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The Optical Illusion Of The Visual World

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ABSTRACT

First and second order correlation of receptor responses in twin pairs of distinct groups of receptors by pairs of successive time-quanta of about 0.04 seconds, constitute vision's luminosity channel. A response is due to one or more light quantum absorptions in a time-quantum. A group consists of 1 R or G cone and 0-100 rods. The retinal twin units contain the three gain controls of the system. Action potentials from the myocardium produce the time-quanta. The extra cellular fluid, blood, and glia cells conduct them to the sensory organs and the motor systems. The small involuntary eye tremor scans the retinal image of the environment in synchrony with the time-quanta. The limits of perceptual hyperfunctions for time and space correspond to the free space between adjacent groups and the rise time of the action potentials. Two or more light quantum absorptions in a time-quantum in a receptor elicit a color signal. The B cone produces a color signal already for any quantum absorption. These signals fill the perceptive products of the luminosity channel with color. In anomalous color vision, some twin units have different cones instead of equal ones.

KEYWORDS

Light quantum;
Edge;
Movement;
Color;
Determinism;
Consciousness

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INTRODUCTION

In cardio physiology, it is for long a cardinal question whether the action potentials of the purkinje cells in the myocardium are there because of the contraction of the ventricles of the heart or the ventricles contract because of the firing of the purkinje cells[1]. Whatever the solution for this chicken-egg problem is, a rigorous straightforward analysis of statistical physics aspects of visual perception led to the unavoidable and remarkably self-evident finding: These action potentials essentially act as common time-quanta for all proprioceptive elements of the sensory organs and motor systems. Electric conduction through the body fluids allows them to execute this task. They regulate the signal processing of the central nervous system. At cardiac arrest, sensory and motor functions immediately completely fail what implies unconsciousness of the subject.

The development of the twofold quantum coincidence mechanism for the absolute threshold of human vision by Van der Velden[2]opened the approach for this analysis. Further De Vries[3] demonstrated that thresholds for visual intensity discrimination agree with the average natural poisson fluctuations in the flux of quanta of the stimulus. A further significant step was due to Reichardt[4,5], who described the general principle of auto-correlation in the central nervous system and the mechanisms for detection of movement in visual perception. The physics analysis revealed irrefutably, the strictly deterministic procedures and the distinct mechanistic of the nerve signal processing[6,7]. Like in the molecular biosciences thanks to the discovery of DNA. Generally, contemporary psychology and relevant parts of sensory physiology not embraces such insights. On the contrary, they accept the scientifically not justified doctrine, that human behavior and its underlying life-processes firstly are by nature at random, noisy and chaotic. As a result, they repeatedly reject them. These disciplines are for a long time dominated by approaches like the Tanner-Swets signal detection theory for psychology. In this theory, “intrinsic noise” of the system has a key role. The theory not defines the noise in physics terms. The assumed actions of the noise are analogous to those of “earth rays” in parapsychology where they cause the false positive deflections of the divining rod in the hands of a psychic subject. In visual neurophysiology, the “brain rays” turned up as “dark light”. More recently, “randomness” of spatial distribution of R and G cones in the retina found eagerly adherence. The basis for this assumption are ophthalmoscopic images of one degree visual angle diameter in which the systematic dependence of intercone distance with retinal eccentricity should have remained visible which it did not[8]. A method that indicates the utmost regular distribution of figure 4 also as being random determined, this “randomness”. This development even went to the extreme assumption that the cells in the different layers of the visual system are at random interconnected[9] wherein randomness again is unspecified. This seems to exclude any scientific study of the functional properties of nerve structures. At large, current literature avoids knowledge of the physiological physics of the central nervous system and human vision. This paper enumerates the basic facts for vision. For more extended reports, other material is available[6,7]

RESULTS

Time and space of conscious human living does not continuously conjugate with time[10] and space of physics but consist of joined physical time-quanta[11] of about 0.042 seconds and space-quanta[7] of distinct receptor groups. A group consists of one R or G cone and from 30 minutes of arc eccentricity onwards, a number of rods between 0-100 that is proportional to the square of eccentricity. These groups sit along clockwise and counter-clockwise revolving spirals and along circles around the center of the fovea. Each spiral and circle contains about 630 groups; each spiral makes almost one full revolution over the retina. Outside the rod-free central fovea, the ratio of radii of successive circles is 1.0152. Histological data of Schultze[12] demonstrate the existence of these spirals and circles just as the accompaniment of a cone with an eccentricity dependent number of rods. The strict regularity of the mosaic pattern of receptors is a remarkable peculiarity known for eyes and ears of many species. See

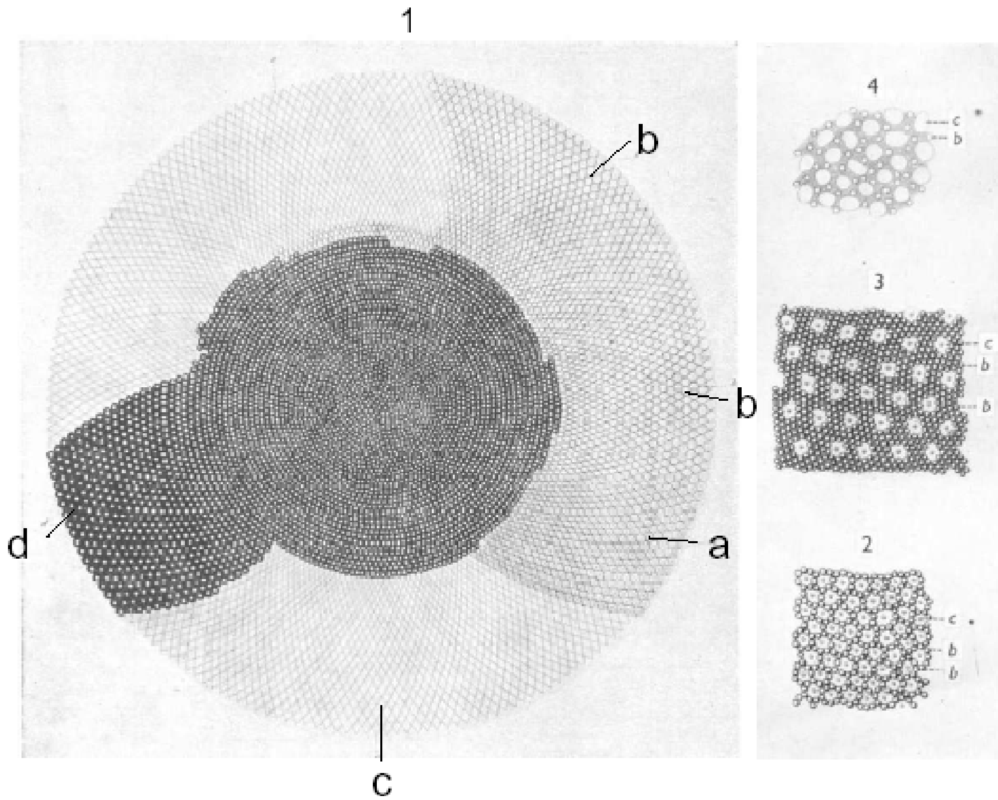

Figure 1 : Receptor mosaic of the human retina, enlargement ca 500×, 1 fovea with a, b, c, d different depths in the preparations, 2 parafovea, 3 periphery, and 4 at the edge of the retina: ora serrata. In 2, 3 and 4, b is a rod and c a cone[10]

figure 1.

The optical density of the photo pigment of the receptor depends on illumination. The influence of this dependence on vision is comparable to the use of sunglasses before the eyes.

A receptor requires for its response in a particular time-quantum, a number of quantum absorptions that is equal to the total number of absorptions in the preceding time-quantum. The minimum is 1 for the dark-adapted eye. This way the receptor's gain becomes reciprocally proportional to intensity I and the relative sensitivity dI/I becomes proportional to the intensity I: Weber's law[13].

On each separate spiral and circle, the groups are mutually connected in distinct pairs. In these twin units, the one group is the ON group and the other the OFF group. On each spiral, in the twin units the ON to OFF sequence corresponds with the direction of revolution of the spiral. This is our arbitrary choice. We may choose just the other way around. On the circles this sequence is alternatively clock- and counter-clockwise.

For perception of light, the ON and OFF group of a twin unit should each respond separately in one of two successive time-quanta[7]. The polarity of the first stimulated group decides on the ON or OFF polarity of the pairing's light response. Hence, each light response carries a latent ON or OFF direction or orientation signal. Direction refers to movement, orientation to whether it concerns a transient from light to dark or from dark to light. See figures 2 and 3.

At the onset of illumination, just the group that delivers the first of a pair of group signals for a light response, needs for a subsequent group signal in the running time-quantum, one receptor signal more than for its just delivered group signal. The total number of quantum absorptions n for k group signals of that group in this time-quantum $n = \frac{1}{2} k \times (k-1)$. This way at the end of the time-quantum, the group re-

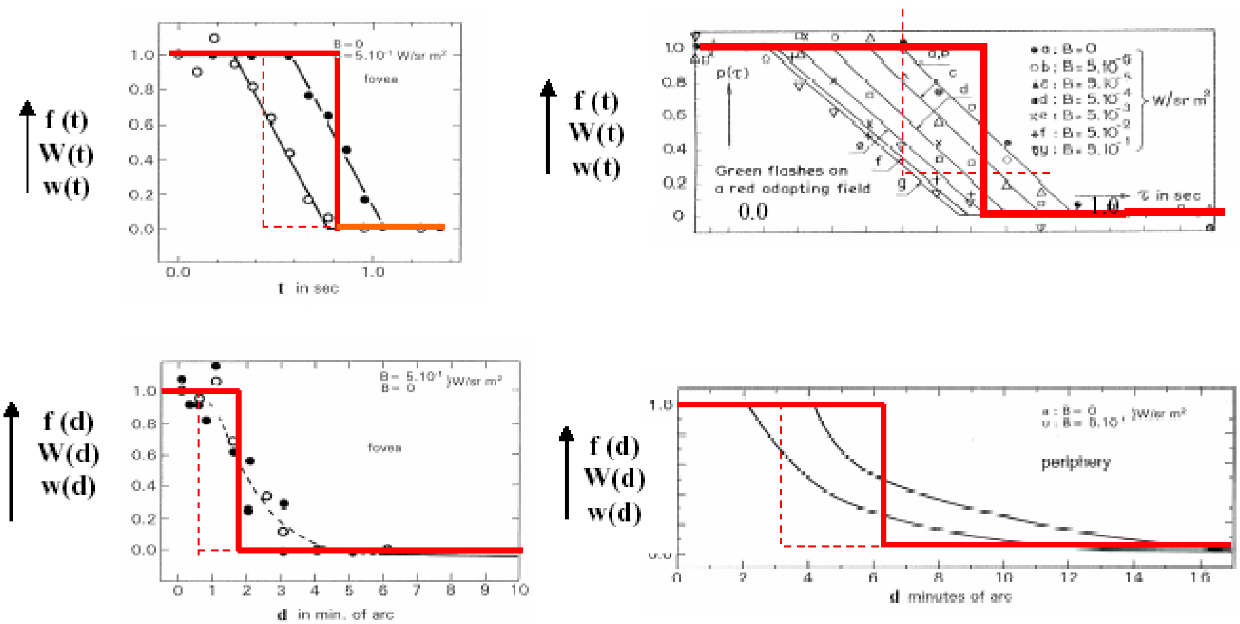

Figure 2 : Results of experiments on the probability for effective pairing of two separately subliminal retinal excitations. They are each due to one of two flashes of 10 milliseconds duration and 1 arc minutes geometrical diameter, in periphery and fovea, either as a function f(t) of their mutual interval of time t or as a function f(d) of the distance d between them on the retina. After correction for duration and diameter of the separate flashes: the heavy full-drawn red lines w(t) and w(d) are for the dark-adapted eye B=0 and represent the duration of a pair of time-quanta and size of a pair of space-quanta. The dashed thin red lines are for the light adapted eye against background B= 0.5 W/sr.m ^{2}and represent duration W (t) and size W (d) of the single time-quantum and space-quantum[7].

quires for a further group signal a number of receptor signals dn that is equal to about twice the square root of the average total number of receptor signals n per time-quantum per group. Consequently, by this gain control dn becomes proportional to the average statistical poisson fluctuations in n. Under constant and homogeneous illumination for moderate values of intensities, the relative sensitivity dI/I for short and small stimuli is proportional to the square root of I: De Vries' law[3,15].

The De Vries gain control is the most influential one for vision's properties. After any ON or OFF excitation in a twin unit the sensitivity for respectively ON or OFF becomes less in relation to the sensitivity for the opposite polarity. Moving after images after prolonged exposure to one-directional moving stimuli are due to this lateral interaction. Further when both groups of a twin unit are each constantly illuminated- no matter whether equal in intensity and color or not- their numbers of group signals per time-quantum become equal. This number n is the geometric mean between what the numbers n_1 and n_2 for both groups would have been in case their intensities were both equal to the intensity either of the one group or of the other: $n = \sqrt{n_1 \times n_2}$. Hence, after a short time of adaptation, any difference in illumination of the two groups becomes invisible[16,17]. Artificial compensation of involuntary eye movements or tremor can provide for elimination of casual variations in illuminations of the two groups. So actually, the eye tremor keeps vision alive. The lateral and meta interaction of the De Vries gain control of the twin units, the involuntary eye tremor and the receptor's Weber gain control, are crucial for the global perceptive constancy of human vision: perception of the environment is rather independent of color and intensity of illumination and of distance and direction of observation. A demonstration in detail fol-

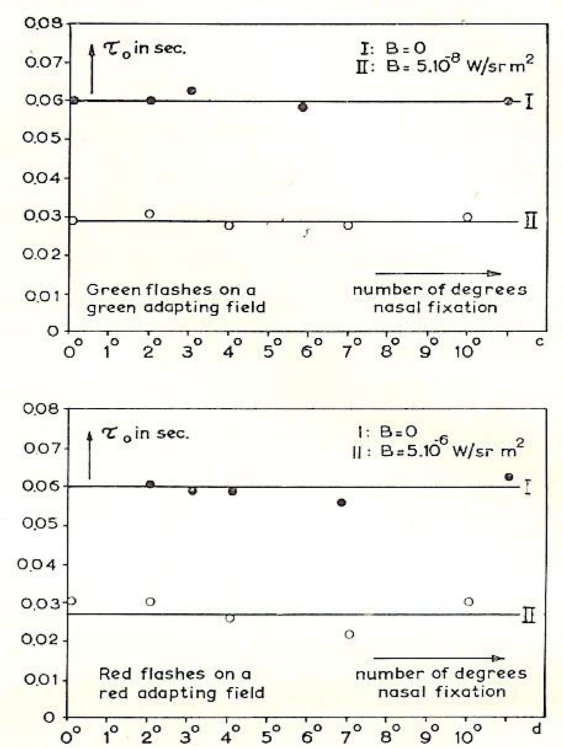

Figure 3 : The largest value of t for which in figure 2 f(t) = 1 for B = 0 and for B = 5.10^{-1}W/sr.m^2 as a function of direction of fixation for different colors of stimuli and background. The data show that the durations of the single and of the pair of time-quanta are all over the retina the same no matter what the types of receptors are that are stimulated by test stimuli and background. An external actor is responsible for such a constancy of the characteristics of the temporal processing of signals over the retina[14]

lows later elsewhere.

For high intensity levels the combined Weber and De Vries gain controls determine the limiting Weber fraction W of the group. Earlier[6] was shown that **W** is about equal to $2\times\left(1+2\sqrt{\mathbf{P}+1}\right)^{-1}$; P is the number of receptors in the group. Spontaneous decompositions of photo pigment molecules by thermal noise occur on average once in about 90 seconds per receptor. The effect of these decompositions on the state of the receptor is different from those by absorption of light quanta[18]. After exposure to day light, these noise events set in the dark the controls back in about 20 minutes to one quantum absorption for a receptor signal and 1 receptor signal for a group signal.

Pairings of ON or OFF light responses from a single pair of successive time-quanta and in neighboring pairs of twin units on two different spirals of the same set or on two circles are for the perception of ON or OFF edge or spatial light-dark or dark-light transient. Pairings of ON or OFF light responses from a pair of successive pairs of successive time-quanta in neighboring pairs of twin units on the same spiral or circle are for perception of ON or OFF movement[6,14]. Movements faster than 2 space-quanta per time-quantum are not seen, slower than 1 space-quantum per 2 light quanta are seen as displacement. During a fixation movement, the subject does not perceive the moving retinal image of the environment[19]. This is not a question of cortical suppression of perception of movement. It is because the image moves globally faster than 2 space-quanta per time-quantum. Hence, light can be seen but movement of contours cannot. The pairings for the perception of light, movement, and shape occur in each of the three sets of twin units on the spirals and circles independently from those in the others. Effectively they are operations of spatio-temporal correlation. Each of these three sub-retinas has access to two networks, one for each of the two polarities ON and OFF. Accordingly, every retina is by three pairs of parallel networks connected with the lateral geniculatum nucleus. For the two eyes together, the LGN contains 12 layers. Each layer handles a topographical representation of its sub-retina. Their combined cortical activity is the vectorial summation of their different responses.

In a triple of successive pairs of time-quanta, areas that correspond to a septet of twin units on the ON and OFF layer in the LGN of a particular sub-retina, cannot both simultaneously be active. When in both layers activity occurs these activities are either temporally and/or spatially complementary. Perceptive transparency of two differently shaped spatial stimuli is an expression of interplay between these activities of the pairs of layers. An example for such conditions is the observation of a transparent rotating sphere whose surface is homogeneously covered with distinct solid small dots.

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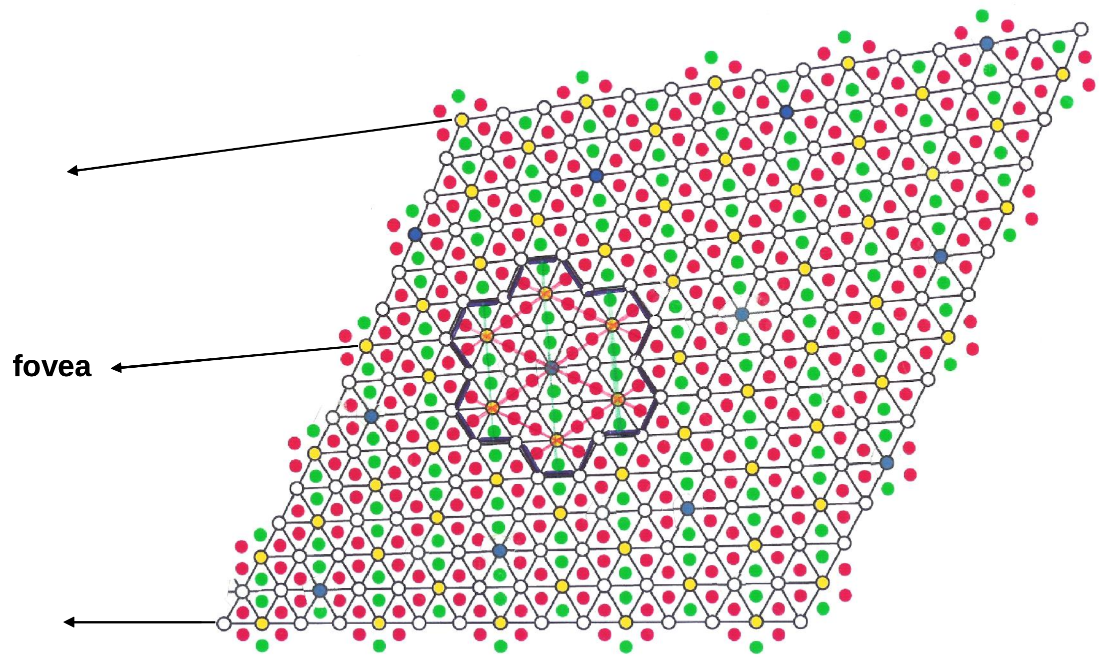

Figure 4 : Scheme of perfectly regular receptor mosaic. Red and green circular dots are space-quanta that contain 0-100 white cones or rods and 1 red respectively green cone. Blue dots are blue cones. The R space-quanta are on clockwise and counter-clockwise revolving spirals, the G cones on circles that are concentric with the fovea. Yellow dots represent the points in the retina for cross pairing of responses of R and G cones for the procreation of yellow. The heavy drawn contour represents the column in the system within which the spatiotemporal correlative operations between the twin units for light, movement, and contour perception occur. White dots indicate the pathways in the lateral geniculatum nucleus for R and G and for Y and B color signals from both eyes for annihilation of each other's color signal. White responses that are equal to the white responses of rods are left[6]

Half of the dots move in one direction and the other half in the opposite direction. The one-half is seen to occupy the convex curved front surface and the other the concave back of the sphere. Another expression of the interplay mentioned is the generally known phenomenon of perceptive rivalry between the two gestalts of a particular spatial stimulus[20,21]. Further discussion of rivalry follows below.

Every space-time correlation improves the accuracy of signal detection by a factor 2[4]. For a specific space-time-quantum, the number of these operations in each of the three mutually independent sub-retinas of each eye is 7. For the two eyes together, a total factor of 2.4x128 is available for improvement of the signal to noise ratio[6]. For high intensity levels for binocular observation of extended spatio-temporal stimuli, **W** becomes about $9.2\times10^{-3}\left[2\sqrt{(\mathbf{P}+1)}+1\right]^{-1}$ Intensity discrimination in the far periphery of the retina where $P = 100$ can reach about 0.0004, in the fovea 0.0031.

For two and more quantum absorptions in a time-quantum every R, G cone, and rod delivers a color signal[22]. This has access to the routes for a red or green and white response. A rod really is a W cone. B cones are not part of the luminosity channel. Each single B cone produces a blue response for any light quantum absorption. These procreations of color signals do not rely on pairings of temporally and spatially separated point processes. Therefore, they cannot contribute to improvement for detection of differences in intensity or color. They just fill the spatiotemporally closed contours of the perceptive products in the luminosity channel, homogeneously with color. The color responses extend the cognitive functions of vision.

Where in the retina a circle meets a spiral green and red responses in successive time-quanta can cross-pair. Here in an antagonistic relation they procreate yellow. This cross pairing represents a correlative operation and it improves discrimination. For about 8 rods in a space-quantum of the parafovea, relative sensitivity still reaches 0.00045. A wavelength difference of 0.1 nm around 579 nm is visible.

The column in the LGN that subtends three spirals or circles from each of the three sub-retinas of the two binocularly fused retinas is the seat of another two categories of antagonistic interaction. Any pair of red and green responses or yellow and blue in such a column mutually annihilate each other's color signals. White responses remain. This white is equal to the white of the rods. Such an arrangement of antagonistic interactions in the LGN implies that particular combinations of red and green color signals in a single eye results in yellow whereas such red signals from the one eye and green from the other do not produce yellow but result in white.

Every space-quantum contains 1R or G cone and 0-100 rods. Normally the two groups of a twin unit have both either one R or G cone. In superior color vision, the R cones occupy the two arrays of spirals and the G cones the array of circles. In less superior vision in the peripheral retina within certain limits, R and G twin units might be distributed less or more irregular[8]. The R/G ratio of their total numbers over the whole retina remains 2[23].

For color defective subjects the two cones in some units are different or there is in a group no cone at all. In peripheral locations, for the Rayleigh equation at the Nagel anomaloscope, normal subjects also have spuriously anomalous settings. This anomaly slightly and systematically depends on eccentricity. This is due to the interference of the variable number of rods or W cones on the De Vries-Weber controls of the two groups of a twin unit. The normal human retina really contains four types of color receptors. Color vision still is trichromatic at every particular retinal location because exactly the same number of rods accompanies each R and G cone.

The time-quanta have a periodicity of ca 24 per second[24]. Illumination that varies with periods that are shorter than about 1/48 seconds appears as continuous, with periods longer than 1/48 seconds as flickering. This rather abrupt transition at 48 periods per second is due to just completely fit and just not fit of two full periods of successive variations within a single time-quantum. Perceptive color variations can follow up to only 12 per second of spectral modulations. In each period, the correlative operations of the luminosity channel should first be completed.

The stimulation of the pupil reflex system is not subject to the processing of the space- and time-quanta. This appears from reflex sensitivity measurements in dependence of stimulus area and duration[25]. It has different pathways in the central nervous system and can remain active when other organs fail.

All three gain control mechanisms of the visual system- the photochemistry, Weber-, and De Vries adaptation- sit at the very distal end in the twin units of the retina. No other adapting procedures further in the physiology of the system are involved. The resulting perceptive constancy is a remarkable property of plasticity of the system that fully relies on the simple controls mentioned. All through human's lifetime, adaptation from full day light- to full dark, takes about 20 minutes, about as long as the shortest duration of twilight on earth.

The signal density in time and space hardly varies with the intensity of the illumination and with the level in the pathway between retina and visual cortex. However, the regularity of the signals increases with intensity and towards the cortex. In the fovea, the number of regular signals per space-quantum per time-quantum reaches up to about four and in the far periphery to 30. Such a signal represents the package of quantum absorptions or receptor responses that is about equal to the actual average statistic fluctuations of the average number of quantum absorptions per space-quantum per time-quantum. At some places in the cortex, graded potentials represent conversions of the frequencies of the regular pulses. The mere occurrence of a signal from an extra single absorption of a quantum in the photo pigment of a receptor or of a single receptor response, that results in an extra pulse beyond these numbers 4 to 30, governs the appearance of cardinal features as light, movement, and outline. This basic principle is utmost mechanistic and deterministic.

DISCUSSION

For generation of the time-quanta a robust machine is available. Special purkinje cells at the myocardium make each an action potential during every contraction of the ventricles of the heart. The potentials occur rather regularly with intervals of about 0.04 seconds[1].

By electric conduction via blood, extra cellular fluid and the network of gliacells, their electrical effects are immediately synchronously available all over the central nervous system. Consequently, dependencies on time of different sensory and motor functions are similar[26,27,28,29]. The action potentials also regulate the tonus of muscles. As a result both eyes tremble with amplitude of about 15-20 arc-seconds synchronously and in pace with the time-quanta[16,17]. The retinal space-quanta scan the retinal image of the environment in synchrony with the response processing of the time-quanta. For adequate stimuli, the perceptive acuity in place and time reach the limits that are determined by the accuracy for deciding whether a particular light quantum is absorbed in one or the other of two joint space- or time-quanta. For time this accuracy is equal to the rise-time of a few tenths of a milliseconds, for place to the size of about 5 arc-seconds of the free space between individual receptors. For many conditions like the vernier acuity in nonius reading, the limit for spatial resolution is far beyond the diffraction limit of the eye optics, in analogy with scanning microscopy. The limits for pitch discrimination and for the accuracy with which small differences in time at disparate retinal locations in the binocular pulfrich pendulum illusion nears the duration of the potential's rise-time[7]. The discrimination of direction and pitch just as other psychophysics data in hearing suggest that a revisit of its physiological physics in terms of time- and space-quanta in the basilar membrane might reveal new insights similar to those for vision.

For understanding of perceptual rivalry between complementary gestalts, two significant points are considered. No ambiguity exists about the pairing of receptor groups in distinct twin units. Normally, space-quanta pair around places where the spirals and circle of the three sets of space-quanta intertwine. For the pairing of successive time-quanta, a significant ambiguity occurs. There is no evident reason why a particular time-quantum pair either with the previous one or with the next one. The other point concerns the existence of the pairs of antagonistic muscles that move the eye bulbs. The action potentials of the purkinje cells modulate the tonus of just one muscle of such a pair. Which one is rather a random process. The synchronous involuntary tremors of both eyes are just by chance in phase or in counter-phase. The intersection of the axes of the optics of the eyes move either vice versa from left to right or from near to far. These ambiguities in time-quantum pairing and phases of eye tremor both result in rather at random transitions of spatially and/or temporally differences in the dominances of ON and OFF light responses of the twin units. After all they induce the rather at random variations of the dominances of rivalry perceptual gestalts.

CONCLUSIONS

At cardiac arrest, thus at disappearance of the action potentials of the purkinje cells the central nervous system with the sensory and motor systems including the speech organ, immediately fail completely and the subject becomes unconscious. The potentials carry human consciousness through its present. The paradoxical duration of this human present is 0.04 seconds.

Thanks to the existence of the time-quanta, our on-stepping conscious life is "stroboscopic". The world as seen at the TV-screen seems the "real" world. Stroboscopic stimulus presentation in vision research can trustfully stand in for the use of natural light provided there are at least 48 periods per second, 96 is quite secure. A precise and systematic evaluation of the intuitive and general acceptance of the equivalence for vision of these two widely different types of stimulus time functions is not known. However, the visual world really is an optical illusion and real time of physics passes our consciousness stepwise. After all the world of physics is also a "real" illusion of the human mind. We will never know the intrinsic limits of that mind.

The explanation of vision's stroboscopy concerns the physiological physics of the visual system. It describes the simple perfection of human vision for detection and discrimination of spatio-temporally and spectral energetically well-defined stimuli. Cognitive psychology regards different aspects of the visual world. To understand many phenomena in this domain the acceptance of the existence of a steadily and continuously moving space-time window instead of space-time quanta, has proven to be useful. In this respect, it may be helpful to consider the well-established scientific principle of complementarity. Its earliest and most explicit appearance is in physics the description of light or, more generally, of radiation, which is regarded either as packets of energy- light quanta- or as traveling electro-magnetic waves. Dependent on the type of phenomenon under study either the one or the other description is valid. In physics, the human mind may never succeed to unite the two complementary descriptions for radiation in a single and unique concept. In the life sciences, the human mind cannot do better. Quantal versus continuous timing can be interpreted as analogous to quantal versus continuous radiation. Analogous are also the reality of distinct receptor groups and the existence of the continuously moving space window for cognition of shape on the other.

Well established facts about the visual functions of many vertebrates and invertebrates- like cat, rabbit, crab, crayfish, lobster, frog, goldfish, fly- suggest that in nature the picture as described above for human, is the only one for vision. Because of its correlative processing with space- and time-quanta, It is also a useful basis for the analysis of the physiological physics of other sensory systems for spatio-temporal stimuli like hearing, feeling, touching. The correlative processing with time- and space-quanta acts for these senses as well. Very likely, the tremor of the skeletal muscles in synchrony with the time-quanta regulates the control of movements.

The life sciences enjoy an increasing knowledge and understanding of features of morphology, physiology, and development of complex living systems by specific molecular and sub-molecular phenomena. Particularly the recent progress in genetics and genomics is impressive. Surely, it will be a long way until this level is reached for the functions of the central nervous system and its sensory and motor organs. The exposition given above of visual sensory functions and perception is a promising step towards such a development. The brain really has more features of a digital machine than expected, and the reader might realize this after having read and understood this vision of a simple yet perfectly and intelligently evolved human eye.

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