Comparison of TGD Inspired Theory of Consciousness with Some Other Theories of Consciousness

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This work 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 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 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.

I will also 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.

Contents

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 [J18] 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 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, [K9]) 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 [K1]. This looks strange at first glance but allows to interpret the growth of syntropy introduced by Fantappie [J17] 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 [J21]. 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 [K10, K1]. 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" [J29].

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 consciouesness.

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" [J18]. 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 [K1] 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 [J29] 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`) [J2] 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 [K5] 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`) [J13], 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 hierarcy 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 [K17]. 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 [K13]. 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 [K4].

   (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 [K17]. 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 [L1].

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 [J17] 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 [K15].

   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.

4.6 Could interaction free measurement be used to deduce information about self model?

The assumption that self model is a negentropically entangled system which does not change in state function reduction, leads to a problem. If the conscious information about this kind of subself corresponds to change of negentropy in quantum jump, it seems impossible to get this information. Quite generally, if moment of consciousness corresponds to quantum jump and thus change, how it is possible to carry conscious information about quantum state? The following proposal for non-destructive reading of memories and future plans allows to resolve this problem.

4.6.1 Bomb testing problem as a model for interaction free measurement

One can consider a generalization of so called interaction free measurement as a manner to deduced information about self model. This information would be obtained as sequences of bits and might be correspond to declarative, verbal memories rather than direct sensory experiences.

1. The bomb testing problem of Elitzur and Vaidman gives a nice concrete description of what happens in interaction free measurement, see `http://en.wikipedia.org/wiki/ElitzurVaidman_bomb-testing_problem` [B1] for an illustration of the system considered.

   The challenge is to find whether the bomb is dud or not. Bomb explodes if it receives photon with given energy. The simplest test would explode all bombs. Interaction free measurement

allows to make test by destroying only small number of bombs and at idealized limit no bombs are destroyed.

The system involves four lenses arranged in square and two detectors C and D at the upper right corner of the square. In the first lense at the lower left corner the incoming photon beam splits to reflected and transmitted beams: the path travelled by transmitted beam contains the bomb.

(a) The bomb absorbs photon with a probability which tells the fraction of photon beam going to the path at which bomb is (is transmitted through the lense). The other possibility is that this measurement process creates a state in which photon travels along the other path (is reflected). This photon goes through a lense and ends up to detector C or D through lense.

(b) If the bomb is dud, the photon travels through both paths and interference at the lense leads the photon to detector D. If C detects photon we know that the bomb was not a dud without exploding it. If D detects the photon, it was either dud or not and we can repeat the experiment as long as bomb explodes, or C detects photon and stop if the detector continues to be D (dud). This arrangement can be refined so that at the ideal limit no explosions take place and all.

2. The measurement of bomb property is interaction free experiment in the sense that state function reduction performed by absorber/bomb can eliminate the interaction in the sense that photon travels along the path not containing the bomb. One might say that state function reduction is an interaction which can eliminates the usual interaction with photon beam. State function reduction performed by bomb can change the history of photon so it travels along the path not containing the bomb.

This picture is only metaphorical representation of something much more general.

1. Bomb could be of course replaced with any two-state system absorbing photons in one state but not in the other state, say atom. Now one would test in which state the atom is gaining one bit of information in the optimal situation. Two-state atom could thus represent bit and one could in principle read the bit sequence formed by atoms (say in row) by this method without any photon absorption so that the row of atoms would remain in the original state.

2. Two-state system could be replaced with N-state system. In this case the testing selects at first step one state as analogs of bomb intact and the remaining states as analogs of dud. If the answer was "dud" in the first step, the next step selects one preferred state from $N-1$ states and regards the remaining states as "dud". The process continues until the state of the system is measured.

3. In TGD framework the photon paths branching at lenses correspond to branching 3-surfaces analogous to branching strings in string model and photon wave splits to sum of waves travelling along the two paths.

4.6.2 Memory recall as an interaction free measurement

One can imagine several applications if the information to be read in interaction free manner can be interpreted as bit sequences represented as states of two-state system. Lasers in ground states and its excited state would be analogous many particle quantum system. In TGD framework the analog of laser consisting of two space-time sheets with different sizes and different zero point kinetic energies would be the analogous system.

For instance, a model of memory recall with memories realized as negentropically entangled states such that each state represents a qubit can be considered. The model applies also to the reading of future plans (memories on reversed time direction).

1. Reading of a particular qubit of memory means sending of negative energy photon signal to the past, which can be absorbed in the reading process. The problem is however that the memory representation is changed in this process since two state system returns to the ground state. This

could be seen as analog of no-cloning theorem (the read thoughts define the clone). Interaction free measurement could help to overcome the problem partially. Memory would not be affected at all at the limit so that no-cloning theorem would be circumvented at this limit.

2. A possible problem is that the analogs of detectors C and D for a given qubit are in geometric past and one must be able to decide whether it was C or D that absorbed the negative energy photon! Direct conscious experience should tell whether the detector C or D fired: could this experience correspond to visual quale black/white and more generally to a pair of complementary colors?

3. ZEO means that zero energy states appear have both imbedding space arrows of time and these arrows appear alternately. This dichotomy would correspond to sensory representation-motor action dichotomy and would suggest that there is no fundamental difference between memory recall and future prediction by self model and they different only the direction of the signal.

4. Since photon absorption is the basic process, the conscious experience about the qubit pattern could be visual sensation or even some other kind of sensory qualia induced by the absoroption of photons. The model for the lipids of cell membrane as pixels of a sensory screen suggests that neuronal/cell membranes could serve defined digital self model at the length scale of neurons.

Some comments are in order.

1. To avoid misunderstandings it should be emphasized that TGD based view about memory is not the same as the standard view. In ZEO brain is four-dimensional and in principle memories can be negentropically entanglement memories in geometric past. It is possible to build copies of memories by memory recall, and learning would correspond to a generation of large enough number of copies of the memory mental image. Memory recall could be seen as a negative energy signal inducing the interaction free measurement of memory qubits. Dark photons with EEG frequencies (say in theta band characterizing hippocompus) but having energies of visible photons could be involved with the memory recall. Correlation between EEG and biophotons supports this view.

2. If the systems taking the role of the detectors C and D in interaction free measurement are analogous to population reversed lasers, their return to the ground state could automatically generate virtual sensory input propagating to the sensory organs and allowing to check whether it is consistent with the actual sensory input. The generation of the feeback signal takes some time expected however to be much shorter than that for a typical neuronal activity.

   Since the signals would propagate with light velocity, the virtual sensory input could travel practically instantaneously from the brain to sensory organs and possibly also vice versa. Libet's experiments on passive aspects of consciousness [J12] in fact demonstrate a time delay which is fraction of second having interpretation in terms of time to propagate to a layer of magnetic body of size scale of Earth and back: these delays are consistent with the fact that the chronon of sensory experience is about .1 seconds. The propagation of photon signals in both directions would make possible construction of sensory representation in time scale much shorter than that of neural activity. This mechanism could also explain generation of after images.

3. Photons can be replaced with phonons or quanta of any other wave motion with constant propagation velocity (no dispersion of signal) in a given reference frame. This suggests that imagination and internal speech correspond to the two reading mechanisms of memories.

4.6.3 Some critical questions

There are two basic objections against quantum theories of consciousness. How it is possible to have conscious information about invariant under quantum jumps if only change is experienced continuously? The outcome of state function reduction in standard quantum theory is random: how can one understand freedom of choice and intentional behaviour in terms of state function reduction? NMP and the possibility of negentropic entanglement imply that TGD based quantum theory is not equivalent with the standard one, and this allows to circumvent the objections.

There are however two further questions, which I cannot answer yet. Can one really assume that the notion of interaction free measurement continues to make sense in TGD framework? Could NMP allow to make this notion exact or make it impossible? Could the invariants or at least their existence be experienced directly without interaction free measurement?

The experiments carried out to test whether 40 Hz thalamocortical resonance is correlate for conscious experience suggests that the resonance is present only when a new pattern is discovered, not when it has become a memory. The TGD inspired interpretation would be that the resonances accompanies negentropy gain and quantum jump is necessary for conscious experience. However, the reports about higher states of consciousness (and also my own experiences) suggest that the invariants can be experienced directly when all thoughts (interaction free measurements) are eliminated. This experience cannot be however communicated: one understands does not know what one understands. Therefore also the original vision that negentropic entanglement corresponds to conscious experience - experience of pure understanding, which is not communicable - and in apparent contradiction with the basic hypothesis about quantum jump, would be correct after all!

4.6.4 Why vision and hearing are so fundamental for cognition?

The interaction free measurement is formulated in terms of photons. It can be however formulated also for sound waves using phonon detectors and acoustic waves traversing through two different paths. Quantum coherence is required but the hierarchy of Planck constants makes sense also for phonons by the basic equation $E = hf$.

In TGD framework there are good reasons to believe that sound waves are not only something emerging at the level of condensed matter but correspond to oscillations of string like objects at 4-D space-time surface. These strings connect the wormhole contacts assignable to the light-like orbits of partonic 2-surfaces. Partonic 2-surfaces can be assigned with elementary particles but also to 2-surfaces with arbitrarily large size scale. The outer boundary of any physical object would correspond to a partonic 2-surface. String world sheets carry fermion fields localized at them (right-handed neutrino is an exception in that it is delocalized at entire space-time surface). The fact that strings always connect two partonic 2-surfaces corresponds to the fundamental two-particle character of sound waves. Sound would be as fundamental phenomenon as photons and other massless bosons.

This encourages to ask whether photon (more generally gauge boson: TGD suggests that scaled up copies of gluons and weak bosons behaving like massless particles even in cell length scale are possible) and photon absorption could define fundamental conscious representations of information realized in terms of interaction free measurements for negentropically entangled states remaining unchanged under state function reduction in good approximation.

Photons would correspond to "seeing" but at neuronal level rather than at the level of retina - and imagination. Phonons would correspond to hearing at neuronal level and internal speech which is also essential for cognition. Both internal speech and imagination could be understood at fundamental aspects of cognition. Dark photons with energies of visible photons (decaying to what is interpreted as biophotons) and dark phonons would be behind imagination and internal speech. I have already earlier proposed that the lipid layers of neuronal membranes (and maybe also ordinary cell membranes) can be regarded as pixels of a sensory map representing neuronal qualia [K5]. These pixels could serve as the counterparts of the detectors C and D appearing in interaction free measurement. The evidence for the importance of biophotons (in TGD framework dark photons decay to biophotons in energy conserving manner) in biology and neuroscience is emerging, see for instance the experiments of Persinger's group [J14, J15, J16]. I have discussed these findings from TGD point of view in [L1].

One can speculate about direct translation between the words of language and visual pre-images. In general I try to avoid reference to anything personal since but at this time I cannot resists the temptaton to mention that during my first "great experience", which served as a powerful inspiration for TGD inspired theory of consciousness, I was able to see my thoughts and discovered that this kind of correspondence seems to exists: I did experimentation with internal speech by uttering words and immediately getting visual image to my visual field as a response!

Biophotons seem to be associated only with the right hemisphere [J14]. This suggests that right hemisphere or some parts of it prefer dark photons being thus specialized to visual imagination in accordance with the fact that spatial relationships are the speciality of the right hemisphere. Could this mean that left hemisphere or some parts of it prefer dark phonons (or dark photons in IR range transforming [L1] to ordinary photons at ear and generating virtual auditory input? Left hemisphere

indeed is the verbal hemisphere specialized to linear linguistic cognition and produces also internal speech.

4.6.5 Realization of memory representations in terms of braided flux tubes

While reading a marvellous book "The Field" by Lynn McTaggart [I2] about evolution of ideas about the role of electromagnetic fields in biology and neuroscience, I became aware of two questions which I had not yet answered. The first question is following: How various representations (sensory - , memory -,...) - "Akashic records" - are realized as negentropically entangled states?

Magnetic body should be the seat of memories in some sense.

1. I have already earlier proposed this kind of realization based on the observation that braiding in time direction generates space-like braiding [K3]. Dancers on the parquette with their feet connected to the wall by threads illustrates the idea. When dancers move at the parquette their world lines define a time-like braiding in 3-dimensional space-time assignable to the floor. Also the threads connecting the dancers to the wall get braided - or entangled - as one might also say. There is clearly a duality between time-like and space-like braidings: the running topological quantum computer program coded by braiding in time direction is stored as space-like braiding defining memory representation of what happened. Note that same mechanism realizes also predictions and future plans as time reversed topological quantum computer programs in ZEO. CDs in various scales contain this kind of programs and their memory representations.

2. I have also proposed that the geometric entanglement - braiding - of flux tubes defines a space-time correlate for quantum entanglement. In the case of topological quantum computation it would be naturally described by probabilities, which are rational numbers (or perhaps even algebraic numbers in some algebraic extension of p-adic numbers characterizing together value of the p-adic prime the evolutionary level of the system). Hence the notion of number theoretic negentropy makes sense and one obtains a connection with topological quantum computation.

3. The representation of memories in terms of space-like braiding of magnetic flux tubes connecting various systems would be universal, and not restricted to DNA-cell membrane system in which the flux tubes would connect DNA nucleotides [K3, K12] or codons (this seems to be the more plausible option [L1]) with the lipids. One could indeed speak about Akashic records (see `http://en.wikipedia.org/wiki/Akashic_records`).

4. The time reversals or these representations defined by the zero energy states of opposite arrow of the imbedding space time would define a representation for future predictions/ plans in ZEO. For instance, the development of a seed to a full-grown organism could be coded in this manner in time scale where CD has time scale of order of the lifetime of the organism. Already Burr found evidence that the radiation field assignable to the seed has the same shape as the plant [I1, I2] or animal (salamander in his experiments). This energy field would naturally correspond to the magnetic body containing dark photon Bose-Einstein condensates. The Akashic records and their time reversal would naturally correspond to the morphic fields of Sheldrake [I3, I4]: memories and future plans in time scales longer than than duration of life cycle for an individual member of species would be possibles. Every scientist of course agrees that the societies are busily predicting and planning their futures but find very difficult to accept the idea that this could have some concrete quantum physical correlate.

4.6.6 How to construct and read conscious hologram?

While reading the book of McTaggart also a second question popped up: How the vision about brain as a conscious hologram is realized in the proposed conceptual framework?

The idea about living system as a hologram has strong empirical basis. One of the most dramatic demonstrations of the hologram like character of brain was the discovery of Pietch [J25] that salamander's brain can be sliced to pieces and shuffled like a deck of cards and put together. When the resulting stuff is returned to the head of the salamander, it recovers! This extreme robustness is very strong support for the non-local hologram like storage of biological information. Ironically, Pietch tried to demonstrate that the theory of Karl Pribram [J26, J27] about brain as a hologram is wrong! In TGD framework one can go even further and ask whether this robustness actually demonstrates

that various representations (sensory - , cognitive - , memory - ...) are realized at the long magnetic flux loops and sheets of the magnetic body rather than brain.

The notion of conscious hologram [K2] is one of the key ideas of TGD inspired theory of consciousness. Hitherto I have not been owever able to find a really convincing concrete proposal for how brain could be a hologram in TGD Universe. The reading of memory - and other representations by interaction free measurement however leads to a natural proposal for what the hologram might be.

1. Certainly the formation of the hologram must closely relate to the vision about universal Akashic records realized in terms of braided flux tubes and their non-destructive reading by interaction free measurement. Oversimplifying, tor a given bit of the representation the photons scattered without interaction would kick either of the two detectors C and D associated with it to an excited state (see `http://en.wikipedia.org/wiki/ElitzurVaidman_bomb_tester`). This process is very much like absorption of photons by a photosensitive plate defining an ordinary hologram.

2. The lipids of the cell membrane are good candidates as something in 1-1 correspondence with the basic units of this hologram (note the analogy with computer screen - also a liquid crystal!). If one irradiates the laser like system formed by the detectors not only by the radiation scattered from the quantum Akashic records but by its superposition with the reference wave of same frequency, one obtains a good candidate for a hologram. It would be defined by the excited quantum state consisting of laser systems analogous to the detectors C and D. Any piece of the system should give and approximate representation of the memory and robustness of the representation is achieved.

3. In semiclassical treatment the probability that a given laser like detector is excited must be proportional to the modulus squared of the net field amplitude, which is a superposition of reference wave and scattered wave Also just. as in the case of ordinary holograms, the irradiation of the laser like system by the negative energy counterpart of the reference wave (its phase conjugate emitted in a state resulting in state function reduction to the opposite boundary of CD) effectively generates the conjugate of the scattered wave since only those parts of the system can return to the ground state with considerable probability for which the probability to go to excited state is high enough. Note that this implies that magnetic body contains geometric representations of the perceptive field as indeed assumed [K7, K8]. This is however not quite the classical hologram. Rather, the total number of absorbed negative energy phase conjugate photons for given pixel defines the "real" picture. A given point of the hologram corresponds to an ensemble of laser like detectors so that a statistically deterministic response is obtained as an ensemble average.

How to realize this concretely?

1. I have proposed that the lipids of cell membrane could serve as pixels of sensory representations [K5]. They could indeed serve as the pixels of conscious hologram. Each pixel should contain large number of laser like "detectors" so that statistical determinism would be achieved.

2. There should be pair C and D of detectors such that either of them absorbs photon in an interaction free measurement so that a value of bit is defined. Universality serves as a strong constraint as one tries to guess what C and D could be.

   (a) The lipids at the two lipid layers of cell membrane could be in 1-1 correspondence with C and D. This option is not however universal.

   (b) It is however quite possible that the magnetic fields involved are what I have called wormhole magnetic fields [K14], which carry monopole flux and and involve two space-time sheets carrying opposite net fluxes. As a matter of fact, all elementary particles correspond to flux quanta of wormhole magnetic fields. In this case the two sheets would naturally correspond to detectors C and D and in the simplest situation they would have same Minkowski space projection. Universality of both detectors and holograms is achieved.

3. The cyclotron Bose-Einstein condensates for charged particles at magnetic flux tubes assignable to lipids are good candidates for the laser like systems if they contain cyclotron Bose-Einstein condensates. There are however several options since the magnetic flux tubes are closed and there are several manners to realize this.

(a) DNA as topological quantum computer vision and the view about cell membrane as a sensory receptor communicating data to the magnetic body in turn sending control signals via DNA suggest the following. Magnetic flux loops have a part connecting DNA with nuclear or cell membrane (this would be the analog for the dipole of the dipole magnetic field) and part which is long - even with size scale of Earth and corresponds to the magnetic field created by the DNA-cell membrane system. This picture applies both to the flux tubes of ordinary magnetic field and to the flux tubes of the wormhole magnetic field.

(b) An assumption in accordance with the general role of magnetic body is that Akashic records reside at the short portions of flux tubes connecting lipids with DNA codons: their braiding would define badsic example about universal representations in living matter. The laser like detectors would reside at the long portions of the flux tubes connecting cell membrane and DNA. If wormhole magnetic fields are in question, the detectors C and D could correspond to the two parallel flux tubes carrying opposite monopole fluxes.

(c) Universality suggest that this picture allows many alternative realizations. In principle, the relative motion of any system (partonic 2-surfaces with light-like orbits) connected by flux tubes could give rise to Akashic records. The lipids of axonal membrane are excellent candidates for the pixels and the flux tubes connecting the lipids to microtubuli [J1] would also define Akashic records with long parts of the flux tubes serving as the laser like system. The maximization of the memory capacity would also explain why the neural pathways to brain tend to maximize their lengths by connecting right side of the body to left hemisphere and vice versa.

4. What remains still open is how to integrate the Josephson junctions defined by the lipid layers of the cell membrane to this picture.

4.7 Could quantum jump represent the basic aspects of abstraction process automatically?

Could quantum jump automatically represent the basic aspects of abstraction process and its reversal as it manifests itself at the level of brain?

1. The sizes of CDs in the quantum superposition defining zero energy state tend to increase. This means that the time scale of sensory and cognitive representations increases. Also new sub-CDs are generated as the size scales of CDs increase and this means generation of new mental images identifiable as memories.

2. NMP favors the formation of negentropic entanglement between sub-CDs so that sequences of mental images with both space-like entanglement (spatial patterns) and time-like entanglement (sequences of spatial patterns) are formed. NMP guarantees their stability. Zeno effect could make possible the analog of thermodynamical equilibrium to prevail for several quantum jumps on same boundary of CD having no effect in a given length scale. If quantum jumps occur independently for several scales, they can occur simultaneously in other scales.

3. Map from real to p-adic sector occurs defines a cognitive representation, a prediction for the future (or past when intention is realize as action). In the ideal situation "thermal equilibrium" with respect to NMP is achieved for a given CD. Next state function reduction having observable effects occurs at the opposite boundary of CD and gives rise to motor action or intention about motor action defined by this sensory representation. The transformation to real sector realizes intention.

4.8 Quantum jump as the counterpart of fundamental algorithm?

In TGD framework the materialistic identification of consciousness as a property of the physical state of brain is not made. Consciousness is assigned with quantum jump and is therefore something between two quantum worlds.

In quantum TGD context functionalism does not look like an attractive idea. However, the idea that cognitive processing as identification and naming of objects of the perceptive field could be totally

universal and taking place already at the elementary particle level, does so. The additional feature would be coloring of this cognitive map. Sensory qualia would do this and could be assigned to the quantum jump and identifiable basically in terms of increments of various quantum numbers in quantum jump.

The TGD counterpart of the functionalistic dream could be dream about the reduction of basic aspects of brain function - formation of sensory and motor representations and their realization, to the basic the basic anatomy of quantum jump and properties of negentropically entangled states approximately invariant under quantum jumps. All systems, even electron would do this, but brain would be highly specialized to this fundamental process.

4.9 Could quantum computationalism make sense?

There are strong objections against classical computationalism but what about its quantum variant? The first question is about what one means with quantum computationalism. The usual quantum computation algorithm is modelled by classical computation and might not catch all aspects of activity that one might want to call quantum computation or more generally, conscious cognitive processing.

The vision about DNA as topological quantum computer is one of the key ideas of TGD inspired quantum biology and might actually apply to much wider class of biomolecules biological structures. The notion of magnetic body which distinguishes TGD from ordinary biology and neuroscience is central here. The braiding of magnetic flux represents topological quantum computation programs. One can actually see the braid strands connecting DNA nucleotides or triplets with lipids of nuclear or cell membrane as a representation for quantum software whereas DNA represents the hardware. The reconnections of flux tubes would generate quantum coherence between distant objects and the phase transitions changing their lengths could make possible the miracles of bio-catalysis. The so called cultural evolution could correspond to the evolution of the magnetic bodies.

Could brain - or perhaps even entire Universe - perform quantum computation in some generalized sense and whether sensory processing could be seen as quantum computation in this more general sense? In TGD framework one can consider a generalization of the notion of quantum computation so that quantum jump identified as moment of consciousness defines quantum computation in generalized sense and can be seen also as the counterpart of fundamental algorithm giving rise to sensory and cognitive representations and realizations of motor actions as their time reversals.

1. Generalized Feynman diagrams [K6] involve propagator lines for fermions to which one can assign topological quantum computation with basic gate identified as the basic braiding operation. These braid strands can be assigned with fermions at the ends of the light-like orbits of partonic 2-surfaces. Also the magnetic flux tubes can take the role of braid strands.

2. The vertices, which come in two varieties, do not have counterpart in ordinary quantum computation and seem to represent something totally new. The first vertex is the analog of string vertex and represents fusion or decay of 3-surface (or associated partonic 2-surface).

   (a) To this vertex one can naturally assign direct sum of state spaces associated with the braid strands carrying fermions. This $\oplus$ vertex has also time reversal and identifiable as co-vertex so that algebra and co-algebra structures are present simultaneously.

   (b) Second vertex is not encountered in string model and generalizes the ordinary 3-vertex of ordinary Feynman diagrams. At this vertex the orbits of 3 partonic 2-surfaces meet at their common end (partonic 2-surface). Now tensor product $\otimes$ is the natural operations and again one has algebra and co-algebra structure. These vertices are algebraically completely analogous with the ordinary sum and product.

   This led to the crazy proposal that arithmetics, the notions of real and p-adics numbers, and even more general mathematical notions generalize by replacing numbers with Hilbert spaces and that calculus for Hilbert spaces could make sense [K15]. This brings in infinite abstraction hierarchy and means a huge generalization of the structure of mathematics but might be needed if one wants to understand reflective consciousness.

3. The replacement of points of Hilbert space with Hilbert space to get a new structure means an abstraction. Single state is replaced with a set of states defined by state basis. Could this process

correspond to the formation of abstractions is at the fundamental level? If so $\oplus$ could mean formation of quantum superposition of perceptively equivalent zero energy states representing the percept. $\otimes$ would represent association of different percepts (say through different sensory channels) which represent same object. The superposition of tensor product states would define rule and abstraction and could be the basic cognitive process assignable to generalized Feynman diagrams.

4. This process would be far reaching generalization of the ordinary arithmetics with $+$ and $\times$ to that for $\oplus$ and $\otimes$ and their co-operations. The basic fact about practical arithmetics is that the same computation as a sequence of operations can be performed with very many manners but there is the shortest manner to do it. At the level of generalized Feynman diagrams this would mean huge symmetries. The physical equivalence classes of generalized Feynman diagrams would be huge and in twistor approach to generalized Feyman diagrams these symmetries have an identification as counterparts for the symmetries of twistor diagrams. Whether the representatives inside these equivalence classes are also cognitively equivalent is not clear. These observations suggest that generalized Feynman diagrams might be much nearer to what happens when human brain computes and that quantum computation in the ordinary sense corresponds only to a single line of generalized Feynman diagram, and has same relation to what really happens in brain as single particle quantum mechanics to full quantum field theory.

5 Philosophical and conceptual foundations of consciousness science

Revonsuo Revonsuobook discusses both philosophical, historical, and conceptual foundations of consciousness science. In the following I will restrict the attention to philosophical and conceptual foundations. In the following discussion the book of Revonsuo serves as excellent reference providing also references to various articles relating to the topics discussed so that I have not included them.

5.1 Philosophical foundations

Revonsuo distinguishes between dualism and monism as basic approaches and discusses in detail both kind of approaches and in section "Why the mind-body problem will not go away?" considers the basic problems (explanatory gap/hard problem) shared by both approaches. In materialism the understanding of qualia, phenomenal experience, is the problem. In dualism the assumption of material and mental as separate "substances" leads to problems with the laws of physics. If one assumes that the mental causation to reduces to that of laws of classical physics, consciousness loses its causal role and becomes a mere epiphenomenon.

Quantum consciousness allows a third philosophical approach giving hopes of avoiding the problems of monism and dualism. This view is not discussed by Revonsuo. If quantum jump is identified as a moment of consciousness, the attempts to reduce the phenomenal aspects of consciousness to the properties of quantum states do not make sense. Consciousness would be in the change, in the recreation of quantum world.

The challenge is to understand that the contents of consciousness represents also properties of the internal and external world at least approximately invariant under quantum jumps (mental images must represent useful information: rules, memory mental images, self model, model for the external world, etc...). Here quantum theory provides a solution: interaction free measurement [B1] allows in arbitrarily good approximation to obtain conscious knowledge about subsystem (defining memory representation now) without changing its state.

5.2 Conceptual foundations

Revonsuo also discusses conceptual foundations of consciousness.

5.2.1 Phenomenal consciousness and qualia

1. Phenomenal consciousness and qualia should certainly be the central concepts of consciousness science. Ironically, in many theories of consciousness (eliminative materialism and some forms of

functionalism and representationalism) qualia and phenomenal consciousness are not accepted at all so that not much remains to be explained as Dennett's "Consciousness Explained" (title of this book) expresses it.

In TGD framework quantum jumps is naturally the source of phenomenal consciousness and qualia cannot be properties of the state since they are assigned with the re-creation of the Universe in quantum jump. This means that the "-ness" in "consciousness" is not appropriate. In finnish language the word "tajunta" would be much more appropriate word.

One must of course considerably generalize the notion of quantum jump from the state function reduction of wave mechanics in order to understand basic aspects of conscious experience. In ZEO the positive energy parts of zero energy states are characterized by quantum numbers. In complete analogy, fundamental qualia can be labeled by the increments of various quantum numbers in quantum jump for positive/negative energy part of zero energy state.

2. Phenomenal consciousness seems to consists of centre and periphery. Attention seems to distinguish between centre and periphery. Whether a genuine background is present in phenomenal conscious experience is however difficult to test, say by introspection.

   Change blindess and inattentional blindness are general phenomena involving no brain disorder and in strong conflict with the intuitive belief that sensory experience represents all that is present in the perceptive field. In experiments demonstrating change blindness subject person sees a complex visual scenery. A little bit later the subject person is shown second picture and told that some big change distinguishes it from the first picture. As a rule subject persons are unable to identify this change unless they have directed their attention to just the particular feature that changes. Change blindedness obviously relates to the memory representations about the earlier sensory percepts. It seems that without attention they do not become parts of the memory representation.

   Inattentional blindness means that subject person concentrated on some cognitive task, does not notice unexpected stimuli in the perceptive field. A classic example is a situation in which person focuses attention to basket ball and fails to notice a person walking over the playground in gorilla mask. These findings have inspired the hypothesis that attention can be equated with consciousness and that only the target of attention is in the spotlight of consciousness. The mental image representing person in gorilla mask would not be negentropically entangled with the memory representation.

5.2.2 Attention

What attention could then mean in TGD framework?

1. Both change blindness and inattentional blindness that the mental images representing object of perceptive field becomes part of memory representation when it is attended. This suggests that attention corresponds to the generation of negentropic entanglement binding the new mental images to the negentropically entanglement sequence of earlier mental images. Generation of negentropic entanglement would characterize attention. Clearly, attention cannot be equated with consciousness.

   We do not usually remember our dreams unless we wake-up immedately: could this be due to the fact that the dream mental images are not attended unless person wakes up during the dream? Could the objects of dream percept attended during lucid dreaming?

2. The target of attention should become a part of self + world model of the perceiver at the level of cognitive and memory representations at least. To direct attention is to store as a memory. If this does not happen, there is no potentially conscious memory about the object (memory recall would correspond to interaction free measurement) although it t could contribute to phenomenal consciousness even when it is not attended. Illusions in which subject person is deluded to identify some inanimate system as his body part are consistent with the proposed definition of attention.

3. I have proposed the formation of magnetic flux tubes connecting target of attention and perceiver as a space-time correlate of attention. "Perceiver" would correspond to a space-time sheet

to which one can assign a negentropically entangled collection of sub-CDs representing a model for self + external world. Obviously the systems connection by a bridge of attention would form a single macroscopic quantum system. The negentropic entanglement of zero energy states associated with corresponding sub-CDs weoul be the quantum correlate of attention. At imbedding space level the correlate could be overlap of the M^4 projections of the CDs involved.

Various meditation practices suggests that the attention ican be generated also when the target is inanimate object and means the experiencer becomes one with the target of attention. The recent experiments of Persinger [J14, J15, J16] provide support for the role of magnetic flux tubes as correlates for the formation of macroscopic quantum coherence binding the two systems to single quantum system.

4. Selective attention would also mean a state function reduction for a particular sub-CD representing sensory mental image negentropically entangling it with the collection of sub-CD:s representing self model of perceiver but eliminating its entanglement with sub-CDs representing other objects of the perceptive field.

5. Attention would have metabolism as a physiological correlate. I have proposed that ATP either carries negentropic entanglement and transfers it to the target or that the energy liberated in the process ATP$\rightarrow$ ADP generates negentropic entanglement. I have also proposed that ATP $\rightarrow$ ADP process means standardized manner to build reconnection in the network of magnetic flux tubes changing the connectedness of the magnetic Indra's net between bio-molecules. In the case of two objects with disjoint magnetic bodies, reconnection of the flux tubes means that they become connected by a pair of magnetic flux tubes making possible negentropic entanglement. This is just what should happen when the new mental images is connected to the negentropically entangled connection of old mental images. Therefore a rather direct connection with metabolism, attention, and building of sensory representations seems to emerge.

5.2.3 Reflective consciousness

Reflective consciousness is second key aspect of consciousness besides phenomenal consciousness. Some consciousness theorists accept only reflective consciousness since it makes consciousness theorizing easy by allowing the reduction of brain to classical computer.

1. Reflective level of consciousness is typically about conscious experience itself and is often equated with the formation of representations. Becoming conscious about what one was conscious suggests however strongly that the representations are extended in this step. The binding of new mental images by negentropic entangled to a negentropically entangled collection of older mental images is what would happen in this process and the dynamics of quantum jump in ZEO would automatically induce this process.

2. The mathematical description of abstraction involves two elements: tensor product and direct sum. Tensor product identified as a correlate for association is the first element. The higher the abstraction level, the larger the number of factors in the tensor product. For instance, various sensory qualia are tensor producted in associative areas so that large number of different views about object a generated simultaneously.

   Direct sum by superposing perceptively equivalent zero energy states represents the averaging aspect of abstraction allowing to get rid of un-necessary details and to see the wood from trees. The measure for the abstraction level for direct sum can be identified as perceptiv/cognitive resolution. The notion of resolution emerges unavoidably from the notion of p-adic manifold based on cognitive maps mapping real preferred extremals of Kähler action to their p-adic counterparts and their inverses. This map is defined only for a discrete set of rational points (also algebraic for algebraic extensions of p-adic numbers). A reasonable working hypothesis is that the preferred extremals in the quantum superpositions have same discretizations characterized by the resolution. An alternative working hypothesis is that they have same geometric correlation functions in the resolution used.

3. In particular, quantum jump typically implies the increase of the size scale of CD involved and the addition of tensor factors to the negentropically entangled structure representing self model and model for self + external world.

5.2.4 About the definition of consciousness

The notion of consciousness is rather fuzzy and there is large number of definitions of consciousness which emphasize some aspect of consciousness and neglect others. Revonsuo lists some definitions and discusses their failures.

1. Consciousness as the ability to respond to stimulation emphasizes the visible behavioral aspects of consciousness state (ability to respond to them). The problem is that pure reflex responses are not conscious-to-us and person can be fully paralyzed and still be fully conscious. Responsiveness would be better term than consciousness in this case.

2. Consciousness as the ability to represent information from the extermal world. This definition applies only to the representative part of conscious experience and one can imagine a person having phenomenal conscious but without ability to build cognitive representations. Living matter and also computers and even camera form representations about external world so that this ability obviously not complete characterization of consciousness.

3. Consciousness defined as wakefulness requires both awareness about self and environment and ability to respond to changes in the environment. Dream experiences represent the obvious objection now.

4. Consciousness as access to output systems, control of behavior or behavioral interactions with the world. Functionalists want to reduce consciousness to the existence of some input-output function and define consciousnessas "acccess consciousness". Conscious information is information which can be represented verbally or realized as a motor response. This definition neglects completely the phenomenal aspects of consciousess and according to it computers are conscious.

All the definitions discussed by Revonsuo regard consciousness as a property of system. If this property is physical then consciousness becomes epiphenomenon without causal role. In TGD framework the identification of quantum jump as consciousness means that consciousness is not a property of physical world but something between two physical worlds.

6 Philosophical and empirical theories of consciousness

Revonsuo [J29] analyzes in detail selected philosophical and empirical theories of theories of consciousness demonstrating their problems.

6.1 Some philosophical theories of consciousness

Revonsuo discusses as examples of philosophical theories of consciousness.

- Multiple drafts theory [J9] (Dennett, see `http://en.wikipedia.org/wiki/Multiple_drafts_theory`),
- Sensorimotor theory [J24] (O'Regan and Noe, see `http://nivea.psycho.univ-paris5.fr/Synthese/MyinFinal.html`).
- Biological naturalism [J30] (Searle, see `http://en.wikipedia.org/wiki/Biological_naturalism`).
- Naturalistic dualism [J6] (Chalmers, see `http://en.wikipedia.org/wiki/David_Chalmers#Philosophy_of_mind`)
- Higher order theories of consciousness (HOTs) [J5] (entire industry).
- External representationalism [J32, J10] (Tye, Dretshke, see `http://en.wikipedia.org/wiki/Fred_Dretske`)).
- Neurophenomenology [J3, J33] (Varela, Lutz, Thompson, Noe, see `http://en.wikipedia.org/wiki/Neurophenomenology`).
- Reflexive monism [J34] (Velmans, see `http://en.wikipedia.org/wiki/Reflexive_monism`)).

- Virtual reality theory [J20, J23] (Metsinger, Lehar)). The book of Revonsuo gives a lot of references to these theories.

In the following some comments about these theories from TGD vantage point.

1. Dennett can be seen as eliminative materialist and functionalist. Dennett's theory denies qualia, phenomenal consciousness, and subjectivity - all that is usually counted as core elemens of consciousness - and accepts only representational, narrative consciousness. Consciousness accompanies complex, parallel information processing system in this framework and complex enough computer is conscious in Dennett's Universe. "Multiple drafts" means that different streams of information are competing with each other to get access to output systems - or to gain fame in brain - as Dennett puts it. The competion for metabolic resources between subselves could correspond to this competion in TGD framework.

2. Sensorimotor theory of O'Regan and Noe defines consciousness as ways of acting or as something we do, rather as phenomenal experiences or internal representations. The relation to the external world becomes decisive. The conclusion is that consciousness does not involve brain activity at all so that the search for neural correlates of consciousness would be waste of time. Also the notion of phenomenal consciousness is rejected. There are obvious killer objections against sensorymotor theory. People who are totally paralyzed can still be conscious. Dreams - whose reality even very few philosophers are ready to deny - serve as a second killer objection against the theory.

3. Biological naturalism of Searle identifies consciousness as a biological phenomenon, a higher level emergent feature of brain activity. In acccordance with the materialistic dogma conscious phenomena would be caused by the neurobiological propertes of neuronal systems and consciousness has no causal powers. Subjectivity - first person ontology as philosopher would put it - is however accepted and not assumed to reduce to any objective neurophysiological phenomenon so that consciousness becomes more or less a miracle. The theory therefore assumes strong emergence as opposed to weak emergence meaning that consciousness can be explained using physics. The problem is that there is no ideas about the systems for which phenomenal consciousness should emerge.

   In TGD framework quantum jump would bring in subjectivity. Miracle like emergence is not needed and subjectivity is assigned with a basic process of quantum physics.

4. Chalmers is known for introducing the hard problem: How any physical system can product any experiential, qualitative states at all? Chalmers's naturalistic dualism is a dualistic theory which does not regard phenomenal experience as a part of the physical world but accepts it as an internal representation of information. Chalmers does not however postulate "eternal soul" as Descartes did. The consistency with the laws of physics forces to conclude that consciusness has no causal powers. Chalmers approach implies panpsychism: all physical systems have some kind of phenomenal consciousness.

   The solution of hard problem in TGD approch relies of the identification of quantum jump as moment of consciousness. Consciousness is not assigned with the state but with its change. Panpsychism is unavoidable and self hierarchy expresses this concretely. In TGD consistency with the laws of quantum physics is achieved and the more refined view about quantum jump allows to understand the basic sensory input-motor action sequence at various levels of self hierarchy.

5. In higher order theories (HOTs) consciousness is always reflective consciousness. Phenomenal consciousness is denied and all conscious experiences are representational (intentionality, aboutness, directedness). HOTs deny consciouesness from all creatures no able to formulate higher order thoughts. Therefore infants and animals are doomed to be unconscious zombies in HOT universe.

   In TGD framework the negentropically entangled states defining abstractions and rules at various levels of hierarchy would define almost invariants about which interaction free measurements provide information. This conscious information would be the only kind of conscious information accepted in HOTs as conscious information.

6. Externalistic representationalism (Tye, Dretske) assumes that brain constructs only representations of inputs coming from the external world. Therefore also phenomenal aspects, qualia, are something in the external world and only represented in brain. Redness of rose is thus a property of rose, not something generated by the absorption of photons of certain wavelength in retina. The idea that the visual perception of distant galaxy would mean direct experiencing of its visual qualia seems rather strange - at least in the universe of standard physics. The question how the qualia of external world are represented in brain represents a difficult problem for externalistic representationalism.

   The idea that sensory qualia are in the external world looks rather weird in standard physics framework. In TGD framework qualia are assigned with sensory organs defining the boundary between internal and external world for a given CD. In TGD Universe consciousness is however not restricted to brain. The hierarchy of dark matter realized as phases with effective value of Planck constant coming as integer multiple of the ordinary Planck constant and residing at magnetic flux quanta makes macroscopic quantum coherence possible in arbitrarily long length and time scales so that it is quite possible to imagine that the contents of our conscious experience can contain contributions from quite long length and time scales.

   p-Adic space-time sheets have literally infinite size in real sense (this statement makes sense for common rationals and some common algebraic points) so that cognition is in TGD framework a cosmic phenomenon and only cognitive representations defined by the discrete intersections of real and p-adic space-time sheets are located inside CDs.

6.2 Some empirical theories of consciousness

Revonsuo discusses also current empirical theories of consciousness taking as examples the following theories.

- Global workspace theory [J4] (Baars, see `http://en.wikipedia.org/wiki/Global_workspace_theory`).
- Neurobiological theory [J7] (Crick and Koch, see `http://en.wikipedia.org/wiki/The_Astonishing_Hypothesis`).
- The dynamic core theory [J11] (Tononi and Edelman, see `http://en.wikipedia.org/wiki/A_Universe_of_Consciousness`).
- The integrated information theory [J31] (Tononi, see `http://en.wikipedia.org/wiki/Integrated_Information_Theory_(IIT)`).
- Thalamocortical binding theory [J22] (Llinas, see `http://en.wikipedia.org/wiki/Rodolfo_Llins`).
- Recurrent processing theory [J19] (Lamme, see `http://www.ini.unizh.ch/~peterk/Lectures/AttentionSeminar/Lamme.Tins.00.pdf`).
- Microconsciousness theory [J35] (Zeki, see `http://en.wikipedia.org/wiki/Semir_Zeki`).
- Consciousness as the feeling of what happens [J8] (Damasio, see `http://en.wikipedia.org/wiki/Damasio`).

In the following some TGD inspired comments about these theories.

1. The neurobiological theory introduced the hypothesis that 40 Hz frequency assignable to thalamocortical resonance (see `http://en.wikipedia.org/wiki/Recurrent_thalamo-cortical_resonance`) is fundamental for binding the conscious experiences. The motivation is that thalamus has dense net of bi-directional loops to cortex. It turned out later that this resonance is strong only when the objects of perceptive field are recognized.

(a) A possible TGD inspired interpretation is based on the observation that negentropic entanglement is generated during the sensory perception as the sensory mental image or its representation at cortex negentropically entangles with the earlier sensory mental image or its cortical representation to form an updated memory representation. This stage could involve 40 Hz resonant interaction with the earlier stored sequence of sensory memories giving rise to the negentropic entanglement (the proess is driven by NMP).

(b) The experience of understanding that I earlier erratically assigned with negentropic entanglement (in conflict with NMP!) would be assigned with the *generation* of negentropic entanglement (in accordance with NMP!) and with the defining postulate of TGD inspired theory of consciousness. Revonsuo has performed an experiment which demonstrates that 40 Hz resonance appears when a random looking visual pattern consting of dots and short line segments is recognized to represent 3-D object but fades out after the recognition [J28]. The finding conforms with TGD based interpretation.

(c) In TGD framework thalamus would suggest itself as a central self representing "me" having as subselves the negentropically entangled mental images assignable to cortex (reflective consciousness) and the sensory mental images assignable to various sensory organs (phenomenal consciousness).

2. Damasio's theory emphasizes the importance of emotions as a basic building brick of conscious experience. In TGD framework emotions are associated with negentropy: positive emotions correspond to negentropy gain and negative emotions to negentropy loss. NMP states that the information gain in state function reduction is maximal and is therefore analogous to second law and indeed implies for ordinary entanglement second law at the ensemble level [K9]. NMP suggests the analog of thermodynamics and even non-equilibrium thermodynamics for negentropic entanglement. In the presence of constraints on zero energy states (fixed average energy, particle number, etc..) this would imply existence of parameters analogous to temperature, pressure, etc..) so that the use of thermodynamical quantities as metaphors for the macro aspects of consciousness would have justification. In this picture emotions define a central element of experience.

6.3 Major issues of disagreement between theories

Revonsuo summarizes the two chapters by discussing the major issues of disagreement between theories of consciousness. These issues concern the location of consciousness (externalism vs. internalism), the fundamental nature of consciousness (phenomenology vs. cognition), and fundamental form of phenomenal consciousness (atomism vs. holism).

6.3.1 Internalism vs. externalism

Internalism and externalism are basic views about the location of phenomenal conscious experience.

1. Internalism assumes that the neurophysiological and functional state of the brain determines the contents of consciousness. It seems possible to understand the representational aspects of consciousness: brain decomposes sensory field to objects and gives them names represented as patterns of neuronal activity. The understanding of how phenomenal consciousness, qualia, is not so easy. The neurons look the same everywhere and it has not been possible to point out or even imagine how the the organizational structure of the neurons could give distinguish between say hearing, vision, and touch although they all carry geometric and dynamical information.

2. Externalism locates qualia in the external world and that brain only represents them. This option has been already discussed.

What happens in TGD Universe?

1. The first thing to observe is that in TGD framework it is not possible to locate consciousness anywhere: consciousness is in the quantum jump, between two zero energy states of the Universe. The contents of consciousness can be however localized and one could ask whether the seat for the contents of conscious experience is located inside or outside brain. Actually this is too

limited formulation if one takes seriously the self hierarchy and the notion of magnetic body implying that brain alone is not the seat for the contents of consciousness in TGD Universe.

2. In TGD framework both internalism and externalism are both right and wrong: qualia are in the intersection of external and internal worlds defined appropriately. Sensory organs define examples about this kind of intersection but there is fractality involved. Also cell membranes can be seen as sensory organs. This picture follows from the basic assumptions of quantum TGD.

   (a) Strong form of general coordinate invariance implies strong form of holography. Already holography implies that space-time surfaces as carriers of geometric information provide classical space-time correlates associated with the light-like 3-surfaces representing the orbits of partonic 2-surfaces representing boundaries between space-time regions with Euclidian and Minkowskians signatures of the induced metric. By strong form of holography these partonic 2-surfaces and the 4-D tangent space data of space-time surface at them are enough to fix zero energy states: I call this effective 2-dimensionality.

   The partonic 2-surfaces have interpretation as boundaries of physical objects in all scales and they carry the quantum numbers and therefore also the quantum number increments are associated with them and therefore also phenomenal consciousness and qualia. The space-time regions of Minkowskian and Euclidian signature of induced metric define the space-time correlates of "internal" and "external". The partonic 2-surfaces are therefore identifiable as seats of conscious experience. It is important to notice that there is entire fractal hierarchy of partonic 2-surfaces. Partonic 2-surfaces can be also connected by strings carrying fermion number and these string world sheets connect different partonic 2-surfaces: string oscillations define sound as a fundamental phenomenon and are behind hearing and internal speech as already proposed.

   (b) Strong form of holography implies that partonic 2-surfaces and their 3-D orbits are very much like sensory organs which indeed define boundary between internal and external worlds. This motivates the assignment of qualia to sensory organs. The fractal generalization suggests that even elementary particles enjoy primitive phenomenal consciousness. p-Adic physics as physics of cognition suggests that even primitive cognition is associated with elemetnary particles.

   This would elegantly solve the basic objection against internalism since qualia would indeed strongly correlate with their physical cause (oscillations of string like objects in 4-D space-time possibly underlying sound waves, photons and possibly also other masless bosonic quanta at various wave lengths underlying vision, physical touch having topological correlate in TGD Universe).

   Phantom limb and dreams define the basic objections against this picture but it is possible to circumvent these objections if one accepts feedback from brain to sensory organs as virtual sensory input realized as dark photons travelling along magnetic flux tubes, and TGD based view about time allowing to interpret pain in non-existing limb as a sensory memory. Also erratic assigment of position to the actual pain somewhere else than non-existing limb can explain phantom pain. This kind of mis-assigments can be produced as illusions at the level of sensory representations.

   (c) There is however a question to be answered. Space-time regions can have Euclidian or Minkowskian signature of the induced metric. Does holography hold for both and do the light-like 3-surfaces between them represent holographically both. For instance, can one assign the two representations two the two sides of this 3-surface and for strong form of holography to partonic 2-surfaces and the tangent space data at the two sides of space-like 3-surface at the boundary of CD?

   Do these two representations define representations of internal qualia (virtual input from sensory representations) and external qualia (real input from external world)? Is the comparison of the virtual input generated by sensory representation with external input crucial in the construction of sensory representations: sensory representation is faithful only when these qualia are opposites of each other (when defined in terms of quantum number increments). One can get convinced about the reality of virtual qualia by swimming for some

time in windy sea. At the beach the wave motion continues in the body and can make walking difficult.

Representational aspects of consciousness are usually identified as internal aspect localizable inside brain. In TGD framework the notion of magnetic body forces to challenge this assumption.

1. The representational states identified as negentropically entangled subsystems represent association patterns and also temporal sequences of association patterns. These tend to remain unchanged under the dynamics dictated by NMP and therefore reprent information as quantum rules as superpositions of their instances. Interaction free measurement allows to get information about these representation without changing them since photon/phonon absorption represents the necessary change making this information conscious: these secondary qualia have representative role (black/white as value of bit). The representations for declarative memories, a model for external world, self model, predictions of future, plans for motor action and future,... : all this can be represented in terms of negentropically entangled states.

2. There is no reason to localize the representational states to sub-CDs inside brain although cognitive representations and naming of objects of perceptive field might be carried out by brain. The memories and plans of future (related by time reflection) could correspond to something in their real time scale and at the level of magnetic bodies this would mean size scale of Earth (EEG as communication tool to magnetic body) and even light years! Also scaled variants of these representation are expected by fractality and these zoom-ups and zoom-downs defining "stories" might be one of the key features of intelligence.

3. In the case of cognition having p-adic space-time sheets as space-time correlates, it is impossible to locate even contents of consciousness to a finite space-time region in real sense. Cognitive representations consisting of common rational and possibly also some algebraic points of real and p-adic preferred extremals of Kähler action, can be however said to be located to a finite volume of space-time defined by causal diamond.

6.3.2 Phenomenology vs. cognition

As already noticed, in TGD Universe even representational consciousness reduces always to phenomenal consciousness. Imagination and internal speech represent our experiences about phenomenal consciousness at neuronal level and the representation - as we experience it - does not carry sensory qualia. Interaction free measurements make it possible to represent the aspects of quantum states which are invariant in the dynamics dictated by NMP as secondary qualia, say those assignable to photon absorptions. The interaction free measurement can be realized also in terms of sound waves with absorption of phonon replacing the absorption of photon. This could give rise to internal speech and eventually to written language. This suggests that neuronal vision *resp.* hearing is fundamental for imagination *resp.* internal speech. One can also wonder whether there exists a translation of the worlds of language to visual images.

6.3.3 Atomism vs. holism

Atomism postulates that conscious experience can be decomposed to fundamental building bricks defining "micro-consciousness" in the same sense as matter consists of elementary paricles. Holism in turn assumes that the experience is holistic and does not have this kind of decomposition.

In TGD framework the presence of self hierarchy changes the situation. One has fractal hierarchy of levels of consciousness having length scale hierarchy of CDs as imbedding space correlate and p-adic length scale hierarchy as space-time sheets as space-time correlate. One can identify fundamental qualia as increments of quantum numbers dictated by the symmetries of TGD Universe. On the other hand, the geometric aspects of experience related to the patterns defined by subystems of negentropically entanglement subsystems defining representative aspects of consciousness do not reduce to fundamental qualia.

6.4 Common beliefs consciousness theories from TGD point of view

It seems that most theories of consciousness agree in some key aspects.

1. Brain serves as a seat of consciousness including phenomenal experience in the case that qualia and phenomenal experience are accepted at all as something real. The causal powers of conscioiusess are denied since in the ontology inspired by classical physics this would lead to difficulties.

   In TGD framework the situation is different. Brain is the seat of sensory and cognitive representations whereas phenomenal consciousness can be assigned with sensory organs. Qualia can be assigned to quantum number increments associated with quantum jump and sensory representations become conscious via secondary qualia realized as internal speech and imagination.

2. The privacy of consciousness seems to be accepted as something totally obvious. This has been formulated as question "What it feels to be a bat" claimed to have no answer.

   In TGD framework self hierarchy and the notion of magnetic body (field body) encourages to give up the belief on privacy of consciousness. Magnetic flux tubes are identified as space-time correlates for attention binding some parts of the systems connected in this manner to single quantum system so that sharing of mental images becomes possible: therefore the claim that it is not possible to feel what it is to be a bat might be wrong in TGD Universe. For a scientists it is of course very difficult to take seriously the claim that shaman could directly experience what it is to be a bear: maybe scientist should be ready to reconsider their belief system in this respect.

7 Disorders of consciousness

Revonsuo [J29] discusses also various disorders of consciousness typically associated with representative and reflective aspects of consciousness. These disorders pose strong constraints on the theories of consciousness.

In TGD framework the generation of negentropic engtanglement (directed attention) is the basic mechanism making possible the updating of memory representations. If this mechanism fails, the outcome is a disorder explaining various neurophychological deficits of consciousness and neurophysiological dissociation of consciousness from behavior. Failure to generate negentropic entanglement at all or generation of the negentropic entanglement with wrong memory representation would be the basic reasons for disorders. At physiological level ATP$\rightarrow$ ADP transition generates flux tube connections giving rise to negentropic entanglement so that the problem could reduce to dysfunction at this level.

7.1 Neuropsychological deficits of visual consciousness

The first kind of anomalies discussed by Revonsuo are neuropsychological deficits of visual consciousness. Examples of this kind of deficits are visual agnosia: loss of coherent visual objets, semantic dementia: loss of the meaning of objects, asimultangnosia: loss of the phenomenal background, neglect: loss of phenomenal space, and akinetopsia: loss of visual animation.

These anomalies clearly demonstrate the modular character of the information processing in brain. In TGD framework this corresponds to negentropic entanglement for systems representing various components of experience and represenging abstract rules. Neurophysiological deficit could imply that some component is missing (say emotional component giving meaning to the objects in semantic dementia or component represring phenomenal background). Second possibility is that the components are not at all organized to form a negentropically entangled tensor product (visual agnosia).

Loss of visual animation could mean that the sequence of negentropically entangled sub-CDs (timelike entanglement) representing the positition of object in space has too low temporal resolution. In other words visual mental images are updated with too low frequency. The resolution needed to experience discrete sequence of imagines as a continuous motion corresponds to at least 50 Hz frequency for visual mental images.

7.2 Neuropsychological dissociations of visual consciousness from behavior

Second kind of anomalies correspond to neuropsychological dissociations of visual consciousness from behavior. Examples are blind sight, implicitly visually guided action, implicit face recognition in

prosopagnosia, implicit recognition of words and objects in neglect. In most theories of consciousness self hierarchy has only one-level so that the only interpretation is that there is an appropriate zombie represent making possible these dissociations but carrying the information needed for the action in question. In TGD framework also this information would be conscious albeit not conscious-to-us.

1. Consider first the dissociation from of sensory consciousness from motor action. As described above, ZEO more or less forces to conclude that for given CD there are two "mes" corresponding to lower and upper boundary of CD and they correspond to sensory me and motor me for which motor action is time reversed sensory perception. Thus the motor me, I_m, could enjoy time reversed sensory consciousness.

2. The minimal option is that the dissociated subself is present but does not entangle negentropically to the subself system of "me" representing memory mental images. Sensory "me" I_s would have sensory qualia but since it does not attend to the target of perceptive field would not remember anything about it. I_m would have not only the time reversed sensory qualia and they would also negentropically entangle with time reversed memory representations defining plans and volitions. This would mean that motor actions using sensory information would be possible.

A person suffering from blind vision (cortical blindness is not in question) reports that she is unable to see consciously but her visual areas are intact and she demonstrates the access to visual information via successful motor activities. It could be that person has still retinal vision but this phenomenal visual images do not negentropically entangle with cortical representations so that there are no conscious visual qualia or remembered visual qualia.

The proposed picture suggests that both the sensory I_s and motor "me" I_m assignable to sub-CDs in a time scale of say .1 seconds could have phenomenal vision. Only I_m could however build sensory representations consistent with incoming information (containing also the retina level representation in the tensor product). As mental images of CD these representations would correspond to volitions, decisions, and plans: this information would be enough for coherent motor activities.

The unability to recognize faces could be due to the fact that the name of person represented as sub-CD is not negentropically entangled with the collection of visual mental images representing the face. Same applies to inability to recognize words and objects. Implicit recognition however occurs and manifests itself in measured changes of skin conductance. This would suggest that emotional response is still present and realized as negentropic entanglement of the visual sub-CD with emotional sub-CD and expressing itself motorially as change a in skin conductance. The change of skin conductance would therefore be neurophysical correlate for time reversed sensory input.

7.3 Neurophychological disorders of self-awareness

Neurophychological disorders of self-awareness represent third kind of anomalies of consciousenss discussed by Revonsuo and include amnesia, split-brain state, anosognosia, asomatognosia, and deficits of belief systems (delusions). An interesting observation is that left-hemisphere acts as a rationalizing interpreter capable of amazing self deceptions and right hemisphere takes the role devil's advocate.

1. In the case of amnesia the patient lives in eternal now but can remember the events before he became amnesic. Hippocampus seems to be at least partially responsible for constructing memories so that either memory construction or memory recall fails for these memories. One possibility is that for some reason the sensory mental images representing personal history are not anymore negentropically entangled in time direction so that self model is not up-dated. An alternative, but perhaps not so plausible, explanation is that the interaction free measurement reading these mental images fails for some reason.

2. Split-brain state is artificially induced by splitting the corpus callosum. In this state patient behaves as had possessed two separate selves, which can have conflicting future plans, desires, and actions. This seems to be in strong conflict with standard views about consciousness but if one accepts self-hierarchy this is just what is expected. Corpus callosum would entangle the different brain hemispheres to single unit.

   The non-trivial topology of TGD space-time makes also sharing of mental images possible since two unentangled selves can have entangled subselves. This corresponds to a situation in which

one has two space-time sheets which are disjoint but there are smaller space-time sheets (subselves) topologically condensed on them and connected by flux tubes. In the appropriate resolution the larger space-time sheets are un-entangled whereas smaller space-time sheets in their own and better resolution are entangled.

3. In the case of asognonosia thr patient has some deficit but is not conscious about it, and fabulates all kinds of explanations for why the deficit manifests itself in this behavior. The deficit could be paralysis, cortical blindness, neglect of second half of perceptive field, or something else. The simplest explanation is that the self-model is not updated so that basically a failure of negentropic tensor producting would be in question.

   A cortically blind person suffering Anton's syndrome claims that he sees. If qualia are seated at sensory organs, person could have genuine visual qualia if the retina is intact. Flawless sensory representations are necessary for a successful motor action since the zero energy state resulting in motor action is obtained by state function reduction from the zero energy state defining sensory and memory representations. Therefore the loss of appropriate cortical visual representations would make person effectively blind even if phenomenal vision is intact.

   Patient can also suffer from paralysis and refuse to admit that something is wrong. Besides the general explanation one could also consider the possibility that motor representations still contain the lowest level as time reversed sensory representation. This explanation would be analogous to that for Anton's syndrome.

4. In asomatognosis person denies the possession of part of his own body. Also this disorder could be understood if the representation of that part of body is not negentropically entangled with representations of other parts of the body.

8 Altered states of consciousness

Revonsuo [J29] devotes three chapters to altered states of consciousness (ASC) discussing dreaming and sleep as ASCs, hypnosis as a candidate for ASC and higher states of consciousness as ASCs.

8.1 Dreaming and sleep as ASC

The first chapter about ASCs is devoted to dreaming and sleep as altered states of consciousness. Hypnagogic and hypnopompic hallucinations, sleep paralysis, sleep mentation vs. dreaming, the contents of dreaming, lucid dreaming, bad dreams and nightmares, night terrors, sleepwalking and nocturnal wander, and sleep behavior disorder and dreamwalking are the titles of the sections and give a good overall view about topics discussed.

In preceiding sections I have already discussed TGD view about dreams as virtual sensory experiences generated by the input from brain or even magnetic body to the sensory organs, which in TGD Universe serve naturally as seats for the contents of phenomenal experiences. This interpretation distinguishes TGD from the competing theories of consciousness.

8.2 Hypnosis

Second chapter about ASCs is devoted to hypnosis as a possible candidate for ASC and discussed hypnotic induction and hypnotic suggestivity.

Hypnosis can be seen as a challenge to the cherished belief about the privacy of consciousness. Hypnotist and subject person indeed seem to form a larger coherent unit in which the motor system of the subject person becomes effectively part of the motor system of hypnotist. Hypnotist can also induce suggestions giving rise to sensory experiences what could be regarded as hallucinations, perhaps by inducing virtual sensory inputs, which also can be seen as motor actions in very general sense. The formation of negentropic entanglement by the generation of magnetic flux tubes connecting the subject person and hypnotist would be part of the TGD based model. This would allow the hypnotist to negentropically entangle with the self model of the subject at highest level and realize his volitions using the motor system of the subject person.

8.3 Higher states of consciousness

The third chapter devoted to ASCs is about higher states of consciousness: meditation, optimal experience and flow, runner's high, OBEs, NDEs, and mystical experiences. In several experiences of this kind sensory input and motor activity contribute minimally to the conscious experience. Typical for OBEs is that person sees his own body from third person perspective

Remark: Besides genuine OBE like experiences I have personally had also OBE like experiences in which I see my body in somewhat surreal perspective and find myself floating in the roof and thinking hardly for possible tests whether I am really levitating.

OBEs and in particular NDEs obviously challenge the belief that brain alone is the seat of consciousness. Therefore it is not surprising that both OBEs and NDEs are labelled as pathological in materialistic approach to consciousness (or what is left from it after application of the basic dogmas). It is of course possible that this kind of conscious experiences become possible under some brain disorders such as epilepsy.

The explanation of NDE as a kind of final activity of a dying brain looks rather artificial: especially so because these experiences are highly structured and coherent and rather universal rather than being chaotic as one might expect if the state of consciousness corresponds directly to the state of brain as materialistic dogma states.

8.3.1 OBEs and NDEs

TGD suggests the following approach to OBEs [K11] and NDEs.

1. The notion of magnetic body (bringing in mind the "aether body" of the esoteric teachings) could have central role in TGD inspired quantum biology and neuroscience, and especially so in the explanation of OBEs and NDEs. EEG and its scaled variants would provide control and communication tool for the magnetic body and also lower frequencies than those appearing in EEG could be involved so that the flat EEG during NDEs would reflect only the absence of sensorimotor activities.

2. The highest level sensory representations would be naturally realized at magnetic body and give rise to sensory representations about biological body and even its environment and in this manner give rise to the third person aspect of consciousness. If this is the case, one could understand how it is possible to see own biological body as an outsider during OBEs and NDEs.

   The representations at the magnetic body could in turn generate virtual sensory input as a feedback down to the level of sensory organs also in the ordinary wake-up consciousness as a check that these representations are consistent with the sensory input. The mechanism for generating the sensory input as dark photons and perhaps also dark phonons has been already suggested in the discussion of interaction free measurement as a manner to read memory representations.

3. This model is consistent with the correlation of these experiences with the epileptic seizures. Epileptic seizure could lead to a failure to communicate sensory data to the magnetic body by EEG and also to a failure to receive signals from the magnetic body reflecting itself as chaotic motor activities. Therefore the contribution of magnetic body and third person perspective would dominates the experience.

4. One can argue that in absence of sensory input and motor activity, and perhaps even neural activity (EEG in many NDEs is flat) the contribution of the magnetic body to the conscious experience dominates. Magnetic body could provide the virtual sensory input even during ordinary dreams and dreams might be seen as a kind of simulation of the external world by virtual input from the magnetic body and as brain level interpretation for what possibly happens at the level of the magnetic body. Also motor actions could be simulated as motor actions of the magnetic body. Maybe purely mental image exercises known to have genuine effect on motor skills could be interpreted as motor exercises performed by magnetic body!

5. Also some illusions such as moving train illusion (the sensation that the stationary train in which person is sitting moves induced by a train passing by) could be understood as resulting from the motion of personal magnetic body relative to the biological body. The moving train catching the attention of the subject person (recall the proposal that attention has magnetic flux tubes as a correlate) would anchor the magnetic body of the subject person to its rest system.

6. The unpleasant sensation of falling down near a precipice could be due to the imagined falling down. It would be magnetic body which represents the falling down and its acceleration with respect to the biological body generates the sensation. Magnetic body quite generally simulate the motion of biological body and the discrepancy between the simulation and real motion of biological body would generate a conscious experience. If the simulation is ideal, no conscious experience would be generated. This would allow to understand why the learned skill becomes unconscious routine. Similar simulations would take place already in the case of sensory input as already proposed. If time reversal relates motor activity and sensory perception, this kind of symmetry is very natural.

8.3.2 Mystical states

The third chapter about ASCs is about mystical states. Mystical experiences have often long-lasting effects on the life of the experiencer as increased spontaneity and courage to choose one's own way to live. Typically it is difficult to express verbally the contents of experience: for instance, the writings of Krishnamurti emphasize this. I have had some spontaneous mystical experiences of my own, and in the following I will take the liberty to insert remarks about them to the nice summary of Revonsuo about emotional, cognitive and perceptive aspects of mystical stats.

- Emotionally mystical states are highly positive: peace, calmness, harmony, love, joy, awe, bliss are the words used to characterize the emotional state. The realization that everything in the Universe has a deep hidden meaning makes these experiences so special. Universe is experienced a a holy place, not at all that dirty world of everyday experience.

- Mystical states involve the experience of deep understanding of underlying principles of existence and direct answers to deep questions about life and existence. Dramatic expansion of consciousness to even cosmic consciousness is also reported. There is also a direct experience about hierarchical structure of conscious existence and about communication with higher levels of the hierarchy. In religious experiences God represents one (in monoteistic religions often the only accepted) higher level in the hierarchy.

  Remark: In my own mystical experiences I had deep experience of understanding but without knowing what it was that I understood. In the light of afterwisdom the ideas that I became conscious of during these experiences for almost three decades ago could be interpreted as precognitions about some basic ideas of TGD and TGD inspired theory of consciousness.

- Mystical states are also accompanied by a heightened sensory consciousness. The world looks extremely bright, clear, brilliant, colorful, and pure.

  Remark: My own experiences began with the increase of the experienced intensity of the sounds from environment.

- *Remark*: The experience about own body can change dramatically. The usual unpleasant sensory noise suddenly disappears and the entire body ends up to what might be called fluid like state: experience is akin to the sensation localizable to spine that music sometimes creates. In my own case this was actually the beginning of the experience.

- Enlightment experiences are regarded as the highest form of mystic experience and involves the experience timelessness, emptiness, liberation from all attachments, and the realization that even self is an illusion.

Could one say something interesting about these experiences in TGD framework?

1. The experience about hierarchical structure of consciousness is certainly consistent with TGD view which however derives from the mathematical structure of the theory (fractal hierarchy of quantum jumps) rather than being assumed on basis of my personal mystical experiences.

2. The generation of negentropic entanglement should be accompanied by the experience of understanding and the large increase in the size of personal CD could generate large amount of negentropic entanglement. This could also explain the strongly positive emotional coloring of the experiences in general. The experience of understanding would mean genuine understanding but perhaps at levels remaining unconscious or indescribable using the existing tools of language.

3. The generation of negentropic entanglement at the scales of biological body leading to enhanced quantum coherence could create the dramatic change in the experience about own body.

4. The personal magnetic body could be significant in mystic experiences. A phase transition increasing $\hbar_{eff}$ could scale up the size of some parts of the magnetic body. Reconnection mechanism could make possible fusion of the magnetic body with other magnetic bodies: this could relate to the sensation of becoming one with the external world and disappearance of separations. Krishnamurti has beautifully described the experience of becoming the people around him. Also t this experience challenges the belief on absolute privacy of consciousness.

5. The hierarchy of quantum jumps assignable to the hierarchy of CDs with various scales is basic prediction of TGD inspired theory of consciousness. The characteristic time scale of long term memories and planned action and size scale of the perceptive field are natural characteristics for the level of self in self hierarchy. Mystic experiences could correspond to a state function reduction leading to an especially large average size scale of CDs involved in quantum superposition of zero energy state representing "me". This would mean higher abstraction level and large. A phase transition leading to an exceptionally large increase of the effective Planck constant $\hbar_{eff}$ scaling up the size of CD is a good guess for what might happen.

6. Could one find quantum correlate for the experience of understanding without any mental images and without knowing what it is that one understands? This seems to be the case on both reported and my personal experiences. Hence I am forced to ask whether the invariants defined by various representations could be experienced directly in absence of the memories generated by interaction free measurements and giving rise to cognition. The "Akashic records" defined by the negentropically entangled representations would be the counterpart for this wisdom, which can be only felt but not expressed using language or pictures. Accepting this would force to give up the hypothesis that the change in quantum jump alone contributes to conscious experience: also what remains invariant in quantum jump would do so.

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