Article

Comparison of TGD Inspired Theory of Consciousness with Some Other Theories of Consciousness (Part I)

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Abstract

This article has been inspired by two books. The first book "On intelligence" is by Jeff Hawkins. The second book "Consciousness: the science of subjectivity" is by Antti Revonsuo. Jeff Hawkins has developed a highly interesting and inspiring vision about neo-cortex, one of the few serious attempts to build a unified view about what brain does and how it does it. Since key ideas of Hawkins have quantum analogs in TGD framework, there is high motivation for developing a quantum variant of this vision. The vision of Hawkins is very general in the sense that all parts of neo-cortex would run the same fundamental algorithm, which is essentially checking whether the sensory input can be interpreted in terms of standard mental images stored as memories. This process occurs at several abstraction levels and involve massive feedback. If it succeeds at all these levels the sensory input is fully understood.

TGD suggests a generalization of this process. Quantum jump defining moment of consciousness would be the fundamental algorithm realized in all scales defining an abstraction hierarchy. Negentropy Maximization Principle (NMP) would be the variational principle driving this process and in optimal case lead to an experience of understanding at all levels of the scale hierarchy realized in terms of generation of negentropic entanglement. The analogy of NMP with second law suggests strongly thermodynamical analogy and p-adic thermodynamics used in particle mass calculations might be also seen as effective thermodynamics assignable to NMP.

In Part I of this two-part article, I will first discuss the ideas of Hawkins and then summarize some relevant aspects of quantum TGD and TGD inspired theory of consciousness briefly in the hope that this could make representation comprehensible for the reader having no background in TGD (I hope I have achieved this). The representation involves some new elements: reduction of the old idea about motor action as time reversal of sensory perception to the anatomy of quantum jump in zero energy ontology (ZEO); interaction free measurement for photons and photons as a non-destructive reading mechanism of memories and future plans (time reversed memories) represented 4-dimensionally as negentropically entangled states approximately invariant under quantum jumps (this resolves a basic objection against identifying quantum jump as moment of consciousness) leading to the identification of analogs of imagination and internal speech as fundamental elements of cognition; and a more detailed quantum model for association and abstraction processes.

1 Introduction

This work has been inspired by two books. The first book "On intelligence" is by Jeff Hawkins. The second book is by Antti Revonsuo.

1.1 On intelligence

Jeff Hawkins [22] has developed a highly interesting and inspiring vision about neo-cortex, one of the few serious attempts to build a unified view about what brain does and how it does it. Since the key ideas of Hawkins have quantum analogs in TGD framework, there is high motivation for developing a quantum variant of this vision. The vision of Hawkins is very general in the sense that all parts of neo-cortex would run the same fundamental algorithm, which is essentially checking whether the sensory input can

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be interpreted in terms of standard mental images stored as memories. This process occurs at several abstraction levels and involve massive feedback. If it succeeds at all these levels the sensory input is fully understood.

TGD suggests a generalization of this process.

1. Quantum jump defining moment of consciousness would be the fundamental algorithm realized in all scales defining an abstraction hierarchy. Negentropy Maximization Principle (NMP, [44]) would be the variational principle driving this process and in optimal case lead to an experience of understanding at all levels of the scale hierarchy realized in terms of negentropic entanglement. The analogy of NMP with second law suggests strongly thermodynamical analogy and p-adic thermodynamics used in particle mass calculations might be also seen as effective thermodynamics assignable to NMP.

   One can imagine the analogs of temperature and various other parameters as characteristics of "thermal equilibrium" under some constraints with respect to NMP instead of second law. These would be macroscopic parameters characterising the state of consciousness, and one can easily imagine psychological counterparts of thermodynamical notions. Psychological pressure would not be a mere metaphor!

2. The anatomy of quantum jump implies alternating arrow of geometric time at the level of imbedding space [40]. This looks strange at first glance but allows to interpret the growth of syntropy introduced by Fantappie [21] as a growth of entropy in reversed direction of imbedding space time. As a matter fact, one has actually wave function in the moduli space of CDs and in state function reductions localisation of either boundary takes place and gradually leads to the increase of the imbedding space geometric time and implies the alternating arrow for this time. The state function reduction at positive energy boundary of CD has interpretation as a process leading to sensory representation accompanied by p-adic cognitive representation.

   The time reversal of this process has interpretation as motor action in accordance with Libet's classical findings [25]. This symmetry holds true in various length scales for CDs. In the same manner p-adic space-time sheets define cognitive representations and their time reversals as intentions. It seems that self model could be assigned to negentropically entangled collections of sub-CDs and negentropic entanglement would stabilize them.

   A rather obvious inaccuracy in the earlier interpretation of negentropic entanglement has been corrected. The statement that negentropic entanglement corresponds to the experience of understanding (or any conscious experience) is in conflict with the basic postulate of TGD inspired theory of consciousness. The correct wording is that the *generation of negentropic entanglement* gives rise the experience of understanding and possibly some other emotionally positively colored experiences. Generation and loss of negentropic entanglement would be the key to the understanding of emotions.

3. One could understand the fundamental abstraction process as generation of negentropic entanglement serving as a correlate for the experience of understanding. This process creates new mental images (sub-CDs) and to longer sequences of mental images (accumulation of experience by formation of longer quantum association sequences). Abstraction process involves also reduction of measurement resolution characterizing cognitive representations defined in terms of of discrete chart maps mapping discrete set of rational points of real preferred extremals to their p-adic counterparts allowing completion to p-adic preferred extremal. The reversal of this abstraction process gives rise to improved resolution and adds details to the representation. The basic cognitive process has as its building bricks this abstraction process and its reversal.

4. The notion of self, which should be distinguished from a model for self, has been a continual source of worries in TGD inspired theory of consciousness [45, 40]. Hierarchy of quantum jumps suggests that self can be identified as quantum jump and that the conscious information corresponds to the

change of negentropy in quantum jump. The notion of negentropic entanglement however raises the temptation to identify self model (distinguished from self) as a property of quantum state, which consciousness certainly cannot be in TGD framework. Self representations would naturally correspond to negentropically entangled tensor products approximately invariant under quantum jump sequence. One can of course ask whether the notion of self reduced to quantum jump is needed at all.

1.2 Consciousness: the science of subjectivity

Antti Revonsuo has written a wonderful book about consciousness with title "Consciousness: the science of subjectivity" [33].

1. Revonsuo discusses philosophical, historical, and conceptual foundations of consciousness science.
2. Various disorders of consciousness provide test benches for the theories of consciousness and Revonsuo discusses neuropsychological deficits of visual consciousness, neuropsychological dissociations of visual consciousness from behavior, and neuropsychological disorders of self-awareness.
3. If one believes (and even if one does not!) that the state of brain dictates completely the contents of consciousness, it is natural to search for the neural correlates of consciousness since brain state could indeed correlate in one-one manner with certain (say cognitive and representational) aspects of consciousness. Revonsuo analysizes methods and design of a typical NCC experiment, discusses neural basis of consciousness as a state and studies on the neural basis of visual consciousness.
4. A lot of theories of consciousness have been proposed and Revonsuo discusses both philosophical and empirical theories of consciousness critically pointing out the basic difficulties of various approaches. Revonsuo does not discuss quantum theories of consciousness.
5. The last chapters are devoted to altered states of consciousness (ASC) with a discussion of dreaming and sleep, hypnosis, and higher states of consciousness. The understanding of ASCs obviously define also tests for any theory of conscioues ness.

In the following I will first discuss the ideas of Hawkins and then summarize some relevant aspects of quantum TGD and TGD inspired theory of consciousness briefly in the hope that this could make representation comprehensible for the reader having no background in TGD (I hope I have achieved this). The representation involves some new elements: reduction of the old idea about motor action as time reversal of sensory perception to the anatomy of quantum jump in zero energy ontology (ZEO); interaction free measurement for photons and photons as a non-destructive reading mechanisms of memories and future plans represented 4-dimensionally as negentropically entangled states approximately invariant under quantum jumps (this resolves a basic objection against identifying quantum jump as moment of consciousness) leading to the identification of analogs of imagination and internal speech as fundamental elemens of cognition; and a more detailed quantum model for association and abstraction processes.

After that I compare various theories and philosophies of consciousness with TGD approach following the beautifully organized representation of Revonsuo. Also anomalies of consciousness are briefly discussed. My hope is that this comparison would make explicit that TGD based ontology of consciousness indeed circumvents the difficulties against monistic and dualistic approaches and also survives the basic objections that I have been able to invent hitherto.

2 The vision of Hawkins

Jeff Hawkins has written together with Sanda Blaskeslee a very inspiring book about conscious intelligence with title "On intelligence" [22]. What makes the book so inspiring to me is that it tries to build a holistic

strongly structured vision about the functioning of neo-cortex easily generalizable outside to its original context - in my case TGD inspired theory of consciousness based on rather different basic philosophy.

2.1 The philosophical attitudes of Hawkins

Before continuing I want to locate the vision of Hawkins to the map of theories.

1. Hawkins accepts functionalism stating that intelligence and maybe even consciousness are properties of organization and have nothing to with the stuff that the system is made of. This was the justification for AI people to regard brain as a primitive realization of something which can be realized much more elegantly using digital computers. Hawkins assumes that the functional structure at neuronal level determines the contents of consciousness and could therefore be seen as a materialist allowing emergence.

2. Hawkins does not discuss the possibility of quantum consciousness but his vision might allow also quantum formulation and in the followin I will represent such a generalization.

Although Hawkins accepts functionalism, he represents excellent arguments against AI and connectionism, and computationalism in general stating brain is a computer.

1. The argument against computationalism according to AI goes as follows. The time scale of neural processing is 1 ms: this is million times longer than 1 ns: the time scale of processing in modern computers. Despite its slowness brain is able to recognize a face represented in various manners in a fraction of second. For recent day computers this is a mission impossible. Computationalistic brain should make this feat by using basic programs consisting of roughly 100 steps. Parallelism does not help as often claimed. As an analogy Hawkins mentions a task of carrying some amount of material to another side of a desert. Irrespective of how many camels are hired the task takes some minimum time determined by the maximal load carried by single camel over the desert and the distance to the other side.

2. Gradually the failure of AI was accepted, and the follower of AI was connectionism. Connectionism takes the notions of association and and standardized mental image (memory) seriously and is therefore nearer to what brain is thought to do. The possibility to complete full patterns from pieces by a non-linear algorithm seemed to give excellent hopes about progress. The dream was not fulfilled.

   Pattern recognition by computers differs from what brain does in one but overall important aspect: the ability to form invariant representations is lacking. When sensory input representing the same object but from a different perspective is used, computer based pattern recognition fails. A mere shift of the spatial pattern is enough to make recognition impossible. Brain can however easily recognize the pattern seen from different perspectives, the pattern can be even deformed in wide limits. Even patterns represented using pictures, sound, and touch are recognized as same object.

3. Hawkins criticizes also the behavioristic approach assuming that contents of consciousness can be deduced by looking only the behavior. Turing's test relies formulates mathematically this behavioristic dogma. It is probably relatively easy to cheat human subject to to believe that machine is conscious by using Turing test. This however does not demonstrate anything. The basic problem is that the more abstract the level of cognitive process is is, the less it shows itself in the behavior. The situation in which a person is fully conscious but completely paralyzed so that he is not able to express any thoughts via motor actions illustrates a failure of the naive behavioristic approach.

In TGD framework it is easy to agree with Hawkins. Turing machine is a model of computer in which one implicitely takes granted the identification of experienced and geometric time, which differ in

many crucial aspects as even child knows. The starting point of TGD inspired consciousness theory as a generalization of quantum measurement theory is the paradox of quantum measurement theory caused by this identification. The discretization of geometric time is also an extremely heavy idealization and I find it surprising that it has raised so little criticism. In TGD framework the behavioristic approach and the materialistic identification of contents of consciousness with the state of brain must be given up since consciousness cannot be identified as a property of quantum state since it is assigned with the quantum jump between two quantum states.

2.2 Basic observations of Hawkins

Several observations and ideas of Hawking relate to the notion of time.

1. Instead of computation Hawkins sees memory, recognition of familiar objects in the sensory input, and their naming as fundamental processes in neo-cortex. Nerve pulse patterns are identified as names for objects. A cognitive representation is what sensory input gives rise to, and means a decomposiion of the sensory input to objects with names, analogous to a linguistic essentially linear description of the percept.

2. It is not only spatial patterns but temporal sequences of them which matter. At higher level of abstraction one has a sequence of patterns instead of single patttern and the representation is less detailed. Sensory inputs are this kind of temporal sequences as are also plans for motor actions resulting as a reaction to the sensory input. Here "sensory input" and "motor action" could be understood very generally: even the nerve pulse patterns arriving neuron and leaving it can be seen as "sensory inputs" and "motor actions".

3. Hawkins emphasizes the similarities between sensory input and motor action and one can indeed claim that they one and same thing except that they seem to proceed in opposite directions of time: bottom-up and top-down. Libet's well-known findings that the neuronal activity begins a fraction of second earlier than conscious decision for motor action and later experiments suggesting even longer time scales might be understood in this framework. If one takes this idea seriously, one must however modify the existing beliefs about the relation between subjective time and the geometric time of physicists identified as fourth space-time dimension. Subjective time has constant arrow but this arrow might correspond to different arrow of geometric time for sensory input and motor action. This brings in mind TGD based view about time [40] and suggests more detailed interpretation of the arrow of time as it emerges in TGD framework.

4. Hawkins sees as the basic function of neo-cortex construction of predictions based on the "understanding" of the sensory input and coded by cognitive representation. Prediction might seen also as an intention how to behave realized as a motor program defining the reaction to the sensory percept.

This general vision is very elegant. The challenge is to understand what various concepts such as memory, recognition of familiar objects, naming, and understanding do mean physically. This is far from trivial in the materialistic framework of standard physics, and one can hope that quantum TGD generalizing considerably also the quantum theory itself, could help in this challenge. In particular, p-adic physics and p-adic space-time sheets could serve as correlates for the "mind stuff", and one could see the formation of cognitive representations as a formation of p-adic charts about real physical systems. Sensory perception would be real, cognitive representation p-adic. In p-adic topology the decomposition to objects and discretization in a given resolution are natural so that it would be ideal to the description of cognition. Negentropic entanglement would be an excellent candidate for a correlate of understanding.

2.3 Invariant representations

Hawkins emphasizes the ability of brain to recognize objects represented in very different manners as a basic distinction between brain and computers.

1. Invariant representations distinguish brain from computer. Invariant representations are abstractions. Abstraction summarizes something common to a large class of objects and gives a name for this class of objects. For instance, "living room" as a name of this kind of class is extremely economical manner to represent information in terms of a concept instead of remembering every detail of every living room one has spent some time.

   So called idiot savants can have this kind of sensory memory, and are able to perform incredible memory feats, but this kind of memory is not useful unless one is an artist. An interesting question is whether animals could still possess sensory memories: this would be certainly useful gift in jungle. Another interesting question is whether cerebellum could have sensory memories not conscious-to-us and whether these could become conscious-to-us in some altered states of consciousness.

   Abstraction appears also in the music experience. Ordinary listener is not able to identify the key of the music piece but this does not affect the music experience much since only the ratios of the pitches of notes of the melody matter. People with "absolute ear" can however recognize the absolute key of the music piece and regard pieces in different keys as different ones. In the standard scale used for the piano, the ratios are not quite the same in different keys but this causes troubles for people with "absolute ear".

2. Hawkins sees the formation of associations as an important aspect of invariant representations allowing to recognize the same object using different sensory channels. Second aspect of abstraction is the elimination of un-necessary details: kind of reduction of sensory/cognitive resolution. Some kind of averaging could be involved.

3. Hawkins concludes that neo-cortex is specialized to the construction invariant representations and that there is a hierarchy of increasingly abstract invariant representations assignable to sensory percepts and motor actions. All these representations are needed to achieve ideal perception but only the highest level abstractions are usually conscious-to-us. Note that in standard neuro-science framework "conscious-to-us" is synonymous to "conscious" but in quantum TGD approach entire hierarchy of conscious entities can be imaged so that "sub-conscious" translates to "conscious-but-not-to-us". This distinction allows to understand many brain disorders [33] such as being not conscious of being able to see (and other agnosias) or believing that one sees although one is cortically blind or being cortically blind but believing that one is able to see. Note that if primary visual experience is at the level of retina, cortical blindness need not mean subjectively experienced blindness.

One of the hard challenges is to identify the mechanism giving rise to invariant representations. Neural firing patterns are though to transform synaptic connections and in this manner give rise to associations. Hebb's rules define an attempt to model what happens in the process. One can also understand what abstraction could mean.

In TGD framework one can consider the generation of negentropic entanglement as a mechanism of association: negentropically entangled state defines a rule represented as a superposition of state pairs (or n-plets) such that each pair (n-tuple) represents one particular instance of the rule. Abstraction means also getting rid of insignificant details. Here one can consider some kind of averaging (kind of ensemble of mental images at quantum level) or quantum superposition of states representing same object but with different details below cognitive resolution. I have also proposed that quantum states in general are superpositions of preferred extremals which have equivalent statistical geometries meaning that various geometric correlation functions are identical for them.

2.4 Observations about the structure and functioning of the neocortex

The proposal of Hawkins relies heavily on the observations about the structure and functioning of the neo-cortex.

1. Neocortex (see `http://en.wikipedia.org/wiki/Neocortex`) [6] is a very thin grey layer at the top of cortex having thickness of about 3 mm and consisting of 6 layers, which according to Hawkins are functionally hierarchically ordered with layer 1 at the top representing the highest level of abstraction. Layer 4 is the layer to which inputs from distant regions of neocortex arrive and are transferred to the levels above and below it. There is a strong feedback and feedforwad between the layers.

2. Neo-cortex decomposes to various sensory and motor areas. In associative areas the inputs from sensory areas are combined and sent to motor areas. Sensory and motor areas in turn have hierarchical structure: for instance, visual areas consting of sub-areas V1, ..., V5. Sensory input arrives to V1 and V1 is believed to identify from the sensory input various simple features. Higher areas identify more abstract features and sequences of them.

3. Hawkins emphasizes the fact that sensory perception and motor action are not simple bottom-up and top-down processes. Feedback is present and can be even 10 times more massive than input. The proposed interpretation is that input to from a given layer of neo-cortex to a higher layer (from say from 3 to 2) means formation of a more abstract and less detailed representation and vice versa. This representation consists also longer sequences of basic patterns and allows easier recognition. A good example is a situation in which music piece on CD changes: at the lower level this means unexpected input. At higher level music pieces on CD form a sequences and recognition as new piece is possible. The higher level can send this prediction back to the lower level.

4. Neo-cortex and also cortex look the same everywhere. This suggests that all basic units of the cortex perform essentially same basic function or algorithm. This idea is elegant and far reaching and would apply to the formation of cognitive representations which would be just the identification and naming of objects of sensory percept.

5. This picture applies also to motor action. If one accepts that motor action is time reversal of sensory perception and leads from abstract to less abstract and more detailed, one can ask whether the feedback to less abstract levels could be interpreted as motor action at neuronal level. A fractal structure in which sensory perception and motor action takes place in various time and length scales would suggeset this kind of view.

There are many notions which require more detailed definition. The proposed detailed model for feedback need not of course be correct as such. What matters is the existence of hierarchical structure and communications between the levels of the hierarchy. In TGD framework this hierarchy would naturally correspond to self hierarchy and hierachy of quantum jumps within quantum jups. In zero energy ontology it has as correlates the hierarchy of space-time sheets at space-time level and that of causal diamondswithin causal diamonds at the level of imbedding space. Also the p-adic length scale hierarchy and hierarchy of effective Planck constants assigned with dark matter in TGD Universe relate to these hierarchies.

2.5 Universal algorithm

These observations inspire Hawkins to propose for the universal algorithm run by the units of neo-cortex.

1. The homogenuity of neocortex motivates the proposal that all units of the neo-cortex forming a hierarchy are performing the same universal algorithm, which is recognition of the virtual sensory input represented as nerve pulse pattern with some standard input stored in memory. If the recognition attempt fails, the input is sent to a higher more abstract level with less details and this level

makes a similar trial. If the recognition attempt is successful, the input is sent to a lower level (this corresponds to a feedback) and same attempt is made.

2. This process continues until recognition is made at all levels or if this is not possible, the pattern is sent to hippocampus as a genuinely new pattern to be stored to memory. Some maximum time of unsuccessful processing is a natural criterion for the novelty. Percept is thus stored as a memory in hippocampal level only when it represents something new. The percepts which do not enter hippocampus are stored at lower cortical layers but do not represent memories conscious-to-us. This could explain why people at older age are not able to remember details of say movie unless they represent something genuinely new.

To me this picture looks rather attractive and inspires the question whether a generalization to quantum context - say in TGD framework - is possible.

2.6 The basic objection against the vision of Hawkins

The basic objection against Hawkins's vision applies to neuroscience view in general.

1. As Hawkins notices, the homogenuity of the neocortex and brain in general is in conflict with the idea that cortex is the seat of the sensory qualia. It is difficult to understand why the auditory and visual pathways could give rise to so different sensory qualia if only the organization of the sensory pathways matters.

2. A possibility not discussed by Hawkins nor by neuroscientists is that sensory qualia could be formed at the level of sensory organs.

   (a) TGD approach would suggest that qualia are realized at the level of sensory organs [42] and quale mental images (subselves) entangle with the cortical mental images representing names of objects of the perceptive field represented at cortex and thus give rise to a coloring of the cognitive map. This would explain why the qualia associated with different sensory pathways are so different. Pure thought would correspond to cognition without this coloring and dreams would involve a feedback to the level of sensory organs (REM sleep) transforming thinking to vivid imagination. Note that also the feedback to the level of sensory organs and comparison of this virtual sensory input with the actual one is quite possible in TGD framework since there is no reason to restrict the feedback hierarchy to the 6 neo-cortical layers. Dark photons with large value of $\hbar_{eff}$ could make possible this feedback by generating sensory input by transforming to ordinary visible photons interpreted as biophotons.

   (b) The basic objection against this view is the phenomenon of phanton limb (see `http://en.wikipedia.org/wiki/Phantom_limb`) [17], which in standard physics framework forces to locate the pain to the map of sensory field at cortex. One manner to solve the problem would be that that the pain is somewhere else than in phantom limb but mislocated in the construction of cognitive representation: this would be just wrong kind of association. The alternative approach would give up the standard view about the relationship between subjective and geometric time: the phantom pain is sensory memory of an actual pain in the limb which exists in the geometric past at a distance of maybe decades. The third option is that qualia are formed at the level of neurons and under some conditions correspond to those experienced by us. This requires new physics at the level of neurons and clear identification what the physical correlates of qualia are in this new physics.

3 Quantum TGD very briefly

Before discussing the TGD inspired identification of the universal algorithm as quantum jump in turn identified as a moment of consciousness, it is good to briefly summarize some basic aspects of quantum TGD.

3.1 Many-sheeted space-time, imbedding space, WCW

The basic geometric notions of TGD are many-sheeted space-time, imbedding space $M^4 \times CP_2$ and "world of classical worlds" (WCW) identified as the infinite-dimensional space of space-time surfaces, which can be seen as analogs of Bohr orbits representing kind of archetypical field patterns in their geometry. The choice of the imbedding space is fixed by particle physics considerations uniquely and can be justified also by very general mathematical arguments. TGD leads to geometrization of the classical fields appearing in standard model and particle quantum numbers can be understood in terms of the symmetries of the imbedding space.

I will not go the detailed definitions of these notions here but refer to the articles and books at my homepage. What is essential is that TGD space-time is topologically non-trivial in all length scales and objects of various size scales that we see around us can be interpreted in terms of space-time sheets defining their own sub-Universes.

Second essential generalization and deviation from Maxwell's electrodynamics (and other field theories) is topological field quantization. For instance, magnetic field decomposes to flux quanta (flux tubes and sheets) represented as space-time time quanta. This quantization is in key role in the model of living matter and the dynamics of the "magnetic bodies" is crucial for understanding various aspects of bio-catalysis and also EEG. Magnetic body (hierarchy of them) brings to the usual picture of living system as biological body interacting with environment a completely new level.

3.2 Zero energy ontology (ZEO)

The failure of the strict determinism for the preferred extremals of Kähler action means that data in time=constant snapshot do not determine the future and past behavior. Several time=constant snapshots must be assumed and this led originally to the notion of association sequence. Later the notion of zero energyh ontology (ZEO) emerged and was forced by number theoretical universality: vanishing total quantum numbers indeed make sense in number theoretically universal manner. ZEO allows also to avoid the paradox suggested by the fact that Poincare invariance is exact in laboratory scales but not in cosmological scales: the solution relies on the observation that the notions of energy and momentum for the positive energy parts of zero energy states are scaled dependent in ZEO.

1. Zero energy states are superpositions over pairs of positive energy states and negative energy states and correspond to initial and final states of a physical event in positive energy ontology. Positive and negative energy states are localized at the opposite light-like boundaries of a causal diamond (CD) defined as intersection of future and past directed light-cones (CP_2 appears as a Cartesian factor but will not be mentioned separetely in the sequel). Space-time surfaces in the quantum superposition are identified as preferred extremals of Kähler action and are restricted inside CD for the simplest option.

2. CDs form a fractal hierarchy with size scales coming as integer multiples of fundamental size scale. Translates and Lorentz boosts of CDs are also possible. It is not quite clear whether one should allow CDs to intersect or should one require strict nesting. System has in general wave function in the moduli space of CDs and in quantum jump a localization to CDs for which either upper or lower boundary is fixed takes place.

3. CDs are the geometric correlates of selves at the level of imbedding space $M^4 \times CP_2$. The 4-D space-time surfaces define the correlate of selves at space-time level. One can consider two time coordinates: imbedding space time coordinate and that of 4-D surface.

3.3 p-Adic physics and cognition and intentionality

I ended up with p-adic physics from accidental observations related to the mass scale ratios of elementary particle spectrum. The construction of p-adic thermodynamics predicting particle masses with excellent accuracy inspired questions which led to the proposal that p-adic physics describes cognition present already at elementary particle level.

1. Imbedding space has also p-adic sectors corresponds to various p-adic number fields. These sectors are glued together along rational points common to real and p-adic number fields and also via common algebraic points in the case of algebraic extensions of p-adic number fields. The common rational points of real and p-adic space-time surface (or at least partonic 2-surface) define cognitive representation so that cognitive representations are always discrete.

   At the level of WCW the points of real and p-adic sectors identifiable with each other correspond to surfaces, whose algebraic representations make sense both in real and p-adic sense. The general vision is that life resides in this this intersection of real and p-adic worlds. For instance, this motivates the notion of number theoretic entanglement entropy which can be negative and is interpreted as a measure of information assignable to entanglement.

2. Mappings of real space-time surfaces to p-adic ones are fundamental and define cognitive representations [50]. The mappings of p-adic space-time surfaces to real ones are interpreted as realizations of intentional actions. When motor action is identified as the time reversal for the formation of sensory representation, intentional action becomes time reversal for the formation of cognitive representation so that a very powerful and elegant symmetry emerges.

3. Finite measurement resolution is fundamental notion and actually forced by the notion of p-adic manifold. An attractive additional constraint is that the space-time surfaces in the superposition are perceptively equivalent in given measurement resolution characterized by p-adic prime assignable to the space-time surface and corresponding pinary cutoffs and also by the algebraic extension of p-adic numbers characterizing the angle resolution.

3.4 Length scale hierarchies and cognitive hierarchies

TGD involves several hierarchies.

1. One hierarchy is formed by the p-adic length scales assignable to p-adic primes coming as primes near powers of two.

2. Second hierarchy corresponds to size scales of CDs coming as integer multiples of CP_2 scale with secondary p-adic length scales being favored. One can assign to these length scales length scale resolution as p-adic length scale multiplied by a half-integer power of p, and angle resolution defined in terms of algebraic extenion of p-adic numbers used. These length scales are now an essential part of the definition of the notion of p-adic manifold necessary for the construction of number theoretically universal calculus.

   The resolution scales have also natural counterpart at quantum level and can be realized in terms of inclusions of hyper-finite factors of type II_1 [47]. The included factor defines the degrees of freedom which cannot be seen in given resolution and the factor space obtained by dividing with the included factor defines quantum space with finite but fractional dimension.

3. The increase of resolution means getting rid of un-necessary details in the case of cognitive representations it would be un-necessary information allowing a formation of abstraction. The reduction of the resolution means addition of details and formation of lower level representation. In the realization of motor action this process indeed occurs. This process can be however as a formation of sensory representation in non-standard time direction. The findings of Libet conform with this view about motor action.

4. The hierarchy of (effective) Planck constants $\hbar_{eff}$ was conjectured for about 8 years ago [41].

   (a) The values of $\hbar_{eff}$ would come as multiples of ordinary Planck constant: $\hbar_{eff} = n\hbar$. TGD provides two possible explanations for how $\hbar_{eff}$ emerges. The first one relies on multifurcations of space-time surface implied by the failure of strict determinism of the basic variational principle: $\hbar_{eff} = n\hbar$ would correspond to n-furcation taking place at the boundary of causal diamond. Second explanation relies on the general structure of p-adic Lie-algebras predicting effective values of Planck constant coming in the proposed manner [50]. These explanations should and could be equivalent.

   (b) For large values of $\hbar_{eff}$ the quantal scales (say Compton length of electron) become large and this makes possible macroscopic quantum coherence. The hypothesis is that dark matter corresponds to ordinary matter but with non-trivial value of $\hbar_{eff}$. What would make it dark is that particles with different values of $\hbar_{eff}$ cannot occur in the same vertex of a generalized Feynman diagram although particles with different value of $\hbar_{eff}$ can transform to each other.

   (c) The proposal is that magnetic flux quanta (sheets and tubes) can be carriers of dark matter. The phase transitions reducing $\hbar_{eff}$ reduce the length of the magnetic flux tube and if biomolecules form an "Indra's net" connected by flux tubes, these phase transitions could force two biomolecules connected by flux tube near to each other so that they could find each other in the dense molecular soup. The reconnection of closed magnetic flux tubes associated with two molecules in turn generates two flux tube pairs connecting the molecules and allowing the two systems to become effectively single quantum system in dark degrees of freedom with large value of Planck constant. Persinger's recent experiments give support for this vision [49].

4 Quantum jump as the counterpart of fundamental algorithm in TGD?

In order to formulate the interpretation of quantum jump sequence as a fundamental algoritm of sensory perception, cognition, intentional action, and motor action, one must describe the basic ideas of TGD inspired theory of consciousness.

4.1 Basic ideas of TGD inspired theory of consciousness

Before discussing the TGD based analog for universal algorithm, it is good to begin by giving a list about basic ideas of TGD inspired theory of consciousness.

1. Identification of quantum jump between zero energy states as moment of consciousness. It is essential that the quantum states counterparts for entire time evolutions of Schrödinger equation rather than time=constant snapshots of single evolution. In this manner one can avoid the conflict between non-determinism of state function reduction and determinism of Schrödinger equation. This however implies that subjective time whose chronon quantum jump is, cannot be identified with the geometric time of physicists. The correlation between these two times is of course possible in the sense that quantum jump sequences corresponds to an increase of geometric time defined in some natural manner. This correlation must be strong since these two times are usually identified.

2. Originally I distinguished between the notions of quantum jump and self proposed to emerge from some kind of gluing together of quantum jumps to larger structures in a manner analogous to the fusion of particles to bound states. The fractality of quantum jump in the sense that there are quantum jumps within quantum jumps led to the identification of quantum jump and self. This identification has however remained somewhat fuzzy.

   The recent considerations however suggests that negentropic entanglement in time direction is necessary for mental images (having sub-CDs as correlates) to mental images representing spatial patterns and for these patterns in turn to bind to a sequence of mental images representing abstract memories as sequences of mental images. Negentropically entangled sequence would be a quantal counterpart for the original association sequence introduced as purely geometric concept.

   Should these sequences define selves so that self would be something characterizing quantum state rather than something identified as quantum jump? Or could these sequences define a model of self to be distinguished from self identified as quantum jump? By definition negentropic entanglement tends to be preserved in quantum jumps so that it represents information as approximate invariant: this conforms with the idea of invariant representation and quite generally with the idea that invariants represent the useful information. This information would not be however conscious if the original view about conscious information as change of information is accepted. Could one imagine a reading mechanism in which this information is read without changing the negentropically entangled state at all?. This reading process would be analogous to deducing the state of a two-state system in interaction free measurement to be discussed below.

3. Selves/quantum jumps form a hierarchy, which predicts higher level selves identifiable in terms of collective and transpersonal consciousness. Also lower levels of hierarchy should be present so that even neuron and even electron should possess primitive self-awareness.

4. The subselves of self are identified as mental images of self and sub-subselves are assumed to be experienced as ensemble averages- at least when the entanglement is not negentropic. This averaging could be seen as an alternative mechanism for the formation of abstractions. Another mechanism would be based on quantum superposition of perceptively equivalent space-time surfaces. Sharing of mental images by entanglement of subselves is proposed and the motivation comes from the space-time correlates of entanglement identified as magnetic flux tubes connecting the space-time sheets of subselves although space-time sheets of selves are disjoint. This picture requires a generalization of the usual tensor product description for the formation of many-particle states.

Negentropy Maximization Principle (NMP) defines the basic variational principle of TGD inspired theory of consciousness.

1. NMP states that the negentropy gain in the quantum jump is maximal. For the ordinary entanglement entropy NMP implies that state function reduction leads to a pure state, which is an eigenstate of the density matrix characterizing the interaction of subsystem with its environment. An interesting purely mathematical result is that the assumption that density matrix always reduces to a partial trace of pure state density matrix leads to the basic rules of quantum theory probabilities. TGD inspired theory of consciousness, which can be seen as a generalization of quantum measurement theory, allows only this kind of density matrices.

2. If one accepts the notion of negentropic entanglement making sense in the intersection of real and p-adic worlds, number theoretic entropy can become negative in state function reduction. This makes possible formation of negentropically entangled states wheras in the usual state function reduction entanglement is always reduced. Negentropy is however associated with the entanglement rather that single particle states of either particle.

3. NMP and second law are very similar and one can consider the notion of the counterpart of thermodynamical equilibrium in which the avarage values of some conserved quantities are fixed so that one can assign to them temperature like parameters. At least in the ideal situation quantum jump could lead to the analog of thermal equilibrium prevailing in all scales with maximum amount of negentropic entanglement. This is probably too strong an idealization. The assignment of the experience of understanding with the generation of negentropic entanglement is a highly attractive idea. To assign it with negentropic entanglement itself does not conform with the basic postulate.

Both p-adic length scales and CDs form a hierarchy and this raises the question whether or not the quantum jumps inside CDs within CDs are related or not. One can consider three options.

1. For the first option the cascade of state function reductions can begin from any *unentangled* CD and after that proceeds to shorter length scales (smaller sub-CDs) until it stops when maximally negentropic entanglement is reached. This cascade would be analogous to motor action proceeding from long to short scales as detailes of the motor action are fixed. For sensory perception the cascade would be same but in opposite direction of imbedding space geometric time (state function reduction for the opposite boundary of CD). This would imply an effect analogous to quantum Zeno effect. If for given CD quantum jump cascade can begin only if CD is unentangled, negentropic entanglement stabilizes the CD, and it can spend long times in this negentropically entangled state but would not be conscious.

2. One can consider also the possibility that the CD from which the cascade begins is entangled with other CDs so that in quantum superposition of states the state function reduction cascades could occur separately for all summands. This would mean quantum parallelism for state function reductions. For instance, in this picture hadrons could be seen as quantum coherent structures in hadronic length scales but dissipative quantum structures in quark length scales. This options is certainly simpler than the first one but one must keep mind open for both options. It is is not clear to me whether the possible non-uniquencess of the state basis could exclude quantum parallellism.

3. For the third option quantum jumps inside various CDs would occur independently and top-down and bottom-up cascades are not predicted.

4.2 The anatomy of quantum jump in zero energy ontology (ZEO)

Concerning the notion of quantum jump ZEO encourages rather far reaching conclusions. In ZEO the only difference between motor action and sensory represention on one hand and intention and cognitive representation on the other hand is that the arrows of imbedding space time are opposite for them. Furthermore, sensory perception followed by motor actions corresponds to a basic structure in the sequence of state function reductions and it seems that these processes occur fractally for CDs of various size scales.

1. State function reduction can be performed to either boundary of CD but not both simultaneously. State function reduction at either boundary is equivalent to state preparation giving rise to a state with well defined quantum numbers (particle numbers, charges, four-momentum, etc...) at this boundary of CD. At the other boundary single particle quantum numbers are not well defined although total conserved quantum numbers at boundaries are opposite by the zero energy property for every pair of positive and negative energy states in the superposition. State pairs with different total energy, fermion number, etc.. for other boundary are possible: for instance, t coherent states of super-conductor for which fermion number is ill defined are possible in zero energy ontology and do not break the super-selection rules.

2. The basic objects coding for physics are U-matrix, M-matrices and S-matrix. M-matrices correspond to a orthogonal rows of unitary U-matrix between zero energy states, and are expressible as products of a hermitian square root of density matrix and of unitary S-matrix which more or less corresponds

to ordinary S-matrix. One can say that quantum theory is formally a square root of thermodynamics. The thermodynamics in question would however relate more naturally to NMP rather than second law, which at ensemble level and for ordinary entanglement can be seen as a consequence of NMP.

The non-triviality of M-matrix requires that for given state reduced at say the "lower" boundary of CD there is entire distribution of statesat "upper boundary" (given initial state can lead to a continuum of final states). Even more, all size scales of CDs are possible since the position of only the "lower" boundary of CD is localized in quantum jump whereas the location of upper boundary of CD can vary so that one has distribution over CDs with different size scales and over their Lorentz boots and translates.

3. The quantum arrow of time follows from the asymmetry between positive and negative energy parts of the state: the other is prepared and the other corresponds to the superposition of the final states resulting when interactions are turned on. What is remarkable that the arrow of time at imbedding space level at least changes direction when quantum jump occurs to opposite boundary.

   This brings strongly in mind the old proposal of Fantappie [21] that in living matter the arrow of time is not fixed and that entropy and its diametric opposite syntropy apply to the two arrows of the imbedding space time. The arrow of subjective time assignable to second law would hold true but the increase of syntropy would be basically a reflection of second law since only the arrow of the geometric time at imbedding space level has changed sign. The arrow of geometric at space-time level which conscious observer experiences directly could be always the same if quantum classical correspondence holds true in the sense that the arrow of time for zero energy states corresponds to arrow of time for preferred extremals. The failure of strict non-determinism making possible phenomena analogous to multifurcations makes this possible.

4. This picture differs radically from the standard view and if quantum jump represents a fundamental algorith, this variation of the arrow of geometric time from quantum jump to quantum jump should manifest itself in the functioning of brain and living organisms. The basic building brick in the functioning of brain is the formation of sensory representation followed by motor action. These processes look very much like temporal mirror images of each other such as the state function reductions to opposite boundaries of CD look like. The fundamental process could correspond to a sequences of these two kinds of state function reductions for opposite boundaries of CDs and maybe independently for CDs of different size scales in a "many-particle" state defined by a union of CDs.

How the formation of cognitive and sensory representations could relate to quantum jump?

1. ZEO allows quantum jumps between different number fields so that p-adic cognitive representations can be formed and intentional actions realized. How these quantum jumps are realized at the level of generalized Feynman diagrams is non-trivial question: one possibility suggested by the notion of adele combining reals and various p-adic number fields to a larger structure is that the lines and vertices of generalized Feynman diagrams can correspond to different number fields [48].

   The formation of cognitive representation could correspond to a quantum jump in which real space-time sheet identified as a preferred extremal is mapped to its p-adic counterpart or superposition of them with the property that the discretized versions of all p-adic counterparts are identical. In the latter case the chart map of real preferred extremal would be quantal and correspond to delocalized state in WCW. The p-adic chart mappings are not expected to take place but with some probabilities determined by the number theoretically universal U-matrix.

2. Similar consideration applies to intentional actions realized as real chart maps for p-adically realized intention. The natural interpretation of the process is as a time reversal of cognitive map. Cognitive map would be generated from real sensory represention and intentional action would transform time reversed cognitive map to real "motor" action identifiable as time reversal of sensory perception. This would occur in various length scales in fractal manner.

3. The formation of superpositions of preferred extremals associated with discrete p-adic chart maps from real preferred extremals could be interpretated as an abstraction process. Similar abstraction could take place also in the mapping of p-adic space-time surface to a superposition of real preferred extrmals representing intentional action. U-matrix should give also the probability amplitudes for these processes, and the intuitive idea is that the larger then number of common rational and algebraic points of real and p-adic surfaces is, the higher the probability for this is: the first guess is that the amplitude is proportional the number of common points. On the other hand, large number of common points means high measurement resolution so that the number of different surfaces in superposition tends to be smaller.

4. One should not make any un-necessary assumptions about the order of various kinds of quantum jumps. For the most general option real-to-padic and p-adic-to-real quantum jumps can follow any quantum jumps and state function reductions to opposite boundaries of CD can also occur any time in any length scale. Also the length scale of resolution scale assignable to the cognitive representation should be determined probabilistically. Quantal probabilities for quantum jumps should therefore apply to all aspect of quantum jump and now ad hoc assumptions should be made. Very probably internal consistency allows only very few alternative scenarios. The assumption that the cascade beginning from given CD continues downwards until stops due to the emergence of negentropic entanglement looks rather natural constraint.

4.3 How memories are represented and recalled?

Formation of memories and memory recall are key elements in the vision proposed by Hawkins. The question is what memories and memory recall are. If quantum jump is the fundamental process, it should automatically give rise to memories and memory recall.

1. Memories in given scale would naturally correspond to sequences of mental images defined by negentropically entangled sub-CDs of CD in given scale. According to earlier view the sequences of moments of consciousness bind to form higher level moments of consciousness, selves. Somewhat different view is that formation of selves means formation of sequence of negentropically entangled sub-CDs stable against NMP and preserved in quantum jump and even increasing in size. Thus self would correspond to a property of state and consciousness would be associated with the replacement of state with a new one.

2. The hierarchical structure of memories would emerge naturally. Conscious memory recall would correspond to a generation of negentropic entanglement between the new mental images emerging in the state function reduction (recall that the sizes of CDs increase and new sub-CDs emerge) and already existing negentropically entangled mental images. Generation of negentropic entanglement would give rise to the experience of recognition of the new mental images.

3. The natural guess is that negentropic entanglement is generated if the new sensory input is "consistent" with older mental images. The addition of new tensor factor would mean a more abstract representation so that the sequence of quantum jumps would mean accumulation of experience. Consistency with older mental images could mean that the mental images have same "name". The name could correspond to p-adic cognitive representation. The physical correlate could be a collection of resonance frequencies. The names would be same if the frequencies for older mental images and new one are same, so that resonant interactions becomes possible. The generation of negentropic entanglement would be like finding a radio station.

For this proposal memory recall and memory formation are actually more or less the same thing. Only the completely new memories claimed to be formed in hippocampus would not involve memory recall. The new memory would correspond to a new sub-CD or ensemble of sub-CDs representing the

associated negentropically entangled mental images. Neuronal loop could make possible to build copies about the new memory and thinking about it would create copies of corresponding p-adic cognitive representations which in turn could be transformed via state function reduction to an opposite boundary of CD to actions. In TGD framework the 4-D hierarchy of memories could continue from hippocampus to the magnetic body: this would explain the correlation of EEG with memory and also with various other brain functions.

4.4 The roles of sensory perception and motor action in TGD framework

The attempts to define consciousness rely on two basic approaches. The first approach emphasizes direct sensory awareness and formation of cognitive representations from it (phenomal consciousness and reflective consciousness). Second approach emphasizes volition, motor plans, and motor actions.

The analogs of sensory representations and motor actions emerge at the fundamental level in quantum TGD without mentioning anything about brain. In ZEO state function reduction is replaced with a cascade of state function reductions corresponding to various scales for CDs forming a fractal hierarchy. State function reduction can take place to either of the opposite boundaries of CD in a given length scale. The reduction at given boundary of CD would always force delocalization of the opposite boundary of CD creating quantum superposition of CDs with various sizes. Also new sub-CDs (correlates for sensory mental images) within the resulting bigger CDs are naturally generated. This would explain the arrow of geometric time at imbedding space level but the arrows are opposite at the opposite boundaries of CD.

The reduction to opposite boundaries of CD gives rise to zero energy states related by time reversal at the level of imbedding space. If "my" conscious experience corresponds to reductions to either "upper" or "lower" boundary of CD of wake-up cycle defining me, I will experience that the arrow of geometric at the level of imbedding space arrow is constant and would be basically due to the scaling up of the average size of "personal" CD. "Upper"/"lower" can be fixed by the arrow of time assignable to large enough CD defininig environment.

Standard quantum measurement theory assumes that a state function reduction followed immediately by a new one does not affect the reduced state [this gives rise to so called quantum Zeno effect: quantum monitoring of unstable particle prevents its decay (watched kettle does not boil)]. That repeated state function reduction at given boundary of CD does not affect the zero energy state resulting in the reduction for given CD would generalize this hypothesis. If this assumption hold true, the subsequent reductions at the same boundary of CD would effectively correspond to single reduction and one would effectively have an alternating sequence of cascades of state function reductions beginning from opposite boundaries of CDs. Note hower that there a fractal cascade of reductions beginning from sub-CDs the CD is assumed changing the state in smaller scales.

In TGD framework the counterpart of quantum Zeno effect would be achieved by closing an unstable particle inside small enough CD so that the unitary time evolution restricted to CD would not affect the particle appreciably and state function reductions at boundaries of this CD very rarely would give rise to a final state of decay. Watchdog in this case would be the self to which this CD corresponds to.

4.4.1 Motor action as time reversal of sensory perception

In TGD framework motor action could be seen as a time reversal of sensory perception so that sensory-motor pairing could be seen as fundamental element of all conscious existence. Just to fix conventions let us fix arrow of time as the arrow of the imbedding space time for a very large CD, maybe of cosmic size scale, so that there is unique time direction corresponding to future.

1. All scales for CDs are possible. For sub-CDs of given CD the experiences associated with sub-CD define mental images of CD and the experience can be assigned with either boundary of sub-CD. Let us tentatively agree that for a given CD "lower" and "upper" boundaries are in future and past when seen from the center point of CD (past and future could be permuted in the convention).

This choice would conform with the interpretation that motor "me" I_m makes a fuzzy prediction of future as superposition of space-time sheets extending from the lower boundary of CD and sensory "me" I_s generates memories represented by superposition of space-time sheets extending downwards from the upper boundary of CD. I do not quite have the courage to completely exclude the second option in which the roles of motor me and sensory me are changed.

2. With this assumption one can assign to a sub-CD near upper *resp.* lower boundary of sub-CD sensory mental images *resp.* their time reversals. In the interior they would represent memories *resp.* predictions. The larger CD would experience these subselves as mental images and interpret them in terms of ordinary sensory percepts *resp.* volitions, decisions, and plans. The primary sensory experience, phenomenal experience, involves generation of negentropic entanglement as the sensory mental image combines as a tensor factor with the existing sequence of mental images forming a sensory representation defining memory. The reading of this sequence of mental images using interaction free quantum measurement gives rise to a conscious memory about the mental image sequence.

3. A prediction, which looks rather strange at first glance, follows. "My" CD would be seat for two selves having their own phenomenal experiences seated at the opposite boundaries of my CD. They would be sensory me I_s assignable to sensory perception and motor me I_m assignable to motor action as time reversed sensory perception and assignable to the opposite boundaries of CD when they are localized in state function reduction. The time reversed sensory percept is interpreted in terms of predictions, volitons, and plans at least by larger CD having the CD as sub-CD. Sensory and motor "mes" would appear in all scales in the hierarchy of sub-CDs.

4. Since the scale of CDs increases quantum jump by quantum jump on the average and new sub-CDs emerge, the size scale of the largest CD in hierarchy increases and the perceptual fields of the two "me"s associated with it shift towards geometric future *resp.* past of the imbedding space. The sub-CDs near the boundaries of largest CD give rise to sensory percepts of the two "me"s involved with the largest CD in the hierarchy. Those in the interior define memories. The flow of time would correspond to the gradual shifting of the upper/lower boundary of largest CD to future/past and generation of sensory mental images (sub-CDs) near the boundary. Same would of course occur for the smaller CDs. The time interval about which memories are about and also the time scale for predictions of future increases since the size of the personal CD is gradually scaled up.

4.4.2 Quantitative considerations

One can make also quantitative questions.

1. What is the average increase of the temporal distance between the tips of CD in a pair of state function reductions to opposite boundaries defining the chronon of subjective experience? The duration of this chronon can depend on the level of the self hierarchy.

   For human sensory consciousness this chronon would naturally correspond to the time scale of about .1 seconds having interpretation as a duration of sensory mental image. Each pair of state function reductions would generate a layer of the sensory mental images at the lower and upper boundary of "our" CD.

   This leaves open the size scale of "our" CD and lifetime would represent only the size scale for the increase of "our" CD during life cycle. This would mean that the durations of consciousness for the two "me"s assignable to "our" CD would be measured using .1 second as a natural unit.

2. What can one say about the size scales of CDs themselves? Since the memories are about the time interval, which is roughly the duration of life cycle at most, the first guess is that the size of personal CD is of the order of duration of life cycle. By the previous argument however only the increase of

the distance between the tips of "personal" CD naturally corresponds to the duration of life cycle so that the size scale of personal CD could be much larger. Note that the conscious experiences of I_s and I_m assignable to sensory percepts and motor actions should correspond to sub-CD:s with size scale not much larger than .1 seconds. This is consistent with the interpretation of sensory percepts of I_m as plans, decisions, predictions, and volitions. The sub-CDs with time scale of say years are however possible and would correspond to memories and plans in time scales of years.

3. One can imagine also a fractal hierarchy for the increments ΔT_i of the temporal distance T_i between tips of CDs assignable to single pair of quantum jumps to opposite boundaries of CD in given length scale. $\Delta T = .1$ seconds would not be the only possible duration of chronon. This time scale is however very special since it corresponds to the Mersenne prime M_{127} assignable to electron which corresponds to largest Mersenne prime which does not correspond to completely super-astrophysical p-adic length scale. The smaller Mersenne primes - such as M_{107} and M_{89} could correspond to shorter time scales perhaps assignable to nerve pulse in the case of lightest quarks. All primes characterizing elementary particles could define chronons of this kind serving as clocks. The hierarchy of chronons could mean sensory percepts and motor actions have a fractal hierachy of resolutions identifiable as kind of abstraction hierarchy.

   The clocks defined by these chronons of duration T_i should be synchronized in the sense that there would $N_{ij} = \Delta T_i/\Delta T_j$ quantum jumps with time increment T_j per single quantum jump with time increment T_i.

   Could various periodic phenomena such as diurnal period of 24 hours defining sleep-awake cycle, annual cycle, and various bio-rhytms such as EEG rhytms, define also chronons? Could cyclity which seems to appear at the level of sensory and cognitive mental images relate to this kind of chronons: for instance, after images are a good example about mental images having analog of wake-up-sleep cycle.

4.4.3 Questions

There are also questions about the relation to the functioning of brain.

1. How sleep-awake cycle relates to this picture? The above argument suggest that .1 second time scale rather than 24 hour time scale defines the increase of CD scale assignable to single pair of state function reduction assignable to "me". Therefore the period assignable to single moment of human sensory conscious of the two "me"s would be of order .1 seconds.

   This strongly suggests that due to the lack of sensory input and absence of motor actions we are conscious during sleep but do not have memories from this period. Dreams generated by virtual sensory input to retina would produce memories during sleep state. Revonsuo indeed mentions that according to the reports of subject persons after awakenings sleeping period seems to involve either dreams or sleep mentation. Sleep mentation is very simple during nREM sleep: for instance, repetion of some word of internal speech. Sleep mentation would involve motor actions generating internal speech and in some cases also genuine speech. Also genuine motor actions such as sleep walking are possible.

2. Could the sensory-motor dichotomy have some relation to the righ-left dichotomy at the level of brain? Right and left brain hemisphere could naturally correspond to parallel CDs of same size scale. Could right and left brain (or parts of them) organize their wake-up periods as in shift work: if left brain hemisphere is awake right hemisphere sleeps (sensorily perceives the opposite end of its CD) and vice versa, an alternating dominance by either hemisphere results, and one could understand sensory rivalry. The time scale of CDs possibly involved would be much shorter than that of sleep-awake cycle in this case. Interestingly, the duration of hemisphere dominance period in some disorders like schizophrenia is anomalously long.

The CD containing both these CDs - "entire brain CD" - would be also present. The view of "brain CD" about world represented by entangled right and left negentropic mental images would be analogous to initial and final state and thus contain much more information than given by either right or left hemisphere. In the case of visual mental images this would give rise to stereo vision.

Could this shift work between parts of right and left hemisphere be realized in several time scales of CDs? Even in the scale corresponding to sleep-awake rhythm? It is known that in case of some birds and mammals, which must be motorially and sensorily active all the time, the brain hemispheres have this kind of shift work in long time scale.

4.5 Self or only a model of self?

Negentropic entanglement provides a model for associations as rules in which superposition of tensor product states defines rule with entanglement pairs defining its various instances. This generalizes to N-fold tensor products. Associations would be realized as N-neuron negentropic entanglement stable against NMP. One could also think of realizing associative areas in terms of neurons whose inputs form entangled tensor product and when sensory inputs are received they form analogous tensor product in representative degrees of freedom.

Thus negentropic entanglement is necessary for mental images (having sub-CDs as correlates) to mental images representing spatial patterns. Negentropic entanglement in time direction for these patterns (zero energy states) is in turn necessary to bind them to sequences of mental images representing abstract memories as sequences of mental images. Negentropically entangled sequence would be a quantal counterpart for the original association sequence introduced as purely geometric concept.

This picture however challenges the identification of self as quantum jump. Should the negentropically entangled sequences of mental images define selves so that self would be something characterizing zero energy state rather than something identified as quantum jump? Could they define a model of self to be distinguished from self identified as quantum jump? Or could one give up the notion of self alltogether and be satisfied with model of self? At this moment it seems that nothing is lost by assuming only the model of self.

By definition negentropic entanglement tends to be preserved in quantum jumps so that it represents information as approximate invariant: this conforms with the idea of invariant representation and quite generally with the idea that invariants represent the useful information. There is however a problem involved. This information would not be conscious if the original view about conscious information as a change of information is accepted. Could one imagine a reading mechanism in which this information is read without changing the negentropically entangled state at all? This reading process would be analogous to deducing the state of a two-state system in interaction free measurement to be discussed below in more detail.

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(Continued on Part II)

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