Quantum Statistical Brain

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Contents

Abstract

This chapter was originally inspired by the findings of Li et al, which can be summarized as follows. Humans know the uncertainty of their working memory and use it to make decisions; the content and the uncertainty of working memory can be decoded from BOLD signals; decoding errors predict memory errors at the single-trial level; decoded uncertainty correlates with behavioral reports of working memory uncertainty.

Later I learned about the findings of Manassi and Whitney about the stability illusion of perceptions making the world look smoothly changing and effectively shifting the perception towards the past.

It is not too surprising that the states of feature detector neurons obey a statistical distribution. It is however not obvious that the reliability of the memory should correlate with the width of this distribution and that even the subjective estimate for the reliability should reflect this width.

If one accepts the notion of a quantum brain, the distribution of features could reflect the non-determinism of the outcome in the reduction of entanglement quantum measurements producing sensations.

Zero energy ontology (ZEO) leads to the notion of 4-D brain and suggests that the feature ensemble is not spatial, as it should be in standard quantum theory, but a temporal ensemble formed by the memory mental images of the feature. Quite generally, in ZEO sequences of "small" state function reductions (SSFRs) as counterparts of so called weak measurements would form temporal ensembles of memory mental images so that the connection with short term memory would be direct. This picture explains the findings of both Li et al and Manassi and Whitney.

1 Introduction

The considerations of this chapter were inspired by two popular articles. The first popular article (`https://cutt.ly/1IM14xa`) told about findings [J6] (`https://cutt.ly/aIM0ajF`) of Li et al supporting the view that neural noise carries information in the sense that it represents the uncertainty of visual short term memories so that both the content of memory and its uncertainty are represesented.

Second inspiring popular article published in Science Times (`https://cutt.ly/iONjRI2`) had a long title "*Are We Living In the Past? New Study Shows Brain Acts Like A Time Machine That Brings Us 15 Seconds Back*". It caught my attention because the basic prediction of TGD inspired theory of consciousness is that the perceptive field is 4-dimensional rather than 3-D time=constant snapshot as in standard neuroscience.

The original article by Mauro Manassi and David Whitney, published in Science Advances [J9] (`https://cutt.ly/lONjIQn`), has a less provocative title "*Illusion of visual stability through active perceptual serial dependence*". The findings suggest that visual perception is a kind of temporal average over a time interval, which can be even longer than 15 seconds.

1.1 The findings of Li et al

1.1.1 Does neural noise carry information about the uncertainty of visual short term memories?

The highlights of Li et al are following:

- Humans know the uncertainty of their working memory and use it to make decisions.
- The content and the uncertainty of working memory can be decoded from so called BOLD signals.
- Decoding errors predict memory errors at the single-trial level.
- Decoded uncertainty correlates with behavioral reports of working memory uncertainty.

The abstract of the article provides an overall view about what has been done and found.

> Neural representations of visual working memory (VWM) are noisy, and thus, decisions based on VWM are inevitably subject to uncertainty. However, the mechanisms by which the brain simultaneously represents the content and uncertainty of memory remain largely unknown. Here, inspired by the theory of probabilistic population codes, we test the hypothesis that the human brain represents an item maintained in VWM as a probability distribution over stimulus feature space, thereby capturing both its content and uncertainty.
> We used a neural generative model to decode probability distributions over memorized locations from fMRI activation patterns. We found that the mean of the probability distribution decoded from retinotopic cortical areas predicted memory reports on a trial-by-trial basis. Moreover, in several of the same mid-dorsal stream areas, the spread of the distribution predicted subjective trial-by-trial uncertainty judgements. These results provide evidence that VWM content and uncertainty are jointly represented by probabilistic neural codes.

It is not surprising that the states of feature detector neurons should obey a statistical distribution. It is however not obvious that the reliability of the memory should correlate with the width of this distribution and that even the subjective estimate for the reliability should reflect this width.

1.1.2 Does the distribution in the feature space reflect quantum non-determinism?

Could the distribution in the feature space reflect quantum non-determinism rather than uncertainty of sensory perceptions and somehow also the uncertainty of memories.

1. If features as states of feature detector neurons or groups of them correspond to the outcomes of quantum measurements, they have a probability distribution. The real input to these neutron would have produced this distribution and could be estimated from the probability distribution.

   The outcomes are eigenstates of density matrix determined by the entanglement and determined apart from phase factors. For instance, in the measurement of spin of spin 1/2 particle the probabilities of spin 1/2 and spin -1/2 states can be deduced for an ensemble of identical particles but the relative phase of the spin 1/2 and spin -1/2 state cannot be deduced.

2. The interpretation of quantum measurement would differ from the classical one. Classically, and according to recent neuroscience, sensory perception means that brain, system A, detects the state of system B in the external world. Quantum mechanically, the entanglement between A and B is reduced in the measurement and entangled state becomes a tensor product of are eigenstates of the density matrix. The relationship between A and B is what is "measured". For an ensemble of outcomes, the probabilities of outcomes allow to deduce information about the entanglement before measurement.

3. If the reduction of the entanglement between sensory organ and external world can be measured repeatedly, it gives rise to a distribution of outcomes coding also the uncertainty caused by the quantum measurement. This however requires that the entanglement is regenerated between these measurements. Is this possible?

The distribution of features would not reflect uncertainty of memories but the non-determinism of the outcome in the reduction of entanglement. Interestingly, in quantum computation this kind of ensemble is produced and from the distribution of outcomes of the measurement halting the quantum computation, the outcome of the quantum computation is deduced. The method is essentually statistical.

In TGD framework the notion of magnetic body (MB) using biological body as sensory receptor and motor instrument emerges as a new notion. The entanglement between magnetic body and sensory organs could be reduced in sensory perception. There is a hierarchy of levels and entanglements at them and SFR is replaed with a cascade of SFRs proceeding from long to short scales.

1.1.3 Is the feature distribution realized as a temporal ensemble?

In sensory perception, the distribution of features should correspond to a distribution of states of feature detector neurons or their groups. How is this distribution realized? How does this distribution relate to the distribution of memories?

Let us consider the questions about sensory perceptions.

1. The neuroscience based answer to question in the case of sensory perceptions would be "As a spatial ensemble consisting of feature neurons". But how does this distribution relate to the distribution of memories?

2. In TGD framework, the answer would be "As a temporal ensemble". Zero energy ontology (ZEO) leads to a new view about quantum states as superpositions of deterministic time evolutions and modifies the view about quantum measurements allowing to circumvent the basic paradox of quantum measurement theory leading to various interpretations.

   The outcome is the notion of 4-D brain, which suggests a temporal ansemble formed by memory mental images of the feature. In ZEO, the sequences of "small" state function reductions (SSFRs) as counterparts of so called weak measurements would form temporal ensembles of memory mental images so that the connection with short term memory would be direct. The spatial ensemble would be replaed by temporal ensemble experienced consciously as memories.

1.2 The findings of Manassi and Whitney

"Why do the objects in the world appear to be so stable despite constant changes in their retinal images?" was the question that motivated the work of Manassi and Whitney [J9] (`https://cutt.ly/lONjIQn`). Retinal images continuously fluctuate because of sources of internal and external noise. Retinal image motion, occlusions and discontinuities, lighting changes, and perspective changes and many other sources of noise are present. However, the objects do not appear to jitter, fluctuate, or change identity from moment to moment. Why does the perceived world change smoothly over time although the real world does not?

This problem is also encountered in quantum consciousness theories. If conscious experience consists of a sequence of non-deterministic quantum jumps as moments of consciousness, it is not at all clear how a smooth stream of consciousness is possible.

One modern explanation for the smoothness of conscious experience is some kind of change blindness or inattentional blindness. The finite capacity of visual short-term memory is certainly a fact and forces a finite perceptive resolution and effectively eliminates too fast temporal gradients. This finite resolution poses limits in perceptual, decisional and memory processing. This would naturally apply also to other sensory memories.

In the standard view sensory percept corresponds to a time=constant snapshot of the physical world. The basic prediction is that the object at a given moment of time is the real object but in a finite perceptive resolution.

The alternative hypothesis studied in the article is that the visual system, and presumably also other sensory systems, use an active stabilization mechanism, which manifests as a serial dependence in perceptual judgments. Serial dependence causes objects at any moment to be misperceived as being more similar to those in the recent past. The serial dependence has been reported in the appearance of objects, perceptual decisions about objects, and the memories about objects. In all of these examples, serial dependence is found for random or unpredictable sequential images.

This raises the question whether one can understand the serial dependence by identifying the conscious perception at a given time as a weighted temporal average of preceding time= constant perceptions over some time interval T and what additional assumptions are needed to understand the other findings related to the phenomenon. This is what the model explaining the findings of Li et al indeed suggests.

1.3 TGD based view about sensations and short term memories

To develop a more detailed model based on the proposed ideas, one must answer several questions in the TGD framework. What sensory experiences, perceptions, and features are in TGD Universe? What could the phrase "statistical ensemble of features" mean? What does sensory perception as a quantum measurement and quantum measurement itself correspond to?

1.3.1 The notions of sensation, perception, and feature

Sensation as the core of sensory experience must be distinguished from perception. Sensation is just the sensory awareness with nothing added. Perception involves a cognitive representation providing an interpretation of perception and consists of objects and the associations and memories associated with them.

Brain is believed to analyze the sensory input from the sensory organs to features. Features are just those aspects of the input that are relevant to survival or target of attention. Neutrons serve as feature detectors (`https://cutt.ly/vIMObqB`).

This deconstruction process is followed by reconstruction which proceeds upwards from features to objects of the perceptive field so that the perceptive field decomposes to standardized mental images representing objects with various attributes, orientation and motion are such attributes. This is basically pattern recognition. Features are basic building bricks of the sensory mental images and not necessarily conscious to us.

The reconstruction process is analogous to first drawing a simple drawing consisting of lines and then gradually filling the picture by adding colors with varying intensities. Something analogous happens also when the sound-scape of a movie is constructed. One starts from the actual sound-scape but the outcome is quite different and very far from the original. One could say that sensory perception is essentially an artwork.

In the mathematical modeling, one can speak of a feature space. Features have attributes and the claim of the article discussed is that one can assign to features a probability distribution. Brain would not only build features but also represent this probability distribution making it possible to estimate the reliability of the visual short memory. It is however not clear how the distribution gives rise to a conscious experience about reliability and how the short term memory relates to the sensory perception.

1.3.2 Ensemble of features as temporal ensemble of memory mental images?

The probability distribution for features should be realized somehow as a statistical ensemble. One can consider two alternative options.

1. In the standard physics framework spatial ensemble seems to be the only possible realization. The perception would be represented as a large number of copies. The fact that the inputs in the retina are mapped in a topographic manner to various parts of the visual cortex poses strong constraints on the number and location of the copies. If there is a spatial ensemble its neurons should form groups of neary neurons. The problem is how the distribution of features in this ensemble can code for the reliability of sensory or memory mental images and this requires a theory of consciousness.

2. In the TGD framework, the brain is 4-D and it makes sense to speak of a temporal ensemble of memory mental images. These temporal ensembles would correspond to temporal sequences of memory mental images and the distribution aspect would be automatically realized. The variance of this distribution would provide conscious experience about the reliability of the mental images. The natural interpretation would be in terms of short term memory.

For the TGD option, the sensory input to the sensory organ, say retina, would generate a temporal ensemble of visual mental images making possible short term memory. This ensemble would be characterized by a probability distribution. The probability distribution for the states of feature neurons would be a neuronal level example of this kind of distribution. Variance would be one characteristic of this distribution and characterize the reliability of short term memory. Sensory perceptions would give rise to short term memories.

Many questions remain to be answered. How are these memory mental images generated in quantum measurements? How does the memory recall of long term memory generate a short term memory represented as a temporal ensemble of visual mental images?

1. For instance, in the memory recall of a phone number, long term memory is involved. Somehow the memory recall creates "almost" sensory, that is virtual, perception, which suggests that a virtual sensory input from MB is involved and creates a virtual sensory perception giving rise to a visual short term memory.

2. In the TGD framework, these virtual sensory perceptions would also make possible imagination. The virtual sensory input would come from MB to cortex and proceed to the lower levels of the brain but would not reach sensory organs except during dreams, hallucinatory states, and sensory memories (memory feats of idiot savants).

3. The sensation associated with the sensory experience would correspond to a state function reduction (SFR) occurring in quantum measurement. But what does SFR correspond to in TGD?

   In the zero energy ontology (ZEO), the notion of SFR generalizes. The are two kinds of SFRs: "big" SFRS (BSFRs) as analogs of ordinary quantum measurements in which a large change is possible and "small" SFRs (SSFRs) as analogs of so called weak measurements, which are assumed in quantum optics but are not very-well defined in the standard quantum theory and do not appear in the text books.

   SSFRs relate closely to the Zeno effect which states that the state of the physical system remains unaffected if the same measurement is repeated. In reality this is not quite true, and the sequence of SSFRs represents a generalization of a repeated quantum measurement allowing us to understand what really happens.

   Sensory perception would be repetition of SSFRs following analogs of unitary time evolutions and would produce an temporal ensemble of sensory mental images giving rise to short term memory. The system would be measured, it would return back to almost its original state and would be measured again. SSFR is almost a classical measurement.

In the sequel the above summarized view is discussed in more detail. Three sections are devoted to TGD inspired theory of consciousness, quantum biology and quantum brain. A more extensive discussion can be found in [L40]. In the next section a model for the generation of sensory perception and short term memory explaining the findings of Li et al [J6] is considered. The last section discusses the model explaining the findings of Manassi and Whitney [J9].

2 TGD inspired theory of consciousness briefly

TGD inspired theory of consciousness can be regarded as an extension of quantum measurement theory to a theory of consciousness that relies on Zero Energy Ontology (ZEO) [L37].

2.1 Conditions satisfied by the theory of consciousness

Any quantum theory of consciousness must be consistent with existing physics. Since existing physics cannot explain biological phenomena and consciousness, a theory explaining them is bound to predict some new physics.

The new theory must solve the basic problems intractable to current theoretical physics. Many of these problems are philosophical. This theory should also be applicable to quantum biology and neuroscience and answer at least the following questions.

1. In everyday life everyone, even a strict physicalist, will in their subjective experience, regard free will as real, but in the role of natural scientist, deny it since it is inconsistent with the determinism of classical physics. Could the underlying view of time be wrong? Could free will be consistent with deterministic field equations after all?

   It seems that behavior is built from deterministic time evolutions connecting initial and final states. Biological functions, behaviors, and computer programs represent good examples of this. Could free will be in the selection between deterministic time evolutions. These questions suggest a new ontology in which a deterministic classical time evolution becomes the basic entity instead of the time=constant snapshot of time evolution central to the standard ontology.

2. A similar problem plagues quantum measurement theory. The state function reduction (SFR) is non-deterministic whereas the Schrödinger equation is deterministic. This has led to myriads of "interpretations". This problem is analogous to the conflict between free will and classical deterministic physics.

   It is easy to trace the origin of the problem. In standard quantum theory the observer can affect the measured system but still remains an outsider. A quantum theory of consciousness would generalize quantum measurement theory. The notion of "self" as part of a system would replace that of "observer".

   Quantum coherence is assumed to be possible only at very short scales. Coherence of biological systems, however, suggests this assumption is wrong. There is also the question whether there is some scale at which quantum behavior transforms to classical behavior. This question has not been answered. Could the quantum world actually prevail at all scales and only appear as classical? Could discontinuous quantum jumps somehow look like deterministic and smooth classical time evolutions?

3. Experienced time and the geometric time of the physicist are very different. Subjective time however correlates with geometric time: contents of sensory experience correspond to a moment of geometric time within an accuracy of .1 second: one can speak of a sensory chronon. How should one distinguish between these two times?

4. Are there physical correlates for cognition and imagination? Could they be realized at the level of space-time?

5. What do life, death, and aging mean? Could they be universal notions applicable at all scales? Does consciousness survive after the cessation of bodily function in some sense? If this were the case, universality might make it possible to provide indirect, and yet convincing, evidence for life after death.

2.2 ZEO based quantum measurement theory extends to a theory of consciousness

ZEO based quantum measurement theory [L37] leads to a quantum theory of consciousness. In particular, the theory predicts that the arrow of time (AT) changes in "big" (ordinary) SFRs (BSFRs) as opposed to "small" SFRs (SSFRs) as the counterparts of "weak" measurements (`http://tinyurl.com/zt36hpb`).

BSFR suggests that self-organization (SO) at all scales partially reduces to dissipation with a reversed AT implied by the generalization of the second law of thermo-dynamics (SL).

1. SO always involves an energy feed. The energies of quantum states increase with $h_{eff} = nh_0$ and h_{eff} tends to be reduced spontaneously. The energy feed prevents this and hence the reduction of the universal "Intelligence Quotient" (IQ) as the dimension n of EQ characterizing the algebraic complexity of EQ and of a space-time surface [L31, L32]. This prevents also the reduction of the scale of quantum coherence. In biology this corresponds to the metabolic energy feed.

2. In ZEO, the energy feed necessary for SO could be partially replaced with an extraction of energy from the environment by dissipation in a reversed direction of time. The self-organizing system could effectively send negative energy to the environment.

   The basic signature is a generation of gradients in conflict with SL in its standard form. This conforms with what happens in SO but does not of course prove that SO is based solely on time reversed dissipation. Both the energy feed and the extraction of energy from the environment are involved.

For time reversed dissipation no specific mechanisms are required and only metabolic energy storages - systems able to receive the negative energy dissipated in a reversed time direction - are enough. Even thermal energy could be used and there is evidence for this [L51]. This inspires a totally new vision, not only of living matter, but also in regards to possible energy technologies.

3. Time reversals occur at very short time scales at the elementary particle level and for ordinary matter with $h_{eff} = h$). For MBs controlling ordinary matter, time reversals would have long lasting effects on ordinary matter as well.

   MB has an onion-like layered structure implied by the p-adic length scale hypothesis [K15] and h_{eff} hierarchy [L17]. Layers have sizes even larger than the size of the Earth. The slaving hierarchy formed by the layers of MB carrying dark matter could control the dynamics by inducing time reversals at the lower levels as BSFRs interpreted as generalized motor actions (master and slave are standard notions in the theory of SO). A given layer of MB is characterized by its size determined by a p-adic length scale characterizing flux tube thickness and by the value of h_{eff}.

2.2.1 ZEO

The TGD based view of consciousness relies on ZEO solving the basic paradox of quantum measurement theory. First, a brief summary of ZEO [L37] is required.

1. The notion of a causal diamond (CD) is a central concept. Its little cousin "cd" can be identified as a union of two half-cones of M^4 glued together along their bottoms (3-D balls). The half-cones are mirror images of each other. CD=$cd \times CP_2$ is the Cartesian product of cd with CP_2 and obtained by replacing the points of cd with CP_2. The notion of CD emerges naturally in the number theoretic vision of TGD (adelic physics [L9])via the $M^8 - H$ duality [L24, L31, L32].

2. In the ZEO, quantum states are not 3-dimensional, but superpositions of 4-dimensional deterministic time evolutions connecting ordinary 3-dimensional states. By holography time evolutions are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

   Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced by a new superposition. The classical determinism of individual time evolution is not violated. This solves the basic paradox of quantum measurement theory. There are two kinds of SFRs: BSFRs (counterparts of ordinary SFRs) changing the arrow of time (AT) and SSFRs (analogs of "weak" measurements) preserving AT that give rise to an analog of the Zeno effect (`https://cutt.ly/yl7oIUy`) [L37].

To avoid confusion, one may emphasize some aspects of ZEO.

1. ZEO does not mean that the physical states identified in standard quantum theory as 3-D time= constant snapshots - and assigned in ZEO to the opposite boundaries of a causal diamond (CD) - would have zero energy. Rather, these 3-D states have the same conserved quantities, such as energy. Conservation laws allow us to adopt the convention that the values of conserved quantities are opposite for these states so that their sum vanishes.

   This is not new: in quantum field theories (QFTs), one speaks, instead of incoming and outgoing particles, external particles arriving from the geometric past and future and having opposite signs of energy. That conserved quantities vanish in the *4-D* sense, expresses only the content of conservation laws. A weaker form of this condition [L43] states that the total conserved Poincare charges are opposite only at the limit of infinitely large CD. CD would be an analog of quantization volume in QFTs, whose finiteness implies a small conservation of momentum.

2. ZEO implies *two* times: subjective time as a sequence of quantum jumps and geometric time as a space-time coordinate: for instance, the proper time of the observer. Since subjective time does not correspond to a real continuum, these times are not identifiable but are strongly correlated. This correlation has led to their identification although they are different.

2.2.2 BSFR as death and reincarnation in universal sense

In BSFRs, AT is changed and the time evolution in the final state occurs backwards with respect to the time of the external observer. The BSFRs can occur at all scales since TGD predicts a hierarchy of effective Planck constants h_{eff} with arbitrarily large values. There is empirical support for BSFRs.

1. The findings of Minev et al [L15] for atomic systems can be explained by the same mechanism [L19]. BSFR replaces the zero energy state with a new one and changes the roles of the 3-D states (active and passive state) at the boundaries of CD.

   For an observer with a standard AT, the final zero energy state is a superposition of deterministic, smooth time evolutions leading to a fixed 3-D state at the formerly active boundary of CD. Interestingly, once this evolution has started, it cannot be stopped unless one changes the stimulus signal inducing the evolution. The ZEO based interpretation is that a second BSFR as a return back to the initial state occurs.

2. Libet's experiments on the active aspects of consciousness [J3] can be understood from this perspective. For instance, a test subject raises his index finger and neural activity starts *before* the conscious decision to do so. In a physicalistic framework, neural activity leads to the experience of making the decision so that free will would not be real.

   Libet himself proposed what he called a veto option: free will is in the decision to stop the action already initiated. The problem with the veto option [J1] is that the activity beginning .5 seconds earlier looks like dissipation with a reversed AT. In the standard direction of time this looks like self-organization which leads from a chaotic state to an ordered state at around .15 seconds before the raising of the finger. The ZEO explanation is that a macroscopic BSFR occurred and generated a signal proceeding backwards in time which generated neural activity and dissipated to randomness.

3. An example from a different scale comes from earthquakes and supports universality. Earthquakes involve a strange anomaly: they are *preceded* by ELF radiation. One would expect that ELF radiation would follow the earthquake. In the TGD framework, the identification as BSFR can explain the anomaly [L20, L14].

   In biology, the reversals of AT may occur routinely [J7] and indeed are a central element of biological SO in the TGD framework. Time reversal also explains self-organized quantum criticality (SOQC) identifiable as the basic mechanism of homeostasis [L23, L51]. Homeostasis would occur spontaneously rather than being a result of programming.

2.2.3 Sequence of SSFRs as life cycle

SSFRs are counterparts of "weak" measurements, which are much like classical measurements and do not involve any dramatic changes. The sequence of SSFRs gives rise to a conscious entity - self - as a sequence of moments of consciousness. Subjective time as a sequence of SSFRs correlates with the geometric time for which one identification is as the distance T between the tips of CD, whose size increases statistically.

1. In SSFRs [L35] members of states at the "passive" boundary (PB) of the CD are not changed and PB itself is not shifted although it increases in size. The active boundary (AB) recedes from PB and increases in size in a statistical sense. Also, the states at AB change by unitary time evolutions followed by SSFRs that do not affect the states at PB.

   SSFRs correspond to a measurement of observables whose action does not affect the states at PB. Cognitive measurements are excellent candidates for these kind of measurements [L35]. The time T identified as the temporal distance between the tips increases in a statistical sense and correlates with the subjective time identified as a sequence of SSFRs.

2. The identification of a "geometric now" as a correlate of "subjective now" is not unique. The most natural identification of the geometric time is as the linear M^4 time coordinate assignable with the line connecting the tips of CD. The "geometric now" would correspond to the $T_{now} = T/2$ which corresponds to a 3-D ball (not a 2-D sphere, which is its boundary)

at which the expansion of 3-ball with light-velocity changes to contraction - the analogy with the Big Bang followed by the Big Crunch is obvious. T_{now} increases in a statistical sense.

3. $M^8 - H$ duality predicts that the roots r_n of the real polynomial P define special moments $t = r_n$ of M^4 linear time: I have called them "very special moments in the life of self" [L6, L7, L8, L16, L31, L32]. If these moments correspond to the values of T_{now} for SSFRs, the size of CD increases in a step-wise manner.

4. The Lorentz invariant light-cone proper time "a" labeling the hyperboloids inside the lower and upper half-cones of the $CD \subset H = M^4 \times CP_2$ is the second natural candidate for the geometric time coordinate and is completely analogous to cosmic time. It reduces in a good approximation to "t" near the time axis connecting the tips of CD.

   This picture applies at the level of H. $M^8 - H$ duality [L31, L32] forces also consider the M^8 level. M^8 is analogous to momentum space: there is no time and space in the usual sense. Could the claims of timeless and spaceless states of consciousness correspond to the M^8 mode? In momentum space, time and spatial coordinates are replaced with energy and momenta.

$M^8 - H$ duality leads to a more detailed picture of the evolution of self. One may consider first what the evolution of self looks like geometrically.

1. A given space-time surface in M^8 is determined in terms of an octonionic polynomial $P(o)$ obtained by algebraically continuing a real polynomial $P(x)$ with rational coefficients (so that p-adic variants of the space-time surface exist). $P(o)$ is decomposed to quaternion valued "real" and "imaginary" parts and the space-time surface corresponds to a root for the real part of $P(o)$ [L16, L31, L32].

   The associativity of the normal space of the space-time surface is the number theoretical dynamic principle. It implies that space-time surfaces are minimal surfaces. Also their counterparts in $H = M^4 \times CP_2$ - obtained by $M^8 - H$ duality - are minimal surfaces geometrizing the massless wave equation.

2. One can assign to the half-cones of the CD distinct polynomials which must be identical at $t = T/2$. The condition is satisfied if the polynomials are $P(o)$ for the "lower" half-cone and $P(T - o)$ for the "upper" half-cone. The space-time surfaces associated with the half-cones are in well-defined sense mirror images glued together at $T_{geom} = T/2$. This is not however the case for the space-time surfaces assignable to sub-CDs of CD interpreted as correlates of the mental images of the self assignable to CD.

This proposal has strong implications.

1. The evolution by steps consisting of unitary time evolution+SSFR increases the size of CD in a statistical sense (the number of CDs larger than the given CD is infinitely larger than those smaller than it). PB remains unaffected apart from scaling. Hence the size of the region of space-time surface identified as a "root" of the real part of P, increases: more of the surface determined by P becomes visible in each SSFR. This is like opening a packet containing a gift. Each "very special moment" $t = r_n$ brings something new in light.

2. At $T_{now} = T/2$ the sensory input from the geometric past induces sensory mental images drifting to the geometric future and gives rise to memory mental images assignable to sub-CDs. Contrary to a naive expectation, memory mental images indeed drift to the geometric future of T_{now} as the size of CD increases rather than remaining in the geometric past. The emergence of these sub-CDs in shorter scales breaks the mirror symmetry between half-cones.

   This makes it possible to learn from experiences during a given life cycle and utilize that learning during the next life cycle with an opposite AT. In the BSFR, AB becomes passive and these memory mental images become the "silent wisdom" for the time reversed self representing what was learned during the previous life cycle.

2.2.4 ZEO and planned actions

ZEO also provides a model for planned actions. To understand the basic idea, it is good to first describe a strange finding by Armor and Sackett [J2] and its TGD based explanation.

1. Armor and Sackett made a surprising discovery: the prediction of what happens in a future event is more reliable if the person knows that the event will actually occur. The future event was a scavenger hunt and the participant had to predict her performance defined as the number of items to be found. The participants who knew that the event would actually take place, made better predictions.

   Did the participants precognize their performance as passive spectators of themselves in the geometric future so that free will would be an illusion? This need not be the case: the information was about the number of items found and rather abstract. This did not fix the detailed behavior of the participant in the hunt.

2. Reference [L55] shows that the finding actually fits with the vision in which BSFRs occur as cascades which proceed from long to short scales. MBs represent a hierarchy of abstractions about the lowest level. The higher the level, the less detailed the information [L30]. Only this abstract information can be pre-determined.

   The BSFR for MB_2 above MB_1 in the hierarchy - the "boss" - corresponds to a time scale $T_2 > T_1$ and determines the fate of MB_1 in the time scale T_2. MB_1 can apply its free will in the time scale T_1 in the limits posed by its fate. This paradoxical finding makes the distinction between subjective and geometric time very concrete. The fate of the subject person MB_1 is to some degree determined by BSFR of MB_2. With respect subjective (geometric) time, this BSFR occurred *before* (*after*)MB_1 made the prediction.

   This a supports the idea of the organizer of the experiment to perform the experiment was actually communicated by MB_2 to the experimenter. Thus she only actualized her fate.

Could most, if not all, planned actions be like this - induced by BSFR of MB_2 in the geometric future, but in the subjective past (of MB_1)? This would allow for more detailed planning at the level of MB_1. There would be the experience of planning and a realization induced by the signals from the geometric future sent by a higher level in the hierarchy of conscious entities! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than as agents with completely free will.

1. Ordinary matter is at the bottom of the master slave hierarchy and its coherence is forced by the quantum coherence at higher levels MB layers.

2. The BSFR for a higher level MB gives rise to what is experienced as a planned action at the lower levels of the hierarchy. Planned action at a given level induces a cascade of planned actions in shorter time scales which eventually proceed to the atomic level.

3. Sensory perceptions and motor actions would be universal. Sensory perceptions naturally correspond to SSFRs "weak" measurements (`http://tinyurl.com/zt36hpb`), and both BSFRs and SSFRs can occur with both arrows of time. Motor action is identifiable as a cascade of BSFRs, with each BSFR inducing sensory perceptions as SSFRs at lower levels. These would, in turn, induce motor actions as BSFRs in shorter time and length scales.

2.3 Negentropy Maximization Principle (NMP) as variational principle of consciousness

Negentropy Maximization Principle (NMP) defines the variational principle of consciousness in TGD [K6] [L45].

1. NMP replaces the second law (SL) and implies it for ordinary matter. SFR means a reduction of the entanglement for a pair $S_a - S_b$ of sub-system S_a and S_b, its complement in S. Instead of a single measurement, there is a measurement cascade, proceeding from long to short scales. At each step a system decomposes to a pair of unentangled subsystems. NMP states that the negentropy gain in each step is maximized and selects the pair $S_a - S_b$ at each step. This process can be visualized by a tree diagram.

2. In adelic physics [L10, L11] the entropy $N = -S_1 - S_2$ is the sum of real and various p-adic negentropies. p-Adic negentropies can be positive so that for non-trivial EQs one can have $N > 0$. Negentropic entanglement (NE) is stable against NMP so that the process stops. It is natural to assign positively colored emotions to NE. One can also say that NE distinguishes between living and inanimate matter and between dark and ordinary matter.

2.3.1 NMP as a generalization of the second law of thermo-dynamics

On the basis of empirical facts, Jeremy England [I1] has proposed that SL implies evolution. This statement seems to be in conflict with the standard thermodynamic view of biology [L5].

England's view that SL implies evolution, is clearly in error. NMP [L45] explains why England's paradoxical view is apparently true. A generalization of quantum measurement theory to a ZEO based theory of consciousness, and a number theory based view of cognition leading to adelic physics, is required to understand this misinterpretation.

1. SFR decomposes a given system (unentangled from the environment) to 2 subsystems in such a manner that the negentropy gain is maximal for the the "winning" decomposition. This corresponds to the quantum measurement of a universal observable, identified as the density matrix for the subsystem-complement pair.

2. TGD allows a genuine notion of negentropy assignable to entanglement and thus to the density matrix. The negative of the ordinary entanglement entropy $N = -S$ defines negentropy which at best is $N = 0$ since N is always non-positive.

   A genuine measure of information is needed. Since information is associated with cognition, one must expand the realm of physics to include cognition. One can also assign to the extensions of p-adic number fields an entanglement negentropy by the analog of a Shannon formula replacing logarithms of probabilities with the logarithms of their p-adic norms [K6] [L45].

   Remarkably, p-adic entropy can be negative and NMP mandates this. Furthermore, its magnitude is not smaller than that of real entropy. Therefore negentropy identified as the sum $N = -S_1 - S_2$ of real and p-adic entanglement negentropies can be positive for non-trivial EQs. N defines a genuine measure of information and, by NMP, increases during the life span of the conscious entity. This however implies the increase of real entanglement entropy [L5].

   p-Adic number fields, combining with real numbers to form an adele, are needed [L10, L11]. The algebraic extensions of p-adic number fields induced by EQs form an infinite hierarchy with increasing complexity which is identifiable as an evolutionary hierarchy. EQs emerge from $M^8 - H$ duality [L31, L32]. Space-time regions are determined by polynomials defining the EQs via their roots. Evolution as an increase of the dimension of EQ is unavoidable.

3. Consider now the connection with thermo-dynamics. When SFR occurs, entanglement entropy becomes zero, but ensemble entropy increases. That is, the outcome of measurement is not deterministic and reduction probabilities correspond to the eigenvalues of the density matrix. This means an increased thermo-dynamic entropy and generation of disorder.

   However, if the SFR cannot occur, entanglement is stable. For the negentropic states for which negentropy cannot decrease, NMP prevents SFR! The negentropic states approach cognitive fixed points and replace thermodynamic equilibria for which entanglement negentropy is maximum. The conscious entity maximizes its knowledge during its life-span quite universally: this applies to all systems at all scales, not only humans.

   For $h_{eff} = h_0$, NMP implies standard quantum measurement theory. Entanglement can be also non-negentropic for non-trivial EQs. In this case, NMP does not prevent complete de-entanglement from occurring and SL holds true. For dark matter with $h_{eff} > h$ NMP can, however, stabilize entanglement. This gives rise to a generation of conscious information. In summary, a pessimistic SL transforms to an optimistic NMP and implies SL for ordinary matter.

3 Some aspects of TGD inspired quantum biology

3.1 MB carrying dark matter as controller of ordinary biomatter

The TGD based quantum model for living matter relies heavily on the notions of MB carrying $h_{eff} > h$ phases behaving like dark matter and ZEO.

MB contains dark matter identified, as phases of ordinary matter characterized by EQ with a dimension $n = h_{eff}/h_0$ serving as a measure of the algebraic complexity of a given space-time region [L31, L32], and interpreted as a universal IQ. The scales of quantum coherence increase with h_{eff}. The layers of MB characterized by the value of n naturally form a master-slave hierarchy in which ordinary matter with the smallest Planck constant is at the bottom, and controlled by higher levels. The energies of systems increase with h_{eff} and since h_{eff} tends to be spontaneously reduced, an energy feed is needed to preserve the distribution of h_{eff}: the interpretation is as an analog of a metabolic energy feed.

MB acts as a "boss" controlling ordinary matter and induces self-organization [L23].

3.1.1 Anatomy of MB

MB has, as its body parts, magnetic flux quanta: flux tubes and flux sheets. There are two kinds of flux quanta. Flux can be vanishing, which corresponds to a Maxwellian regime. Flux can also be non-vanishing and quantized corresponding to a monopole flux. In the monopole case, the magnetic field requires no current for its creation. This option is not possible in the Maxwellian world. By fractality of the TGD Universe, these flux tubes play a key role at all scales [L21].

Also the Earth's magnetic field with nominal value of $B_E = .5$ Gauss has two parts.

1. The monopole flux part corresponds to the "endogenous" magnetic field $B_{end} = .2$ Gauss and explains the strange effects of ELF EM radiation on the physiology and behavior of vertebrates [J4].

   The presence of this part explains the stability of the Earth's magnetic field. This field should have decayed long ago in a Maxwellian world since it is generated by currents which disappear.The contribution of the molten iron in the Earth's core to B_E decays but the changes of the orientation of B_{end} regenerate it [L28]. Also, magnetic fields that penetrate super-conductors as quantized fluxes and even those of permanent magnets (as opposed to electromagnets) may have a monopole part consisting of flux quanta.

2. The interaction of MB with the gravitational field of Earth is discussed in [L50]. Intriguingly, the metabolic energy currency with the nominal value of .5 eV is rather close to the energy for the escape velocity of a proton. Could the transfer of ions from the surface of the Earth to MB be a standard process?

3.1.2 Communications to and control by MB

Communication from the biological body (BB) to MB and its control by MB would rely on dark photons, which can transform to ordinary photons with a large h_{eff} and vice versa. Molecular transitions would represent one form of control.

1. Cell membranes could act as generalized Josephson junctions generating dark Josephson radiation with energies given by the sum $E_J + \Delta E_c$ of ordinary Josephson energy E_J and the difference ΔE_c of cyclotron energies for flux tubes at the two sides of the membrane. The variation of the membrane potential modulates the Josephson frequency and codes the sensory information at the cell membrane to a dark photon signal sent to MB.

2. The large effects of radiation at ELF frequencies observed by Blackman and others [J4] could be understood in terms of the cyclotron transitions in $B_{end} = .2$ Gauss if "h" in $E = hf$ is replaced with h_{eff}. h_{eff} should be rather large and possibly assignable to the gravitational flux tubes with $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. For the simplest model, M represents the Earth's mass coupling to the small mass m, and v_0 is a parameter with dimensions of velocity expected to have discrete spectrum. The energies $E = h_{eff}f$ of dark photons should be in the biophoton energy range (visible and UV) characterizing molecular transitions [K14, K18].

3. For the value $v_0/c \simeq 2^{-11}$, suggested by the Nottale's model for planetary orbits [E1], the predicted cyclotron energy scale is 3 orders of magnitude higher than the energy scale of visible photons. Several solutions of this problem were considered [L49, L41] . The most plausible solution is $\beta_0 = v_0/c = 1/2$ for living matter so that gravitational Compton length $\Lambda_{gr} = GM/\beta_0$ equals to Schwartschild radius at the surface of Earth. and brings nothing new to the original Nottale hypothesis.

By its higher level of "IQ", MB would naturally be the master controlling BB by cyclotron radiation - possibly via a genome accompanied by dark genome at flux tubes parallel to the DNA strands.

1. Cyclotron Bose-Einstein condensates (BECs) of bosonic ions, Cooper pairs of fermionic ions, and Cooper pairs of protons and electrons would appear as dark matter in living systems and the $h_{eff} = h_{gr}$ hypothesis predicts a universal cyclotron energy spectrum in the range of bio-photon energies.

2. Dark photons may transform to bio-photons [L2, L1] with energies covering the visible and UV energies associated with the transitions of bio-molecules. This control of biomolecules implies that remote mental interactions are routine in living matter. EEG signals would represent a particular instance of these communications: without the presence of MB it is difficult to understand why the brain would use such large amounts of energy to send signals to outer space.

3. In ZEO, the field body (FB) and MB correspond to 4-D rather than 3-D field patterns and quantum states correspond to quantum counterparts of behaviors and biological functions. Conscious holograms could be generated as a result of interference of a dark photon reference beam from MB and a dark photon beam carrying the sensory information. This hologram would be read by MB using the conjugate of the reference beam.

   In ZEO time reversals of these processes also take place. This makes it possible to understand memory as a result of communications with memory mental images (see section 2.2.3).

3.2 Adelic physics, cognition, and biology

$M^8 - H$ duality [L24, L31, L32] concretizes the number theoretic vision.

1. $M^8 - H$ duality states that space- times are representable as 4-D surfaces in either complexified M^8 (complexified octonions O_c) or $H = M^4 \times CP_2$. $n = h_{eff}/h_0$ has an interpretation as a dimension of EQ identifiable as the degree n of the polynomial determining the space-time surface in M^8. Roots correspond to different sheets of n-sheeted space-time surface, and the Galois group G of EQ permutes the sheets with each other and act as a number theoretic symmetry group. Dark matter states at the flux tubes define representations of G.

2. The wave functions in the set of space-time surfaces obtained by the action of G may be interpreted as functions in G defining the group algebra $L(G)$ of G. They define quantal cognitive representations. Also their fermionic counterparts make sense. Galois group G would thus act as the symmetry group of cognition. The notion of cognitive measurement in $L(G)$ makes sense and leads to a model of cognitive process as a cascade of cognitive SSFRs [L35, L45].

3. Galois confinement [L29] would force n-particle states to behave as coherent units like hadrons do as color-confined states.

4. The model makes rather far-reaching predictions. The decomposition of EQ to an extension of an extension of an extension ... of rationals defines a *finite* hierarchy of normal subgroups which in turn makes it possible to express the element of $L(G)$ as entangled products of states in the group algebras associated with the normal subgroups. Simple groups, whose classification is known, are groups which have no normal subgroups [L45, L43] so that this decomposition is trivial. Cognitive processes such as SSFR cascades are impossible for simple Galois groups - thus thinking as analysis is impossible. Could simple groups classify meditative states (or irreducible ideas as analogs of axioms)?

3.3 Genetic code (GC)

The model of bio-harmony [L3, L4, L22, L27, L42] is essential for the TGD based understanding of what might be called emotional intelligence (whose reality is accepted) and its relations with ordinary intelligence. The surprising outcomes are the connection with GC and the key role of bioharmony in quantum information processing in living matter.

1. The notion of bioharmony relies on icosahedral and tetrahedral geometries. The representation of the 12-note scale as a sequence of quints, reduced by an octave equivalence (notes differing by octave are experienced as equvalent) to the basic octave, defines the harmony for a given Hamiltonian cycle: the 20 allowed 3-chords of the icosahedral harmony correspond to the 20 triangular faces. The symmetries of the harmony are defined by some subgroup (Z_6,Z_4, or Z_2) of the icosahedral group.

2. Genetic codons correspond to dark photon triplets (3-chords of light) defined by the triangular faces of an icosahedron and tetrahedron. The counterparts of amino-acids are identified as orbits of 3-chords under the symmetries of a given harmony.

   Any combination of 3 icosahedral harmonies with 20 chords with symmetries Z_6, Z_4 and Z_2 and of the tetrahedral harmony with 4 chords gives a particular bioharmony with 20+20+20+4=64 chords assignable to DNA codons. DNA codons coding for a given amino acid correspond to the chords at the orbit of the symmetry group. Rather remarkably, the numbers of DNA codons coding for a given amino acid come out correctly.

3. Music expresses and creates emotions. Musical harmony codes for moods and emotions as holistic aspects of music. Bio-harmony with 64 3-chords, would assign the binary, local, aspects of information to the 6 bits of the codon and its holistic, emotional aspects to the bio-harmony. A chemical representation of the genetic code can thus correspond to several moods represented by bioharmony. In contrast with physicalism, emotions would appear already at the molecular level, and would have physical effects that are not reducible to bio-chemistry. This understanding is not possible without using the notion of MB.

   The model of bio-harmony requires that the values of B_{end} correspond to those associated with the Pythagorean scale definable by the quint cycle. These frequencies correspond to energies that a molecule must have in order to serve as a basic biomolecule. This criterion could select DNA, RNA, tRNA, and amino-acids.

In the second model of GC [L12], codons are represented as dark proton triplets.

1. The numbers of dark proton triplets turn out to correspond to numbers of DNA, RNA, tRNA codons, and amino acids. The numbers of DNA and RNA codons assignable to a given amino-acid in the vertebrate GC are correctly predicted. Genes would correspond to sequences of dark proton triplets [L22].

2. Dark proton triplet - dark codon - would be analogous to baryon and Galois confinement [L29] behaving like a single quantum unit. The N dark codons of a dark gene would, in turn, bind to Galois confined states of the Galois group of an EQ associated with the sequence of codons. An entire hierarchy of confinements is possible.

3. Galois confinement can be realized also for dark photon triplets and the sequences of N dark-photon triplets representing genes as dark $3N$-photon states. Genes could serve as addresses for communications based on dark $3N$-photon resonances.

   For communications between levels with the same value of h_{eff} there would be both energy and frequency resonance and for levels with different values of h_{eff} only the energy resonance. It is an open question whether dark $3N$-photons transforms to single ordinary photon or $3N$ ordinary photons (biophotons) in dark-ordinary communications.

4. The basic hypothesis is that both DNA, RNA, tRNA, and amino acids are paired with their dark analogs, and that energy resonance mediates the interaction between the members of pairs.

How could the icosahedra and tetrahedra be realized? Why must one glue them together? This looks aesthetically unappealing. However, surprisingly, both icosahedrons and tetrahedrons appear in, perhaps the simplest honeycomb of the hyperbolic 3-space H^3 (cosmic time = constant hyperboloid). H^3 is also central to special relativity and cosmology [L42]. Dark GC can be realized in terms of both dark protons and photons using this particular tessellation and would be universal. This master tessellation would induce sub-tessellations at the space-time surface, in particular representations of GC at magnetic flux tubes. Also 2-D and even 3-D representations of GC can be considered (i.e. cell membrane and microtubules) [L44].

4 TGD based view of brain

The TGD based view of the brain differs in several ways from the standard neuro-scientific model relying on materialism and reductionism [K5, K4]. The notion of MB as a controller of BB (biological body) forces us to abandon the idea of the brain as the sole seat of consciousness. Also the view of the role of nerve pulses is radically different.

4.1 MB and brain

In the TGD framework, the onion-like hierarchical structures of the MB of the brain would correspond to brain regions and provide an abstract map of the brain. The structure of MB with levels labelled by EQs partially characterized by $n = h_{eff}/h_0$ measuring the scale of quantum coherence, would also reflect the geometric and topological structure of the brain.

4.1.1 MB as a hierarchy of abstractions

There is evidence that functionally similar neurons can be modelled using statistically determined hyperbolic geometry [J5]. Functionally similar neurons not necessarily physically near to each other would be near to each other in the effective hyperbolic geometry.

MB could realize this hyperbolic geometry quite concretely as an abstract representation of the hierarchical functional structure of the brain [L30]. That is, functionally similar neurons and also higher level brain structures not near to each other in the brain would be connected to nearby points at MB by flux tubes. Classification, visualizable as putting similar things in the same box, is a basic cognitive function and the hierarchy of MBs could realize classification geometrically.

An astonishing finding supports this view. In the lab, the neurons of the brain of a salamander were shuffled like a pack of cards. The salamander however recovered and preserved its memories (identified as learned behaviors) [J10]. In [K11, K7] this finding was considered as a support for the view that the brain is analogous to a hologram (The TGD Universe can be seen as a conscious hologram [K1]). It seems, however, clear that a single neuron cannot represent the information content of the entire brain. However, if memories are represented by the images of neurons at the level of the MB, the shuffling of neurons has no effect on memories as the experiment indeed demonstrated. Neurons would be analogous to RAM in computer science.

4.1.2 Dark photons and communications and control

Communications both inside the central nervous system (CNS) and also from ordinary cells, could occur by dark cyclotron photon signals with $h_{eff}/h = n$ and light velocity. The value of h_{eff} could be considerably smaller than for the EEG communications from CNS to the large part of the MB. The value of h_{eff} could be estimated from the scaling up of cell length scale to a typical scale found in CNS. This iteration of back-and-forth communications makes pattern completion and recognition possible.

Dark photons could transform in an energy conserving manner to biophotons with energies in the visible and UV range (at least) and thus above thermal energy and therefore have effects that are not masked by thermal radiation. The brain is known to emit biophotons and they are also associated with axons [K18, K14].

Dark Josephson radiation would make information transfer to MB possible whereas the control signals from the MB would be as dark cyclotron photons.

1. Nerve pulse patterns modulate generalized Josephson frequencies for the flux tubes associated with the membrane proteins (such as ion channels and pumps) which act as generalized Josephson junctions. The sensory input is encoded by the Josephson radiation sent to the "big" part of MB [K2].

2. The frequency modulated Josephson radiation generated by nerve pulses would give rise to EEG (and perhaps also to its scaled variants) as a communication of information from the brain to MB via Josephson frequency modulation. In sharp contrast with the brain-centered neuroscience orthodoxy, the size scale of this layer of the MB would be rather large (i.e. of the order of c/f_c and given by the circumference of the Earth for the Schumann frequency $f_c \sim 7.8$ Hz). The structure of the Earth's magnetosphere suggests that both EEG bands and regions of BB correspond to regions of the magnetosphere [L41].

3. Nerve pulse patterns would code for information communicated to various layers of MB assignable to the EEG bands as a frequency modulated generalized Josephson radiation. Generalized Josephson frequency would be the sum of the ordinary Josephson frequency $f_J = ZeV/h_{eff}$ and the difference Δf_J of the cyclotron frequencies $f_c = ZeB/2\pi m$ for flux tubes at different sides of the neuronal membrane and transverse to it. The modulation of f_J by the nerve pulse patterns [K8, K2, K9] would code for sensory and cognitive information.

4. The frequency modulated dark photon radiation absorbed in cyclotron transitions at MB would generate a sequence of cyclotron resonances at MB, which code for sensory input.

   Already the modulation of the membrane potential at the basal ganglia of sensory receptors could communicate sensory information in this manner. If so, nerve pulse patterns could be a secondary representation of sensory information induced by the sequence of resonance peaks from MB back to the brain. This picture also applies to other forms of information (there are also basal ganglia inside the brain).

5. The dual representations of sensory information as resonance peaks and continuous Josephson radiation would be analogous to the local representation of a function provided by its values for a discrete sequence of time values, and to the holistic representation provided by its Fourier transform for a discrete set of frequencies.

MB controls BB and the motor output generated by the control signals from MB would act as "negative energy" signals with a reversed AT: two BSFRs are required to re-establish the original AT. The motor output of MB could take place via genes and induce gene expression as proteins.

Also other forms of gene expression such as as dark photon signals to the cell-/neuronal membranes could induce nerve pulse patterns.

The number theoretic vision suggests a considerable generalization of the idea of resonant communications [L54]. The model of Galois confinement (GC) based on the notion of bio-harmony [L3, L4, L27, L42] and the notion of GC [L35] suggests that dark $3N$-photon states, analogous to BECs, function as coherent dynamic units.

This inspires the notion of $3N$-resonance. Genes could be represented as sequences of N dark photon "3-chords" serving as addresses in dark $3N$-photon communications [L27, L42]. This picture leads to a model of human language [L52, L53].

4.2 General TGD view of sensory perception

The identification of sensory organs as seats of sensory qualia and a new view of the role of nerve pulses distinguish between the standard view of neuroscience and the TGD view.

4.2.1 Sensory organs as seats of sensory qualia

According to the TGD view, sensory perception generates sensory mental images at sensory organs rather than in the brain [L13]. This could solve some of the basic problems in neuroscience due to the similarity of neural tissue in various sensory areas. The basic objection is phantom limb syndrome. The new view of time and memory implied by ZEO would solve this problem: the pain in the phantom limb would be a sensory memory of pain.

This view could solve several mysteries in neuroscience. The stimulation of temporal lobes indeed generates sensory memories, and people with cognitive impairment are known for memory feats such as being able to draw a building, seen in the past, in fine detail, or to learn entire works of music from a single listening.

1. These feats can be understood if the sensory memories and memories in general correspond to "seeing" in time direction.

2. The "obvious" interpretation would be that a beam of dark photons travels to the geometric *past*, is reflected back and produce memories as an analog of ordinary vision. Memories would be in the geometric past. However, on further consideration, the process seems to be more complex.

3. It is possible to build a rather detailed model for sensory memories [L33, L34] based on three ZEO and the notion of CD as a perceptive field of self at the level of imbedding space. A crucial element is the identification of the geometric correlate of the "subjective now" (T_{now}) as the 3-D ball along which the half-cones of CD are glued together.

   Memories as mental images would correspond to sub-selves assigned to sub-CDs residing in the *geometric future* of T_{now} and shifting to the geometric *future* (!) during the sequence of SSFRs defining self and increasing the size of the CD and value of T_{now}. In the BSFR, identified as the death of self in a universal sense, these memories would become "silent wisdom" for the next life cycle with an opposite AT. Computer scientists would refer to this function as construction of log files.

4.2.2 New view of the role of nerve pulse transmission

Since perception is not mere passive reception of sensory input, but involves pattern recognition building standardized mental images, the TGD based view of sensory organs requires back and forth signaling between the brain and sensory organs. There should be a virtual sensory input from the sensory areas of the brain, or from MB via the brain, to sensory organs.

A sensory perception would be an actively constructed work of art, a standardized mental image, which is as near as possible to the sensory input. Pattern recognition would occur when the constructed pattern is sufficiently close to a standardized mental image.

The velocity of nerve pulse conduction is too slow to build a standardized sensory mental image by back and forth signalling. Nerve pulse duration of order of 1 ms defines the lower bound for the duration of the synaptic "bridge" making possible the propagation of dark photon signals. For a 10 cm long neural pathway this duration allows about 10^6 forth and back paths of light for a signal between the sensory cortex and retina.

The TGD view of sensory perception and the function of the nerve pulse transmission differs from the standard view. Nerve pulse conduction would not be communication between parts of the CNS but construction of "waveguides" for dark photons as connected flux tubes from axonal units [L13] [K8]. Nerve pulse patterns at the level of the brain would build standardized cognitive representations by decomposing the sensory input into "named" objects of a perceptive field from which associations could be built.

Sensory organs are seats of sensory qualia and sensory perception. This model explains REM dreams, hallucinations, and psychedelic experiences as experiences involving only the virtual input. Imagination can be understood as an "almost sensory" experience.

More concretely:

1. Sensory mental images at the level of sensory organs are generated by an iteration involving the virtual sensory input from the brain to the sensory organs [L13]. Pattern recognition is realized as a carving of a 4-D work of art representing a standardized mental image as near as possible to the original sensory input.

2. Nerve pulses would connect existing flux tubes parallel to axons to form longer flux tubes: neurotransmitters at synaptic contacts would act as relays. There is an obvious analogy with an old fashioned telephone network. It would requiree too energy to keep all connections on all the time.

The meridians assigned with acupuncture network could correspond to a permanent flux tube network and would not require nerve pulses, transmitters, nor information molecules as relays. For CNS, this flux tube network would be dynamic. Plants would only have the meridian system.

3. The standard view of learning as a strengthening of synaptic connections translates into a gradual build-up of long-lived flux tube connections, which make possible dark photon communications. The sender and receiver neuron groups can also fuse to a single, quantum entangled, system.

4. Actually all information molecules (neural transmitters, hormones, and messenger molecules) could be connection builders. An alternative view is that information molecule such as hormone is attached to the end of a flux tube, which stretches as the molecule travels to the target.

   The same theory applies to water memory [K3], which remains a dismissed concept in mainstream science although the research performed outside the confines of institutional support has revealed much about the involved mechanisms.

4.2.3 Dreams, hallucinations, and imagination

TGD makes it possible to understand sensory imagination as virtual sensory inputs from MB via the brain, which do not reach sensory organs. Imagined motor actions as virtual motor actions would not reach muscles.

Virtual sensory inputs would be received by virtual sensory organs inside the brain. A good candidate is the basal ganglia. Ganglions are also associated with sensory receptors. The input from MB or brain would be represented as dark photons.

The notions of virtual sensory and motor input are central to the understanding of speech comprehension and also inner speech. Hallucinations, psychedelic experiences and REM dreams (motor activities during sleep) could be understood as virtual sensory (motor) inputs reaching the sensory organs (muscles). Memory recall could involve virtual (real in the case of sensory memories) sensory input from MB at which memory mental images are realized [L37, L16].

4.3 Memories

To understand what memories and memory recall could be in ZEO one must specify what the geometrical correlate of "subjective now" is.

"Geometric now" corresponds to the $T_{now} = T/2$ slice of CD with maximal size located in the middle of the CD. If one accepts $M^8 - H$ duality [L24] "geometric now" corresponds to a "special moment in the life of self" [L24, L36] identifiable as intersection of the space-time surface and a 6-sphere which is a brane-like entity (in the sense of branes encountered in M-theory) appearing as a universal special solution to algebraic equations determining the space-time surfaces in M^8_c. The special values of T_{now} would correspond to the roots of the real polynomial defining the space-time surface.

2. During the sequence of SFRs, AB shifts towards the geometric future and the size of CD increases (in the statistical sense). The sub-CDs accompanying sensory and other mental images shift in the direction of the geometric future as CD increases during the SFR sequence and become potential memory mental images experiencing BSFRs in a shorter time scale.

   The time=constant snap-shots at the upper half of CD assignable to the memory mental images are ordered with respect to Minkowski time t but the order is opposite to the order of subjective experiences. This makes possible for the time-reversed re-incarnate to have these memories as "silent wisdom". Snapshots correspond to subselves to which memory recall builds a connection by entanglement or by sending a signal, reflected back in a BSFR of the memory mental image.

How are episodic memories recalled in ZEO?

1. Spontaneous memory recall could correspond to the death of a memory mental image (sub-self/sub-CD) having the same AT as self (CD) followed by re-incarnation with an opposite AT. This would be accompanied by an emission of a past directed "negative energy" signal received by the self associated with the "geometric now". The interpretation is as an extraction of metabolic energy: memory recall indeed requires metabolic energy.

   Active memory recall could correspond to the receipt of a future directed "positive energy" signal by memory mental image arriving from the "geometric now", and allow interpretation as a metabolic energy feed. Reflection of the signal in opposite time direction requires BSFR. Why should BSFR happen? Could the metabolic energy feed induce (by NMP) rapid evolution and aging of the memory mental images leading to its death by BSFR.

2. The prediction is that in an active memory recall by a "positive energy" signals received by the memory sub-CDs, the order of recalled memories is opposite to that of the original experience. There is evidence for this kind of change [J8] (see also the popular article at http://tinyurl.com/y7hbqmug).

5 TGD inspired model for sensory perception and short term memory

The findings of [J6] suggesting a statistical representation of short memories allowing a conscious estimate of the reliability of the memories allow to develop a more detailed form about sensory perceptions based on the interpretation of short term memories as sequence of "small" state function reductions (SSFRs) following analogs of unitary time evolutions.

The identification of SSFRs as cognitive measurements is discussed in [L26] in the number theoretic vision about TGD. In [L39] the possibility that all SFRs, including also "big" SFRs (BSFRs) and even particle scattering events, could be interpreted as cognitive SFRs, is considered. This involves the notion of M^8-H duality meaning that space-time surfaces in H are images of 4-surfaces in M^8 analogous to momentum space under M^8-H duality. At the level of M^4 the physics is purely number theoretic.

1. The first implication is cognitive representation defined by points of 4-surface in M^8 for which coordinates representing components of momentum are algebraic integers for the extension of rationals defined by the polynomial defining the 4-surface in M^4. As a matter of fact, the points of cognitie representation belong to a mass shell of M^4 and active points of cognitive representation contain quark.

2. Second key implications is Galois confinement prividing a purely number theoretic mechanism for the formation of bound states [L48, L47]. In this article these aspects will not be discussed.

This picture leads to a highly detailed identification of scattering amplitudes [L39].

1. The interaction region of particle reaction can be interpreted as a cognitive process in which quarks of Galois singlets move freely and only re-organize to new Galois singlets. One might say that Nature is performing recombinatorics [L39].

2. Scattering interaction corresponds theoretically to a formation of a quantum superposition of functional composites of the polynomials associated with the external particles and a natural proposal is that the outgoing state corresponds to a product of the polynomials. Allowed functional compositions can differ only by a cyclic permutations of composite, which in dual string models and twistor Grassmann approach corresponds to allowance of only planar diagrams.

3. The cognitive measurement is identified as a cascade of measurements for a representation of a Galois group decomposing to a product of representations of its subgroups defined by its decomposition to an inclusion hierarchy of normal subgroups. Due to the inclusion hierarchy, the quantum entanglements involved are directed and the natural interpretation is in terms of directed attention.

In [L46] a model of spin glasses is discussed and the proposal is made that the time evolution of spin glass corresponds to a sequence of analogs of unitary time evolutions followed by SSFRs.

1. The analog of unitary time evolution would correspond to a scaling rather than time translation as in standard quantum theory. This effectively replaces Minkowski time with its logarithm and predicts that decay rates obey power law rather than being exponential. The relaxation processes in spin glasses, which have a lot in common with living matter, indeed obey power law.

2. BSFRs would naturally correspond to time evolution as time translation and would give rise to exponential decay rates. If short term memory and sensory perception involves SSFRs, the prediction is that the decay of memories is not exponential but obeys power law.

5.1 How the sensory perception is formed?

The following represents a simple model for what might happen in sensory perception.

1. Sensory perception means a reduction of entanglement. This reduction is usually interpreted as quantum measurement but one could also say that it gives information about the relationship between A and B rather than state of A, or equivalently B. In a sequence of SSFRs, this measurement is carried out repeatedly for the regenerated entanglement. What this regeneration could mean in the TGD framework is discussed in the general number theoretical model for interactions based on $M^8 - H$ duality [L39]. The original entanglement need not be generated faithfully but could do so in a good approximation.

   What is essential is that Nature would replace single SFR with a sequence of cognitive SSFRs, which would be measurement cascades proceeding from long to short p-adic scales: the p-adic length scale is determined by largest ramified prime of the extension and decreases in the cascade defining SSFR [L39]. This sequence of SSFRs would produce a sequence of sensory mental images giving rise to a temporal statistical ensemble of mental images characterizing the unentangled state, which in the ideal case would be the same after all SFR cascades.

   The situation is analogous to that in quantum computation in which unitary time evolution determined by Hamiltonian produces a state of observables measured as the program halts. In quantum computation, one must produce a spatial ensemble of final states. One can also run the programs several times to build this kind of ensemble. The statistical distribution for the outcomes codes for the solution of the problem that the quantum computer program is supposed to solve, say factorization of an integer. I have considered two decades ago the possibility that living systems, for instance DNA-nuclear membrane system, could act like topological quantum computers: the braiding of magnetic flux tubes would code the quantum computer program [K16, K17, K19].

2. Quantum entanglement would be naturally between magnetic bodies (MBs) of the systems involved [L54, L25, L40]. The sensory input comes from the external world but it is unclear in what scales it can be quantum entangled with sensory receptors. The hierarchy of Planck constants predicts quantum coherence in all scales for MBS so that the entanglement could be macroscopic.

   What seems clear is that the MB of the sensory organ entangles with the MB of the conscious perceiver. The MB of the sensory organ would quantum entangle with the MBs of the receptor neurons and perhaps these in turn quantum entangle in the same scale with the MBs of the external world.

3. Sensory organs and their receptor neurons should entangle with the nearby neurons able to generate nerve pulses in order to communicate the information to brain. The sensory input could be communicated to MB from the neuronal membrane of sensory receptor neuron (which does not generate nerve pulses) to MB as frequency - and amplitude modulated (generalized) Josephson radiation generating a sequence of resonance peaks, which defined feedback from MB to the neurons, which in turn give rise to nerve pulses from the sensory organ to the brain [K2, K9, L41, K8] [L38].

4. The SFR generating the sensation at our level of self hierarchy should occur in the scale of the sensory organ at least. The pair MB-sensory organ would be a natural pair to consider if generalized Josephson radiation communicates the sensory information to MB.

5.2 Models for the sensory input from the sensory organ to MB and vice versa

The basic objection against communications from the sensory organ to MB and vice versa is that the input from the sensory neurons to MB is expected to decompose to non-correlated inputs from separate neurons. If they are non-correlated, it is very difficult to understand how a macroscopic SFR giving rise to unitary conscious experience can take place. This problem is actually the key problem of all theories of consciousness and standard QM does not seem to be enough to overcome this problem.

5.2.1 Sensory input from the sensory organ to MB

What is required would be a large number of simultaneous dark cyclotron transitions as a quantum analog of a phase transition. The (generalized) Josephson radiation from the sensory neurons with the same receptive field should be in synchrony and somehow fuse to a kind of Bose-Einstein condensate. Here the number theoretic vision comes into rescue.

1. The hierarchy of Planck constants is the first prediction of the number theoretic vision. The second prediction is Galois confinement, which provides a universal number theoretic mechanism for the formation of bound states of quarks. All elementary particles and also their bound states would be formed by Galois confinement. Even particle reactions would be at the fundamental number theoretic level recombinations of Galois singlets formed from free quarks to new Galois singlets [L39].

2. For the 4-surface of M^8 determined by a polynomial P, quarks have momenta, which are algebraic integers in an extension of rationals determined by P. For instance, periodic boundary conditions require that the total momentum has integer valued components in units defined by the p-adic mass scale assignable to the Galois singlet is therefore formed.

   Galois confinement would bind Galois-non-singlets to singlets in all scales. In particular, dark N-photons are predicted as also dark N-protons and ions. Dark N-photons would be analogous to Bose-Einstein condensates and could induce N-cyclotron resonances at MB for N-ion Galois singlets. Dark genetic codons would be Galois singlets formed by dark proton triplets and dark genes would be Galois singlets formed from these triples but with momentum which does not have integer components.

Consider now a more detailed model for the secondary sensory input from sensory organ to MB.

1. Generalized Josephson radiation [K2, K9] from neural membranes produces the sensory input to MB. The Josephson radiations from different sensory receptors form a Galois confined state as dark N-photon.

2. Frequency modulation of the generalized Josephson radiation is possible and transforms the information coded by the membrane potential modulation to a sequence of cyclotron resonances at MB. This sequence is communicated back to the sensory organ to neurons able to generate nerve pulses, most naturally neighbors of the sensory receptor neurons. Therefore the communication of sensory input to the brain occurs via the loop sensory receptor → MB → neuron able to fire.

3. The intensity of the generalized Josephson radiation radiation can be modulated by varying the density of the dark Cooper pairs of electrons, protons and fermionic ions and of bosonic ions at the cell membrane acting as a collection of Josephson junctions formed magnetic flux tubes associated with ion channels and pumps. If the intensity is too low, the signal from MB is weak and no nerve pulses are generated. This would be the case during sleep and unconscious states in general.

As the intensity of the sensory input increases, also the intensity of Josephson radiation and therefore also nerve pulse response increases. The period for the amplitude modulation determines the rate of nerve pulses bursts.

4. Biological high temperature superconductors are open systems. The increase of h_{eff} for electrons giving rise to Cooper pairs requires energy and since the Cooper pairs have tendency to decay by the reduction of h_{eff}, the maintenance of the Cooper pair condensate requires a continual energy feed. Either sensory input or metabolic energy feed can provide the needed energy. The latter case the sensory input would mean amplification of the sensory input.

5.2.2 Model for the virtual sensory input from MB to brain

A virtual sensory input from MB to the brain is needed to generate memory mental images associated with short term memory. This input would also make possible imagination and dreams and hallucinations.

It is difficult to imagine a detailed mechanism for the generation of the virtual sensory input to the brain at the level of MB. ZEO however allows us to consider an option requiring no new mechanisms at the level of MB . This option would be based on a time reversal occurring BSFR at the level of MB. From the point of view of an observer with the standard arrow of time, time reversed communications from the sensory organ to MB would look like communications from MB to sensory organ!

The counterpart of the time reverse period following BSFR is analogous to death and is followed by a time-reversed period analogous to reincarnation. Sleep and hibernation would be examples of this time reversed period [L51]. Also at the level of fundamental biomolecules, periods analogous to sleep are a rule. In the case of a neuronal membrane, nerve pulse is followed by a dead time, which would be also analogous to a sleep period as a time reversed period.

6 Are we living in the past?

The original article by Mauro Manassi and David Whitney [J9] (`https://cutt.ly/lONjIQn`) with title "*Illusion of visual stability through active perceptual serial dependence*" suggests that visual perception is a kind of temporal average over a time interval, which can be even longer than 15 seconds.

6.1 The findings of Manassi and Whitney

"Why do the objects in the world appear to be so stable despite constant changes in their retinal images?" was the question that motivated the work of Manassi and Whitney. Retinal images continuously fluctuate because of sources of internal and external noise. Retinal image motion, occlusions and discontinuities, lighting changes, and perspective changes and many other sources of noise are present. However, the objects do not appear to jitter, fluctuate, or change identity from moment to moment. Why does the perceived world change smoothly over time although the real world does not?

This problem is also encountered in quantum consciousness theories. If conscious experience consists of a sequence of non-deterministic quantum jumps as moments of consciousness, it is not at all clear how a smooth stream of consciousness is possible.

One modern explanation for the smoothness of conscious experience is some kind of change blindness or inattentional blindness. The finite capacity of visual short-term memory is certainly a fact and forces a finite perceptive resolution and effectively eliminates too fast temporal gradients. This finite resolution poses limits in perceptual, decisional and memory processing. This would naturally apply also to other sensory memories.

In the standard view sensory percept corresponds to a time=constant snapshot of the physical world. The basic prediction is that the object at a given moment of time is the real object but in a finite perceptive resolution.

The alternative hypothesis studied in the article is that the visual system, and presumably also other sensory systems, use an active stabilization mechanism, which manifests as a serial dependence in perceptual judgments. Serial dependence causes objects at any moment to be misperceived as being more similar to those in the recent past. The serial dependence has been reported in the appearance of objects, perceptual decisions about objects, and the memories about objects. In all of these examples, serial dependence is found for random or unpredictable sequential images.

This raises the question whether one can understand the serial dependence by identifying the conscious perception at a given time as a weighted temporal average of preceding time= constant perceptions over some time interval T and what additional assumptions are needed to understand the other findings related to the phenomenon.

6.2 The experiments demonstrating the serial illusion

Article describes 5 experiments related to serial illusion. The experiments are described in detail in [J9] with illustrations (`https://cutt.ly/lONjIQn`) and in the sequel I summarize them only very briefly. The reader is strongly encouraged to read the original article providing illustrations and references to literature related to serial illusion.

6.2.1 Experiment 1: shift of the perception to past

In Experiment 1 the shift of the perception to the past was demonstrated.

1. 2 separate groups of 44 and 45 participants rated the age of a young or old static face embedded in a blue frame (13 and 25.5 years, respectively). This gave a distribution of ratings around some mean identified as the real age of the face. The rating of the static face alone is referred to as the reference face .

2. A third group of 47 independent participants were presented with a movie of a face that morphed gradually, aging from young to old. These observers then rated the age of the old face. The rating of the static face preceded by the movie is referred to as the test face . The last frame of the video was identical to the reference face.

3. The age ratings between physically identical static faces, either alone (reference face) or with a preceding video (test face) were compared. Although the test and reference faces were identical, the old test face, seen after the video, was rated as 5 years younger than the old reference face, seen without the video (20.2 versus 25.5 years).

4. One can argue that the stability illusion is due to a simple unidirectional bias in age ratings. Therefore a fourth group of 45 new participants watched a movie of a face that gradually morphed from old to young. Following the movie, observers rated the age of a young static test face embedded in a blue frame. The young face was rated as 5 years older than its actual age (18.4 versus 13 years). Therefore the stability illusion can cause faces to appear younger or older depending on the previously seen faces.

These findings are consistent with the temporal averaging hypothesis.

6.2.2 Experiment 2: the effect of noise

The noise is known to increase the serial dependence. Whether this is the case also in the case of illusion stability was tested. Stimuli with and without noise were represented to separate groups of observers. As a measure of the stability illusion strength, *attraction index* as the bias in age ratings toward the beginning of the movie was introduced.

1. A measure of the stability illusion strength, *attraction index* was introduced. *Attraction index* is defined as $\Delta T/T$, $\Delta T = |T_r - T_p|$, where T_r is the real and T_p the perceived age of the test face, and T is the total age range T. Real age refers to the average perceived age in the Experiment without preceding video.

2. When the movie and test face were presented alone or with superimposed dynamic noise, the static test face ratings were attracted by 28 and 42 % of the movie.

3. When the movie was presented with increasing dynamic noise and a test face with high noise, the attraction was around 48 %.

   The results conform with the earlier finding that serial dependence in perception increases with noise and uncertainty. As the increasing dynamical noise yielded the strongest illusory effect, it was used across subsequent experiments.

Why should the increase of the noise increase the strength of the illusion stability? Suppose that the perception is average over time=constant perceptions from a time interval T. For instance, one could think of a Gaussian distribution for the weights of the contributions over the interval T. It would seem that T gets longer in the presence of noise in order to achieve reliability.

6.2.3 Experiment 3: Central tendency bias not involved

It might be argued that the results are due to a central tendency bias, i.e., the tendency to rate test faces as being close to middle age, independent of movie content.

To test this, Experiment 3 replicated the same conditions Experiment 1 but linear increase/decrease in the age of the face was replaced with a more complex increase/decrease using staircase functions leaving intact the starting and ending points of the movies (young and old).

1. Attraction index gradually decreased with decreasing the number of age steps in the movie, thus showing that our illusion is not only due to a simple response or central tendency bias but also strongly depends on the whole content of the face morphing movie
2. The attraction index was computed with the last 6, 18, and 30 seconds of the video preceding the test face. Attraction linearly increased with increasing video duration, thus showing that the attraction effect involves all parts of the preceding video.

These results seem to be consistent with the averaging hypothesis. If Gaussian distribution can be used to model the averaging, the parameter T characterizing the locus of the distribution was at least of order $T = 30$ seconds and that the distribution was rather flat in this range.

6.2.4 Experiment 4: Temporal strength/range of illusion

If our illusion is due to the proposed active mechanism of perceptual serial dependence, it should occur on a broad temporal range in accordance with previous findings.

In experiment 4 the temporal strength of the stability illusion with an interstimulus interval (I.S.I.) of 0, 1, 5, 10, and 15 seconds between the movie and test face was measured.

Test face age ratings were attracted toward the movie at all intervals, thus showing that stability illusion extends across a large period of time . These results also show that, without intervening trials, serial dependence magnitude extends over a larger period of time than previously shown.

6.2.5 Experiment 5: Face feature similarity

The previous serial dependence literature on face stimuli suggests that stability illusion should be determined by face feature similarity and should occur only when the face morphing movie and test face are similar (belong to the same person, and even more, have very nearly the same age).

Unlike previous passive change blindness based explanations, any modulation of the illusion respecting feature similarity should be consistent with serial dependence and would make it possible to make predictions about the perceived age T_p of the test face.

In experiment 5, a movie of a face that morphed from young to old was represented, and after an interval of 1 second, the age of the static test face was varied by making it younger or older than the original test old face. On the basis of the known tuning of serial dependence for face similarity, three predictions were formulated.

1. Stability illusion should occur only with faces similar in age to the test face and not between dissimilar faces. It was found that the old test face was rated as younger (attraction effect) only for a few similar identities that were most similar to the old face; the attraction disappeared for more dissimilar identities.

2. As the old test face was perceived as being $\sim$ 20 years old after watching the movie, it was predicted that, when a reference face that is 20 years old is used as a test face after the movie, the degree of attraction for that face should be zero. No attraction for a test face of 20 years of age was found.

3. Test faces younger than $\sim$ 20 years old should be perceived as older, because the movie content contains older identities across the duration of the morph movie and, hence, should bias test face perception toward older ages. When the test face was younger, it was rated as older than it actually was.

The results and predictions were very well captured by a two-parameter derivative of a Gaussian model, in accordance with previous results, and ideal observer models proposed in the serial dependence literature.

6.3 TGD based explanation for the findings

TGD inspired quantum theory of consciousness as a generalization of quantum measurement theory allowing to overcome its basic problem caused by the conflict between determinism of unitary time evolution and non-determinism of state function reduction (see for instance [K10, K12, K13]). Zero energy ontology (ZEO) as an ontology of quantum theory [L18] [K20] plays a crucial role and leads to the proposal that the perceptive field is 4-dimensional so that one can speak of 4-D brain. This leads to a general vision about sensory perception and memory.

In the TGD framework, the question why the perceived world looks smooth is encountered already at quantum level. ZEO predicts two kinds of state function reductions (SFRs).

1. In "Big" SFRs (BSFRs) the arrow of time changes. In ZEO this explains in all scales why the world looks classical for the observer having arrow of time opposite to that for a system produced in BSFR [L15].

2. Sensory perceptions correspond naturally to "small" SFRs (SSFRs) and since SSFRs are the TGD counterparts of weak measurements of quantum optics and their sequences define what in the wave mechanics would correspond to a repetition of the same measurement (Zeno effect). Therefore one can hope that the problem disappears at quantum level.

   One must however understand why the perceived world seems to evolve smoothly although it does not.

The TGD based explanation for stability illusion and serial dependence relies on the general assumptions of TGD inspired theory of consciousness.

1. TGD inspired theory of consciousness predicts the notion of self hierarchy [K10]. Self has subselves, which in turn have subselves which correspond to particular sub-subselves of self. Self experiences its subselves as separate mental images determined as averages of their subselves. There are therefore three levels involved: self, subself, and sub-sub-self. Self hierarchy is universal and appears in all scales and one can ask whether the super-ego–ego–Id triple of Freud could be interpreted in terms of this hierarchy.

   The correspondences are therefore "We" $\leftrightarrow$ self; mental image $\leftrightarrow$ subself; subself as mental images of self $\leftrightarrow$ average over sub-subselves.

2. In accordance with the vision of the 4-D brain, ZEO makes possible the temporal ensemble of mental images as a basic element of quantum consciousness. No separate neural mechanism for forming the temporal ensemble is needed: its generation is a basic aspect of the quantum world.

3. The perception (subself) as a mental image is identified as a kind of temporal average over time=constant perceptions (sub-subselves), which basically correspond to quantum measurements and can in ZEO be identified as "small" state function reductions (SSFRs) in ZEO. Continuous stream of consciousness would replace the Zeno effect.

   The averaging smooths out various fluctuations (to which also SSFRs contribute at quantum level) and subselves as temporal averages over sub-subselves give rise to an experience of a smoothly changing world. The conscious sensory perception at "our" level is not about time=constant snapshot but an average over this kind of snapshots.

Consider now a model for the stability illusion and various aspects of serial dependence. In the following T_r *resp.* T_p denotes the real *resp.* perceived age (after seeing the video) of the face. T denotes the total age range. t_k denotes the time associated with k^{th} video picture and t the total duration of the video.

1. Sub-subselves in the experiments of [J9] correspond to $t = t_k < t$ video snapshots. Subself at $t = t_k$ corresponds to a statistical average M_k of $0 \leq r \leq k$ video snapshots at t_r. At $t = t_k$, "we" experiences M_k . The averaging over time gives rise to experience, which is biased towards earlier perceptions. The averaging creates the smoothing of the perception and generates the illusion that the perceived mental image is shifted to the past.

   If the perceived ages $T_{p,k}$, to be distinguished from t_k corresponding to real ages $T_{r,k} = T_0 + k\Delta T_r$ contribute with the same weight in the age interval T, the average corresponds to the central value of $T = T_0 + T/2$. In the general case, the average depends on the details of the distribution for $T_{r,k}$ and on the distribution of weights for t_k in accordance with the results of Experiment 3.

2. The higher the noise level, the longer the maximal time interval t_M over which the averaging takes place in order to gain reliability. This requires active response by changing t_M for M_k. t_M must increase with the noise level. For instance, if the weights in the average are Gaussian, the width of the Gaussian distribution must increase with the noise level. This explains the findings of Experiment 2 relating to the effects of noise.

Experiment 5 provides the information needed to formulate a model for what could happen in the addition of a new face at $t = t_N$.

1. The test face F_{N+1} is first experienced as a different person. After that it is checked whether F_{N+1} corresponds to any memory mental image M_k in the ensemble $\{M_k|k = 1, ..., N\}$. This involves memory recall besides time=constant snapshot perception.

   If F_{N+1} is similar to some M_k in $\{M_k|k = 1, ..., N\}$, it is added to M_N and defines a new memory mental image M_{N+1} and there is a stability illusion.

   If it does not correspond to any M_k, it is not recognized as an already perceived face, and is not added to M_N as a new memory M_{N+1} so that there is no stability illusion.

2. This model explains the results of 3 sub-experiments of Experiment 5 relating to the face feature similarity. The second experiment however deserves a detailed comment since it involves criticality in the sense that a small variation of the real age of $F(N+1)$ should lead to a disappearance of the stability illusion.

   Let $T_{p,A}$ be the perceived age of the test face in experiment A and $T_{r,B}$ the real age in the next experiment. For $T_{B,r} = T_{A,p}$ the stability illusion is absent whereas for $T_{B,r} \leq T_{A,p}$ it is present. The situation is therefore critical.

   The proposed model explains the presence of the illusion. One can however argue that $T_{B,r} \geq T_{A,p}$ rather than $T_{B,r} = T_{A,p}$ should actually hold true, or more precisely, there was no memory mental image M_k with $T_p \leq T_r$. A small variation of $T_{B,r}$ makes it possible to test whether the situation is really critical.

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