by thick bundles of axons in the optical nerves in parallel, so what is the problem? The problem is that these "pixels" should be serially interconnected and this takes time. Alternatively, a wave-representation in vision, e.g., as a result of filtering spatial frequency, cannot be based on a "field-like" psychophysical correlate of visual consciousness. This must be a priori excluded now – at least, in the form of a classical electromagnetic field – since our head (and the whole body as well) can be introduced into a mega-tesla coil of fMRI scanners with no damage to ongoing cortical processing.

In a quite unusual and rather straightforward proposal, made in the context of the so-called feature-binding problem [39], oscillatory synchronization of different brain loci has been suggested to be the "glue" for the psychophysics of spatiotemporal integration. However, the mechanism of this process has been left open. To close the gap, it is discussed here, as a hypothesis, that the entanglement of distant particles by quantum non-locality may provide us with an absorber-type approach to solve the communication problem between the spatially separate neuronal circuits by a "time-loop" structure.

So we can now try to outline the connection between the sketched hypothesis, which is based on the quantum-absorber approach, with certain aspects particular to cortical synchronization and the psychophysics of the representation of space via cycles of time loops within the brain. According to this hypothesis, representational simultaneity – as a brain process spread over spatially distant loci – is achieved by temporally bidirectional interactions of neuronal processing on a quantum scale. Absorber effects between the presumed "advanced" vs. "retarded" signal components are supposed to generate a standing waves pattern. The latter might be speculatively assigned to the carrier process of an internal psychophysics of visual space representation.

Evidence, which may be re-interpreted in support of this idea according to the framework of the presented hypothesis, comes from an alternative view on some phenomena of stereo vision in connection with inter-hemispheric communication and integration. In order to account for the coherence, e.g., of binocular stereo vision, a synchronous visual flow in both left and right brain hemispheres has to be established. Therefore, the temporally delayed signals of both eyes' left and right visual hemi-fields (which are processed in different hemispheres), should be integrated with anticipated versions of their complements in order to close the time gap.

In light of this, it may be admitted that the functional structure of stereo vision displays several features relevant to the context of the present discussion. Anatomically, the visual nerve, which transfers the optic signals into the brain, is only partially crossed over with respect to the addressing of brain hemispheres via the so-called chiasma opticum. The crossing is true only for the nasal (inner) sides, with respect to the focus of fixation of the visual field of each eye, which is connected to the contra-lateral brain hemisphere. By contrast, the temporal (outer) side of the visual field of both eyes is fed into the same-sided ipsi-lateral hemisphere. In other words, the visual signal about the right half of the visual world is transmitted, from both eyes, first via the left lateral geniculate body (LGN) into the visual cortex of the left brain hemisphere. At the same time, vice versa, the left half of the visual world is transmitted via the right LGN into the right visual cortex. Only afterwards the information about left-hemispheric and right-hemispheric hemi-fields' vision is re-united via contra-lateral connections through the corpus callosum (CC). That means the contra-lateral visual signals from the opposite hemisphere are, in the absorber terminology, "retarded" with respect to one another. Does the visual system perform a correction for this delay, sending an "advanced" copy of its own input from each hemisphere to the contra-lateral counterpart, much in the same way as discussed above in the context of the coupled oscillator problem?

There is a perceptual phenomenon in binocular vision which may be interpreted in accordance with this idea, namely, the so-called Pulfrich effect [35]. Occluding one eye with a dark sun-glass while looking at a pendulum swinging in line with a parallel trajectory in front of the observer, the following phenomenon might be perceived: Apparently, the pendulum is seen to deviate from the fronto-parallel plane, describing a rotation in three-dimensional space. The effect is based on the induction of delayed retino-cortical transmission rates by the unilaterally darkened visual input. Inducing, therefore, a spatio-temporal shift between the left and the right eyes' stimulus patterns, this is interpreted by the stereo vision system as a depth parallax giving rise to the three-dimensional rotary movement. Every time the pendulum crosses the fixation focus, it is turning from the left to the right brain hemisphere, or vice versa. The result is an additional retarding moment which should be anticipatively counterbalanced by an advanced signal component.

So our brain's inter-hemispheric communication, which is required to account for the micro-timing of stereo vision – as exemplified by the Pulfrich phenomenon –, might be based on an absorber-type "tuning into the future" mechanism[6] which is comparable to the one proposed for the quantum scale. In order to obtain a synchronous visual flow in both the left and right hemispheres of the brain, thus integrating the temporally delayed information of the left and right eyes' hemi-fields, which are initially processed in different hemispheres, anticipation is needed in order to close the time gap.

Converging evidence comes from a neuro-ophthalmologic disorder which might be considered in the present context, namely, the perceptual deficiencies occurring in so-called amblyopia [21]. Associated, as a rule, with strabismus, it means, as a rule, not only the loss of stereo vision, but also an unilateral decay of visual acuity due to deficits in central visual function rather than peripheral optical damage. As has been shown for intracerebral recordings from the amblyopic cat, made by the Singer research group at the Max Planck Institute Frankfurt, this is not due to losses in the visual brain channels *per se* but rather to deficits in their co-operative processing. In fact, it is the synchroni-

[6] There exists, of course, a textbook-standard explanation of the Pulfrich effect, stating that the visual integration in depth is calculated from memory and retrieval procedures. These are even additionally more retarded in time, since the underlying calculation must wait for the inter-hemispheric transfer's backward loop. However, the present explanation has the interesting feature of producing "just in time" output, the anticipated effects of which were advanced via an absorber-type mechanism.

sation between neuronal processing at different loci (coherence) which is preserved for the good eye and lost for the lazy eye [23, 36]. This is interesting with respect to the model of quantum-holographic processing in the brain, as has been proposed by Karl Pribram [33, 34], Marcer & Schempp [28, 29, 30] and others, since coherence of the neuronal processing is a prerequisite for the presumed "holochoric" brain states. Standard neuroscience has decisively argued against holography as a brain process. The basic argument is the finding that the nervous system cannot guarantee a linear transmission of the phase since it has been shown to perform in a rather non-linear way. In other words, it was argued that different time courses of retarded neuronal transfer functions in different neuronal circuits destroy the required phase locking of the neuronal signals.

In contrast, a consequence of the absorber hypothesis is that a transaction between advanced neuronal states might compensate for the retarded ones, resulting in a temporal zero shift of neuronal processing. Analogously, the signals of the neuronal transmission circuits may, accordingly, be conceived as the retarded component an arrangement of standing waves in time and space, being compensatd by a complementary advanced component to a plus/minus zero delay. In fact, such a transactional interpretation is incorporated in the concept of quantum holography, as it has been proposed by Marcer and Schempp [28, 29, 30]. Based on a neuronal mechanism of phase-conjugate adaptive resonance, according to this model, the advanced-resonance phenomena can be explained in an analogy to the ones known from the "time-reversed" reflection properties of so-called phase-conjugate mirrors. The latter are used in non-linear optics, e.g., in the context of so-called four-beam mixing. Departing from a conventional mirror, the laser-like "pumped" surface of the phase-conjugate mirror does not reflect light in the usual way of "spreading" it in all possible directions. Rather it reflects the light beam "back-in-phase" to its original location in space *and* in time. As a model for the explanation of spatio-temporal phase losses in amblyopia [17], this could imply a straightforward consequence. Namely, that the above-mentioned losses of neuronal processing coherence shown in the physiological recordings of the strabismic cat may be due to deficits in the advanced (absorber-type) component of visual processing, leading to a breakdown in the coherence of the reverberating time loops due to a loss of the compensation of the retarded component neuronal synfire chains. Here, an absorber-type behavior of the so-called mirror neurons [36] might be assumed as a hypothesis: Incorporated in an anticipatory non-locality mechanism in the nervous system [9], these units were to be conceived of as constituting a kind of "time-mirror" function [22] in the recurrent information processing. This is currently, as is the whole absorber model of quantum brain dynamics, of course, a speculative assumption, to be proven by further investigation.

6. Computing vs Tuning in the Control of Sensory-Motor Coordination

The most fruitful application of the quantum transactional "time-loop" model of visual psychophysics may be probably found in the anticipative control of sensory-motor coordination. To anyone who ever played, or even only watched, a football game or a tennis match, it is evident that the player's sensory-motor control task cannot be reduced to the aim of hitting the ball at its currently visible position. On the one hand, it takes time to register and to process the visual input, to generate and to carry out the motor commands etc. On the other hand, meanwhile, the ball has been continuing its flight and should be hit, instead of its sensorily processed location, at a certain future position where it is meant to arrive only when the player's foot or hand with the racket will have reached it. Nevertheless, in such fast games the player's usual report is the impression of having hit the ball just at the place where it was actually perceived. Therefore, a component of strong anticipation is involved not only in the player's performance, but also in the real-timing anchoring of his or her perceptual processing control.

Indeed, a psychological account for a certain class of behavioural regulatory issues, known as the ideomotor approach of perceptually guided action control and learning, is based on such an assumption [38]. A good illustration, e.g., is the development of a baby's sensory-motor behaviour which is apparently stochastic after birth, becoming more and more co-ordinated within a few months. Obviously, the brain's development should lead to a growing degree of synchronicity and coherence in the reverberating neuronal communications, as a prerequisite for smoothly cascaded sensory and motor processes. However, the baby's sensory-motor learning process lacks any kind of "robotic" regularity. In line with the ideomotor approach it is concluded that the efferent commands to the bundles of muscles are initially chosen at random, the useful of them being selectively reinforced stepwise based on feedback of their anticipated afferent consequences, i.e. the desired visual changes induced by the muscular activity. Accordingly, the ideomotor theory explains developmental and executive aspects of action control departing from the proposition, that the actually ongoing behaviour is perceptually guided by the anticipated consequences of its own future visual reafferentation, dependent on the desired outcomes of the to be performed actions [17]. However, the neuronal signals, due to considerable transmission latencies, are "retarded" with respect to the actual state of the organism and its environment. The question arises, how is the needed knowledge about the "advanced" future states gained by the visuo-motor system?

Standard theory claims this to be a matter of computation. Knowing the past and its changes until the present, it is possible to anticipatively calculate its probable states in the future, i.e. to predict them by computing from memory about earlier experiences with similar situations. Alternatively, in the light of the quantum transactional hypothesis for the psychophysical interface, the present paper discusses a view which is rooted, in opposition to the "computing" approach of the AI tradition, rather in a sensory-motor "tuning" view proposed by J.J. Gibson [13] and his followers. Proponents of this idea argue that an organism has to do no more computing than its environment has to do, because the sensory systems are conceived to be "tuned-in" to the relevant environmental information. Therefore, the question arises: Is the proposed absorber-type mechanism a possible solution of the anticipative-control problem for an organism whose neuronal input transfer function is "retarded" with respect to the actual environmental states? Can such an organism be tuned in resonance with "advanced" perceptual changes, being caused only by the output of its own future locomotion which actually might have been not even started yet?

If this were the base for such anticipative tuning, then the following assumption may be derived from the "time-loop" hypothesis: Our ideomotor control should be psychophysically coupled via resonance into the depth of the upcoming but uncertain yet quantum-transactional states the ongoing event has to arrive next in the narrow horizon.

7. Neurocognitive Evidence for an Absorber-type Mechanism in the Ideomotor Control of Perceptually Guided Behaviour?

If we preliminarily accept, as a hypothesis, the assumptions of the absorber approach applied to an anticipatively timed architecture of ideomotor action control, then, we might ask for neuro-cognitive evidence in favor of this idea. Candidates for "time-loop" effects which might be expected to arise from the visuo-cortical analogue[7] to a quantum-transactional interface and the corresponding modes of cortical synchronization of the underlying brain processes should be found in the psycho-physiological and behavioral data. In such a context, the frequently discussed Libet [27] experiments might be re-considered. These experiments show a seemingly paradoxical time difference between an action which is already under way, and the time when the decision for that action was made. Apparently the decision took place later[8] than the onset of the action itself. In the experimental setting, an observer is instructed to decide "by free will" within a certain interval the actual moment to press a button and to fix the time of decision making (and, in a control condition, also the time of executing the action) by observing a clock. Certain physiological data (EEG, EMG) are recorded, resulting in the paradox that these parameters give an earlier response (up to 500 msec) than the estimated time of the decision-making itself. This is especially curious in comparison with subsequent control experiments with so-called trans-cranial magnetic stimulation (TMS) of the motor cortex. Evoking unwillingly forced finger-movement responses, the estimated timing of the latter did not show the typical temporal reversal [14, 15]. The Libet-type experiments are very popular nowadays, since their interpretation in the framework of the standard neuro-cognitive approach, according to some theorists, seems to give rise to the conclusion about the non-existence of free will. It is argued by certain leading neuroscientists, that the cerebral circuitry autonomously does the whole job for itself, whereas the mentally-timed feeling of "having made the decision made by myself" comes later, due to a pot-hoc interpretation generated within the compartmental architecture of the brain, rather than being induced in advance by an act of "free will" [9].

---

[7] At present, it is far from clear whether this analogy has to be conceived of only as a useful heuristics or whether there is something in common in the presumed brain's and the quantum mechanical "absorber" behaviour. However, the present chapter discusses this idea from an intentionally speculative view, looking for certain conclusions which could be drawn, giving the transactional explanation the preliminary credit of a working hypothesis.

[8] At least this might be concluded under acceptance of the chronometric conditions of these experiments, involving the procedure of judgment-based assignment of the subjective decision time – as is shown on the observed clockwork – to the reaction time, the time course of the EEG, EMG and other parameters.

[9] As has been frequently discussed, the whole debate is, of course, probably obsolete in several aspects, as far as it is applied to the topic of free will, as the experimental procedure is not able to really give a deci-

Alternatively, based on Cramer's quantum transactional interpretation [4, 5], Fred Alan Wolf has argued that the outcome of Libet's experiments is the result of a mechanical absorber effect [41] which can be accounted for in the terms of the Wheeler-Feynman theory. Indeed, visual processing, on the one hand, takes up to 500 msec of time. However, perceptual locomotion control requires a temporally much closer sensory-motor interfacing loop (preferably "just in time", i.e., as close as possible to dt=0). Accordingly, a straightforward idea has been proposed as a solution for this conflict. It has been argued that the interrelations between certain brain states associated with the sensory-motor processing control and the underlying external events are entangled in much the same way as absorber and emitter are in a quantum-correlated transactional state. Thus, the retarded brain processes might serve as an internal absorber for an advanced (up to 500 msec) component of the sensory signals. Accordingly, the transactional results of sensory processing are – in analogy to non-local quantum absorber states – supposed to be dated "back-in-time" then, into the "entangled" temporal context of ongoing external events. Thus, our absorber hypothesis derived from the quantum-transactional model for the psychophysical interface perfectly fits to the requirements of a tuning instead of computing model of anticipative ideomotor action control.

8. Oscillating Cycles of Synfire Chains as a Representational Basis for Spatio-Temporal Interaction in the Visual Brain

However, beyond the psychophysical representational aspects and the ones of sensory-motor control, the absorber model is argued to imply essential conclusions for the cortical synchronization process *per se*, i.e. on a neurological scale. In light of the discussed hypothesis, absorber effects appear, on the operational site, as anticipations of future states of the system. In the following, we present arguments for the significance of advanced signals as an anticipative feedback for the synchronization of spatially distant retarded brain processes. Our argumentation will be derived from an analogy between the synchronization of neuronal activity and the one of chains of coupled oscillators on different scales, including such of cosmological extension.

Such an analogy holds true because the brain's neuronal feedback loops consist, in principle, of assemblies of hierarchically intertwined coupled oscillators. We assume as a (meanwhile) well-established fact, that the functional architecture of recurrent visual processing is organized as a hierarchy of interdependent levels of loop structures, the so-called synfire chains [1, 2]. Their timing is known to be coordinated by neuronal cycles of cascade-like activation lasting up to more than 500 msec of temporal delay. In spite of the considerable duration of the reverberations of these neuronal loops, their timing accuracy is perfectly synchronized. Their precision of timing is adjusted for a deviation of less than 1 msec, relative to the repetitive reoccurrence of activating one

---

sive answer to the controversy. One of the problems is that the conclusions drawn are anchored in the chronometric arguments of a classical physics and psychophysics of the 19th century which has been made obsolete by the quantum-mechanical revolution, as is also argued in the present chapter.

and the same neuron in the chain. Obviously, if an actual visual input is fed into such a synfire network, its processing results come up, due to the relatively long latency, retarded with respect to the changing environmental situation. In recompense of that, the visual signal's recurrent visual processing is argued to be critically dependent on advanced predictions anticipating the next input. As will be shown below, these anticipations are needed in order to adjust the timing aspects of the coupled oscillators' synchronism in a way which stabilizes the equilibration of non-linear brain dynamics. Due to non-linear dynamics, which is a key feature of any kind of coupled-oscillator systems, in the range from the sub-atomic scale up to the cosmological one, delayed feedback loops can trigger the emergence of chaotic attractors in a wide variety of conditions[10].

Beyond the brain's and neuronal system's dynamics, the same architecture of oscillators in hierarchy – which is sensitive to chaos induction by retarded feedback – also underlies other bio-regulatory processes, such as the enzymatic metabolism, the control of the heart rate and blood circulation, as well as many of the organic and non-organic chemical and even pure mechanical oscillatory regulation processes. Helio-geocyclic processes might serve as an example of the latter [24, 25], as do, last but not least, the loop-synchronization adjustments of the solar system's reverberations and those of the whole universe. Since these have been extensively studied, starting from Newton's work on the planets' revolutions around the sun until the discovery of chaos by Poincaré in his attempt to find a solution of the three-planets problem, they may serve in the following as a fitting analogy for processes taking place in the brain.

9. Coupled Oscillator Chains in Anticipatory Synchronization

According to the framework of anticipatory regulation developed by Daniel Dubois [6], our universe – as well as our brain – has to cope with a synchronization problem of regulatory stability which has hitherto been ignored[11]. The reason for this is apparently hidden in Isaac Newton's differential equations describing the planets' periodical revolving movements. Since the underlying differentiation process dx/dt assumes a temporal delay approximately equal to zero, Newton's equations are implicitly based on the assumption of an infinite speed of gravitational signal transmission. However, in the

[10] One may get an illustration of this with the help of a coupled-oscillators system sold in gimmick shops, the so-called "chaos pendulum". On the one hand, such a device usually consists of a regularly oscillating primary pendulum (whose cosmological analogue might be, e.g., the sun-earth system). On the other hand, the construction involves a secondary sub-pendulum (comparable, e.g., to the earth-moon rotary system), whose oscillations are, in contrast, totally irregular. Fortunately, however, chaotic pendulum dynamics has never been observed in the interactions of our sun, its planets and moons, although it can be observed in the case of brain dysfunction, as has be shown in the case of amblyopia in the strabismic cat.

[11] The author adapted selected issues from the work of Daniel Dubois in order to discuss corresponding topics of the present paper. Being intentionally speculative about interrelations between brain synchronization and visual representations of spatial extension, our "time-loop" model is inspired by the absorber theory and, as will be seen later, cosmological basis observations of the Kosyrev effect. The full responsibility for the proposed view rests with the present paper's author.

light of Einstein's relativistic physics, gravitational distortions should have a finite transmission speed too, less than or equal to the velocity of light c[12]. If this were so, then the gravitational signals would travel at least about one second from earth to moon and about eight minutes from sun to earth; on their way back, again, the same temporal delays should accumulate. Instead of Newton's infinitesimally small dt, therefore, a considerable amount of delta t has to be taken into account in the solar system's regulatory feedback loops, not to speak of the galactic and extra-galactic measures of spatial and temporal distance.

With respect to the topic of the present chapter, it should be admitted that this problem is neither an exotic issue concerning distant stars, nor is it just an issue of funny gimmick pendulum toys. Since, in fact, all bio-regulatory processes, e.g., human and animal metabolism, heart rhythm, blood circulation, and – last but not least – the brain's and the nervous system's exhibitory/inhibitory balance are based on an architecture of hierarchically coupled harmonic oscillators with non-linear dynamics, the delayed feedback problem and its consequence of the system slipping into chaos appears to be similar in all these cases.

Daniel Dubois gives an impressive example of the regulatory problem with delayed feedback loops in coupled harmonic oscillatory systems, which is especially appropriate within the context of the visually guided behavioral control by oscillatory synchronized brain processes [8]. Considering the visuo-motor synchronization of a robot's arm trying to grasp an object in rotary motion, he argues that the cycle of registering and processing the input, generating and executing the motor commands etc., takes a certain amount of time. So it may easily turn out that this delay of minus delta t is in harmonic relation to the temporal cycle of the object's revolutions. In this case, the robot's attempt to grasp the object may become systematically erroneous or even chaotic according to the standard Feigenbaum [11] scenario. The same problem, however, should apply to the Sun, when it "attempts to grasp" the revolving Earth in its delayed position and, similarly, to Earth itself, with respect to the moon's delayed position. So why then, one might ask, is the moon stable in its revolutions around the Earth, just like the Earth revolves around the Sun and the Sun around the galaxy? And why are the brain's processing circuits of synfire chains, as a rule, also stable?

If delayed feedback is a chaos-inducing condition, Dubois proposes, vice versa, that the anticipated future state after the delay, fed forward into the system's regulation, leads to its "dechaotization". In fact, the robot's arm's control processes become smooth and synchronized after introducing an anticipative (in Dubois' nomenclature: incursive or hyper-incursive) term into the discretized feedback equations. In light of this, these equations were reformulated by Dubois, by using, instead of the state parameters of the delayed position, (i.e. the state at "–" delta t), the parameters of an anticipated future state, corresponding to the absolute value of the delay time, but with an inverse sign

[12] In Einsteins general relativity, gravitation is due to curvature of space, induced by the masses of the stars, the planets etc. However, distortions of the space curvature should be transmitted by a finite speed of light. Therefore, Dubois argues, space curvature should anticipatively adapt to gravity distortions in the way an absorber system does.

(i.e., the state at time "+" delta t). Therefore, the anticipating feed-forward neutralizes the delayed feedback, and the resulting dt equals $\pm$ zero.

In an anticipation-based calculation, Dubois was able to show for the planet Mercury that this idea seems to be applicable to cosmology too [7]. Using the discretized Newtonian equations, the calculations resulted in big rosettes of "epicyclical" cycloid revolutions of the planet's orbit which, in fact, have never been observed. This was due to the retarded correspondence with a negative delta t (a delay of about –1,8 minutes) based on the velocity of light as the speed of sun-mercury gravitational effect transmission. However, if one inserted into these equations a set of advanced parameters corresponding to exactly the same interval but with an inverted temporally positive sign (delta t of about +1.8 minutes ahead), this feedback from the system's own anticipated future state was able to produce a nearly ideal trajectory. The latter, whose ultra-small rosettes were consistent with the recorded astronomic observations of many decades, deviated only marginally from the Newtonian one. As has been mathematically proven by Dubois, anticipation appears to be a vital requirement for avoiding planetary resonance-driven coupling to a chaotic attractor. The same principle should hold true for the analogous problem in brain synchronization.

10. Absorber-Type Brain States and Stellar Observations of the Possible Effects of a Cosmological Phase-Conjugate Mirror

So the question arises: Are the hypothetical quantum absorber effects, such as the sketched above, if relevant to the foundations of our psychophysical interface, likely to occur within our biological tissue, "inside" the neuronal system? Or should the neuronal tissue conceived to be resonant to certain quantum transactions "outside there", maybe even rooted in the hypothetically assumed anticipative regulatory architecture of cosmic space? The argument for such an idea is, that our brain must not necessarily be assumed to "calculate" all the needed anticipations by its own "computing" facilities. If the data about the probable future were already omnipresent within and around us, then they could be simply "downloaded" by appropriately "tuning" the brain's filter capacities.

Nowadays, quantum transactional effects of potential psychobiological relevance are preferably searched for at the "microscopic" scale of sub-cellular nano-structures. This has been proposed by several authors associated with the ideas of, for example, micro black holes in the neuronal tissue [32], quantum computations within the microtubuli skeleton [16] interpreted as a non-classic wave guiding system, as well as of the genome apparatus working as a biophotonic quantum holographic non-local processing system [12, 30].

Complementary to the rethinking of brain processes at the sub-cellular nano-scale, we take the risk of having a look at some preliminary evidence about rather long-range non-locality effects. These can be found, if the reported evidence is valid, even on a light-year-wide cosmological scale. The cosmological scale is argued to be of relevance as an analogue to the regulatory problems of cortical synchronization which have been discussed above. Beyond that it might be considered relevant with respect to the presumed non-local aspects of brain processing ("cosmic consciousness"), even in the view of practical astro-observational techniques. Take a look at the stars and consider, e.g., an astrophysical experiment on the observer-dependent alternating registration of wave vs. particle aspects of transmitted radiation. Suppose further, the radiation source is hidden light years away behind a gravitational lens (a so-called Einstein-cross). Is the expected outcome of this alternating wave vs. particle observation just a cosmological variant of the EPR paradox? Are we able by alternating the tool of our observation, to influence whether the observed photons did or did not interfere with one another in the antediluvian age then they have had passed the gravitational lens? Is this an observation-induced absorber effect, i.e. a macroscopically distant quantum transaction to an event, the origin of which is dated "back in time" some millions of light years ago?

In light of these questions, an intentionally speculative look "outside" the nervous system – namely, into outer space – is appended to the context of the neuro-cognitive issues of the present paper as a "side step" in order to provide us with the observation of a rather "macroscopic" absorber-type quantum event, which is possibly hidden behind a rather striking result of Soviet astronomy: the so-called Kosyrev effect.

The Andromeda nebula is the centre of our neighbouring galaxy, which is located at a distance of about 2.5 million light years away. Its spiral arms cannot be observed without a radio telescope. However, in projective size, they form the apparently largest stellar object in the firmament. Altogether, it appears to be about six lunar diameters wide and cannot be mistaken for any other stellar object. At the end of the 1970s, the Soviet astronomers Nicolai Kosyrev and Victor Nasonov performed a series of observations, mainly of the Andromeda galaxy, using the facilities of a great reflector telescope [26]. However, instead of the usual ocular lens system, they inserted into the focus of the reflector a newly developed special CCD-type sensor. This detector consisted of a matrix of ultra sensitive piezo-electric crystals. Convinced that their device was highly sensitive to ultra-weak gravitational fluctuations[13], Kosyrev and Nasonov used it to scan a spatial profile of the gravitational signals of stellar objects, notably those of the Andromeda galaxy.

To their astonishment, the two astronomers reported registering the spiral profile of the galaxy not only at Andromeda's observed proper location, i.e., the place of the source of electromagnetic radiation, which in fact was sent out 2.5 million years ago. Additionally, they reported observing the same profile also at two distinct subsequent locations. One of them was the position which the Andromeda galaxy, according to calculations of its displacement's direction and velocity parameters, should have reached nowadays, "here and now", so to speak, at it's apparently instantaneously transmitted actual position. This was a quite unexpected observation, since it clearly seemed to be in conflict with Einstein's relativistic cosmology. According to Einstein, the velocity of light sets an upper limit to any kind of signal or matter transmission in space. However, even more astonishingly, Kosyrev and Nasonov reported to have registered one more of

[13] In Kosyrev's own theoretical thinking, the details of which are beyond the scope of this chapter, although, maybe, of interest in the context of the present book,gravitation is intimately linked with hypothetical physical properties of time, such as its "temporal density" aspect.

Andromeda's profiles at a third location, which the galaxy will have reached, based on today's predictions, in a far away future. This third piezo-detected profile was spatially located just the same 2.5 million light years ahead as the actually observable conventional radiation is temporally delayed. Thus, as compared to the ordinarily observable position, the future one appears to be in a "space-time mirrored" state, since it corresponded reciprocally – i.e., with an "opposite sign" – to the temporally delayed spatial position of the actually observable light signal. Apparently, the observed effect seemed not to depend on conventional electromagnetic radiation, since it persisted even after shielding the telescope with a metallic cover.

All in all, the Kosyrev effect is one of the strangest stellar phenomena which have been ever reported and is far from being accepted by the majority of astrophysicists. The reported evidence is nowadays far from established[14] and only a few attempts at replication have been made by other observers [24, 25]. Is this phenomenon only a marginal curiosity in the history of cosmological observation? Or does it provide, alternatively, a major hint at the way in which the dynamic revolving equilibrium states of our universe are synchronized in a similar way, as we have argued here and in some related papers [19, 20][15], for the dynamic equilibrium states of oscillation-based neuronal communication processes in the brain too? And does it provide, last but not least, an argument for an alternative hypothesis about the regulation of resonant tuning-based anticipatory visually-guided action control? Is the neuronal "time-loop" architecture in visual space representation, which is proposed as a hypothesis here, of the same origin as the astrophysical basis of the Kosyrev effect and the absorber-type quantum entanglement effects on the nanoscale?

Since the reported evidence of the Kosyrev effect is not sufficient for decisive conclusions at present, its significance as an argument in the context of the discussed topics has to be regarded as a speculation, to be verified or falsified by future investigations. These are continued, for example, on the lines of the work of Korotaev et al. [24, 25] who established anticipatory correlations between the dissipative components of helio- and geomagnetic cycles. As a hypothesis, however, the Kosyrev effect's possible role in a common basic anticipatory mechanism of phase-conjugate adaptive resonance might be discussed.

If these observations were valid, the reported evidence shows just the kind of "back-in-time" resonance, which may be predicted for the behavior of a phase-conjugate mir-

[14] The relevance of the Kosyrev effect in the context of visuo-motor action control and neuronal communication and synchronisation processes depends, among other factors, on the verification or falsification of the underlying astronomical findings. Accordingly, the conclusion drawn is at present a rather preliminary one, which might be better understood as a heuristics to be discussed, rather than providing the basis of a comprehensive theory.

[15] In these papers and context of the present discussion, we treat the consequences of Kosyrev's findings in a way in which they appear "tailored" to fit as complementarily as possible to the models of standard relativistic and/or quantum cosmology. Kosyrev's own theoretical ideas as an issue of discussion about the physical properties of time – e.g., as a source of "anti-entropic" radiation, which is in intimate relationship with gravitational forces of different temporal density coming out of stellar objects due to their angular momentum of rotation – are beyond the scope of this paper.

ror, as it has been applied in non-linear optics to the technique of four-beam mixing as well as it has been proposed in the context of quantum holography [28, 29, 30]. In this context, Marcer and Schempp argued visual consciousness to depend on such a mechanism of phase conjugate-adaptive resonance. Accordingly, the question for possible analogies and interconnections between the hypothetical cosmological phase-conjugate mirrors and the presumed ones in brain's mirror neurons' function [36] appears to be justified.

From the framework of a holochoric quantum-transactional absorber-type model of cortical synchronisation and space-time representation, phase-conjugate adaptive resonance effects can be predicted to occur at different (macroscopic, mesoscopic, microscopic) levels of the universe. If the Kosyrev-effect will be verified by forthcoming research as an authentic phenomenon on rather different scale, then its influence will be not restricted to the outer space, as we discussed earlier [19, 20], but it should be found everywhere around us and in ourselves. The visuo-cortical tuning into this universal and omnipresent anticipatory mechanism might be speculatively argued to provide a hyperincursive solution (in Dubois' [6, 8] terms), e.g., for tracking a circularly moving object as can be shown for the visuo-motor control of the above cited robot's arm [8] and, maybe, for the synchronization of the neuronal system's synfire loops for the temporal control of spatial representation[16].

Taken together, we discussed a wide range of reported findings in light of the proposed hypothesis of the existence of macroscopic, mesoscopic and microscopic "time loop" absorber effects, which are suggested to provide us with a heuristics for a preliminary idea about the relations between a possible resonant transactional control of cortical synchronization and the internal psychophysics of visual space-time representation. According to our "time-loop" hypothesis, they depend at least partially on spatio-temporal non-locality effects on a neurophysiological scale in analogy to the ones on a quantum mechanical scale as well as, possibly, even on a cosmological scale.

References

1. Abeles M., *Corticonics*. Cambridge, UK: Cambridge Univ. Press (1991)
2. Abeles M., H. Bergman, E. Margalit, E. Vaadia, Spatiotemporal firing patterns in the frontal cortex of behaving monkeys. *J. Neurophysiol.*, 70, 1629–38 (1993)
3. Aspect A. & P. Grangier, Experiments on Einstein-Podolsky-Rosen-type correlations with pairs of visible photons. In: Penrose, R. & Isham, C.J. (eds.) *Quantum concepts in space and time*. Oxford: Oxford University Press (1986)

[16] Note that the Kosyrev effect shows exactly the properties required for a phase conjugate mirror capable of transforming succession into simultaneity: Assuming the velocity of light c as a transmission speed, with a convergence on a temporal interpolation of dt = $\pm$ 0, the anticipatory spin off into the future (+ delta t), according to the soviet astrophysicists' calculations, appears to be advanced by exactly the same amount (2.5 million light years) ahead, as the ordinary electromagnetic signal (- delta t) is retarded. Applied to the nervous system, however, the anticipation/retardation parameters should be adjusted to about $\pm$500 msec and the propagation velocity to approximately the range of the speed of sound.

4. Cramer J.G., The transactional interpretation of quantum mechanics. In D.M. Dubois (ed.) Proceedings of the Fourth International Conference on Computing Anticipatory Systems, *AIP Conference Proceedings*, 573, 61-76 (2001)
5. Cramer J.G., The transactional interpretation of quantum physics. *Reviews of Modern Physics*, 58, 647-688 (1986)
6. Dubois D.M. & G. Nibart, Towards a Computational Derivation of a Dual Relativity with Forward-Backward Space-Time Shifts, *International Journal of Computing Anticipatory Systems*, 5, 25-37 (2000)
7. Dubois D.M., Anticipative effect in relativistic physical systems, exemplified by the perihelion of the Mercury planet. Vigier IV Symposium, September 15th to September 19th (2004)
8. Dubois D.M., Incursive Anticipatory Control of a Chaotic Robot Arm, Computing Anticipatory Systems: CASYS - First International Conference, edited by D. M. Dubois. Published by The American Institute of Physics, *AIP Conference Proceedings*, 437, 406-417 (1998)
9. Dubois D.M., Non-locality Property of Neural Systems Based on Incursive Discrete Parabolic Equation. *International Journal of Computing Anticipatory Systems*, 7, 233-244 (2000)
10. Einstein A., B. Podolsky, N. Rosen, Can Quantum-Mechanical Description of Physical Reality be Considered Complete? *Phys. Rev.*, 47, 777-780 (1935)
11. Feigenbaum M.J., Quantitative universality for a class of nonlinear Transformations. *J. Statstical. Phys.*, 19, 25 -52 (1978)
12. Gariaev P.P., B.I. Birshtein, A.I. Iarochenko, P.J. Marcer, G.G. Tertishny, K.A. Leonova & U. Kaempf, The DNA-wave Biocomputer. In: Dubois, D.M. (ed.) CASYS – *International Journal of Computing Anticipatory Systems*, Liege: CHAOS ASBL, Vol. 10, 290-310 (2001)
13. Gibson J.J. , The ecological approach to visual perception. N.Y.: Houghton Mifflin (1979)
14. Haggard P. & E. Magno, Localising awareness of action with transcranial magnetic stimulation. *Exp. Brain. Res.*, 127, 102–107 (1999)
15. Haggard P., S. Clark, & J. Kalogeras, Voluntary action and conscious awareness. *Nature Neuroscience*, 5, 382-285 (2002)
16. Hameroff S., Funda-mentality: Is the conscious mind subtly linked to a basic level of the universe? *Trends in Cognitive Sciences*, 2(4), 119-127 (1998)
17. Hess R.F., D.C. Burr & F.W. Campbell, A preliminary investigation of neural function and dysfunction in amblyopia: Cooperative activity of the amblyopic channels. *Vis Res*, 7, 757-782 (1980)
18. Hoffmann J., C. Stöcker & W. Kunde, Anticipatory Control of Actions. *International Journal of Sport and Exercise Psychology* (2004)
19. Kämpf U., The significance of "advanced" and "retarded" signals for a transactional interpretation of ideomotor action control and inter-hemispheric cortical synchronisation. In: Dubois, D.M. (ed.) CASYS – *International Journal of Computing Anticipatory Systems*, Liege: CHAOS ASBL, Vol. 19, 247-260 (2006)
20. Kämpf U., Possible quantum absorber effects in cortical synchronization. In: Vrobel S., Rösser, & T.Marks-Tarlow (eds.) Simultaneity – Temporal Structures and Observer Perspectives, 414-435 (2008)
21. Kämpf U, F. Muchamedjarow & T. Seiler, Unterstützende Amblyopiebehandlung durch Computerspiele mit Hintergrundstimulation: Eine placebokontrollierte Studie. *Klinische Monatsblätter für Augenheilkunde*, 218, 243 –250 (2001)

22. Kämpf U., W. Mascolus, F. Muchamedjarow, A. Shamshinova & T. Kaschenko, Coherence induction via phase conjugate adaptive resonance coupling: computer generated sinusoidal grating patterns as a background stimulus in amblyopia treatment. *Journal of Psychophysiology*, 20(2), 149 (2006)
23. König P., A.K. Engel, S. Löwel & W. Singer, Squint affects the synchronzation of oscillatory responses in cat visual cortex. *Eur. J. Neurosci.*, 5, 501-508 (1993)
24. Korotaev S.M., V.O. Serdyuk & M.O. Sorokin, Effect of macroscopic nonlocality on geomagnetic and solar-ionospheric processes. *Geomagn. Aeron.*, 40, 323-330 (2000)
25. Korotaev S.M., V.O. Serdyuk, V.I. Nalivayko, A.V. Novysh, S.P. Gaidash & Yu.V. Gorokhov, Experimental estimation of macroscopic nonlocality effect in solar and geomagnetic activity. *Phys. Wave Phenomena*, 11(1), 46-54 (2003)
26. Kosyrev N.A. & V.V. Nasonov, Properties of time found by astronomical observations. Academy of Sciences of the USSR, *Problems of cosmological research*, 9 (1980)
27. Libet B., E.W. Wright, B. Feinstein, & D.K. Pearl, Subjective referral of the timing for a conscious sensory experience. *Brain*, 102, 193-224 (1979)
28. Marcer P. & W. Schempp, (1998) The brain as a conscious system, *International Journal of General Systems*, 27, 1/3, 231-248.
29. Marcer P. & W. Schempp, Model of the Neuron working by Quantum Holography, *Informatica*, 21, 5 19-534 (1997)
30. Marcer P. & W. Schempp, The Model of the Prokaryote cell as an Anticipatory System Working by Quantum Holography, Proceedings of CASYS 97, *International Journal of Computing Anticipatory Systems*, 2, 307-315 (1997a)
31. Meschede D., (ed.) *Gehrtsen Physik*, 21nd edition, p. 892 (2002)
32. Pitkänen M., Biosystems as macroscopic quantum systems. In: Dubois, D.M. (ed.) CASYS – *International Journal of Computing Anticipatory Systems*, Liege: CHAOS ASBL, 10, 368-383 (2001)
33. Pribram K.H., *Brain and Perception: Holonomy and Structure in Figural Processing*, Lawrence Eribaum Associates, New Jersey (1991)
34. Pribram K.H. & J. C. Eccles, Rethinking Neural Networks: Quantum Fields and Biological Data. Lawrence Erlbaum Associates, New Jersey (1993)
35. Pulfrich C., *Stereoskopisches Sehen und Messen*. Jena, Fischer Verlag (1911)
36. Rizzolatti G., & L. Craighero, The mirror-neuron system. *Ann.l Rev. Neurosc.*, 27, 169-92 (2004)
37. Roelfsema P.R., P. König, A.K. Engel, R. Sireteanu & W. Singer, Reduced synchronization in the visual cortex of cats with strabismic amblyopia. *Eur. J. Neurosci.*, 6, 1645-1655 (1994)
38. Stöcker, C., & J. Hoffmann, The ideomotor principle and motor sequence acquisition: tone effects facilitate movement chunking. *Psychological Research*, 68, 126-137 (2004)
39. von der Malsburg C.& W. Schneider, A neural coctail-party processor. *Biol Cybernetics*, 54, 29-40 (1986)
40. Wheeler J.A. & R.P. Feynman, Interaction with the absorber as the mechanism of radiation. *Rev. Mod. Phys.*, 17, 157-181 (1945)
41. Wolf F.A., The timing of conscious experience: A causality-violating two-valued transactional interpretation of subjective antedating and spatial-temporal projection. (1989)
42. Zeilinger A., Einsteins Spuk. - München: Goldmann (2007)
43. Yasue, K. & M. Jibu, Quantum Brain Dynamics and Consciousness: An Introduction. John Benjamins Publishing Company (1995)