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Micro-calibration of space and motion by photoreceptors synchronized in parallel with cortical oscillations: A unified theory of visual perception

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ABSTRACT

A fundamental function of the visual system is detecting motion, yet visual perception is poorly understood. Current research has determined that the retina and ganglion cells elicit responses for motion detection; however, the underlying mechanism for this is incompletely understood. Previously we proposed that retinogeniculo-cortical oscillations and photoreceptors work in parallel to process vision. Here we propose that motion could also be processed within the retina, and not in the brain as current theory suggests. In this paper, we discuss: 1) internal neural space formation; 2) primary, secondary, and tertiary roles of vision; 3) gamma as the secondary role; and 4) synchronization and coherence. Movement within the external field is instantly detected by primary processing within the space formed by the retina, providing a unified view of the world from an internal point of view. Our new theory begins to answer questions about: 1) perception of space, erect images, and motion, 2) purpose of lateral inhibition, 3) speed of visual perception, and 4) how peripheral color vision occurs without a large population of cones located peripherally in the retina. We explain that strong oscillatory activity influences on brain activity and is necessary for: 1) visual processing, and 2) formation of the internal visuospatial area necessary for visual consciousness, which could allow rods to receive precise visual and visuospatial information, while retinal waves could link the lateral geniculate body with the cortex to form a neural space formed by membrane potential-based oscillations and photoreceptors. We propose that vision is tripartite, with three components that allow a person to make sense of the world, terming them "primary, secondary, and tertiary roles" of vision. Finally, we propose that Gamma waves that are higher in strength and volume allow communication among the retina, thalamus, and various areas of the cortex, and synchronization brings cortical faculties to the retina, while the thalamus is the link that couples the retina to the rest of the brain through activity by gamma oscillations. This novel theory lays groundwork for further research by providing a theoretical understanding that expands upon the functions of the retina, photoreceptors, and retinal plexus to include parallel processing needed to form the internal visual space that we perceive as the external world.

Introduction

A new theory of lateral inhibition that detailed the major role of dynamic parallel processing between ON-center and OFF-center photoreceptors and retinogeniculo-cortical oscillations that leads to vision within the retina was previously proposed [4]. This theory explained that ON-center photoreceptors lead to OFF-center lateral inhibition which magnified and amplified the original signal received by the eyes [4]. It was proposed that the initial image that falls on the retina is flat and compressed (referred to as "coiled-in") by ON-center photoreceptors, so that the visual image within the photoreceptor discs, then becomes decompressed and integrated with the visual cortex and association cortex via retinogeniculo-cortical oscillations. This creates a well-mapped visual space within the thin layer of the photoreceptors we refer to as the 'internal visual space' [4]. The flat, compressed image is a weak, external image contained within the lumens that is converted into graded potentials which are transmitted via horizontal and bipolar cells to the OFF-center layer of photoreceptors. Previously, we proposed that the amplification and magnification of the image occurs through lateral inhibition within the predetermined space, and is mapped by approximately 1000 discs located in each photoreceptor, allowing a person to see the external objects instantly, retaining the panoramic view of the original external space [4]. This phenomenon occurs because the image is converted from lumens into a chemical image

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(rhodopsin) and into an electrical image instantly without the image having to be sent to the visual cortex then back to the eye to be interpreted as right-side up ("erect") [4].

Internal neural space formation

Visual perception is still poorly understood; however, this article offers a theory that begins to answer questions about: 1) perception of space, erect images, and motion, 2) purpose of lateral inhibition, 3) speed of visual perception, and 4) how peripheral color vision occurs without a large population of cones located peripherally in the retina. To begin, the primary visual pathway, the retinogeniculostriate projection (the optic nerve, optic tract, lateral geniculate nucleus, optic radiation, and striate cortex) is organized in such a way that it topographically maps the visual field, and vision loss corresponds with known areas within the visual space [5]. We suggest that vision loss could occur as a result of the physical damage compromising oscillatory activity, preventing information from being transferred to the thalamus. We contend that this transfer of information is of great importance because strong oscillatory influence on brain activity is necessary for 1) visual processing, and 2) formation of the internal visuospatial area necessary for visual consciousness. The present article contends that the striate cortex, parietal cortex, and various association cortices are areas that power the horizontal cells, and amacrine cells through oscillatory activity (alpha and gamma). We suggest that oscillations allow rods to receive precise visual and visuospatial information, while retinal waves link the lateral geniculate body with the cortex to form a neural space that is formed by membrane potential-based oscillations and photoreceptors.

Alpha oscillations are the "dominant oscillations in the human brain" [6], and are fundamental in central nervous system functioning, while gamma oscillations are important in 1) neural coding, 2) fixed patterns of eye movement, and 3) are closely connected with visual speed, accuracy and discrimination [4]. Together, alpha and gamma oscillations are fundamental in the formation of an internal neural space that 1) becomes the infrastructure for visual consciousness, and 2) condenses the external world into the internal visual space [4,7]. The retinogeniculo-cortical oscillations allow the retina and brain to function as one organ and allows for bidirectional synchronization with the photoreceptors [4,7]. When light enters the eye, it enters at a perpendicular angle and the image and its corresponding information is coiled and compressed. This represents graded potentials that are intensified and amplified through lateral inhibition in the OFF-center cones, decompressed and expanded in the brain being perceived as an external image. Retinogeniculo-cortical oscillations allow information to be transmitted, processed, and understood within milliseconds. We suggest that the individual photoreceptors see only a portion of the entire image, much like pixels of a computer screen (see Fig. 1). The rods and cones see in strips and compress the image onto the discs. When an object moves across the photoreceptors, motion is perceived. All of the tiny portions of the image and its movements combine in the OFF-center cones to form the final image and motion. This image and motion is normally cohesive because the photoreceptors are integrated with the brain via the retinal plexus [4,7].

Primary, secondary, and tertiary processes of vision

What is the functional importance of: 1) gamma oscillations at local and global cortical levels, and 2) gamma waves in the retina? Additionally, how are we able to perceive the external world within a fraction of a second? To begin, feed forward and feedback inhibitory pathways influence the retinal information received by the cortex retinal information [8]; however, only 7% of retinal information is received by the geniculate relay cells [9]. Interestingly this small percentage of retinal input dominates and drives geniculate relay cells [9], but evidence suggests that thalamic action potentials contain more information than retinal action potentials [8]. We suggest that this implies that information received from the visual, spatial, and executive visual cortices, along with memory, includes information received from the retinal plexus. The remaining 93% of information that is returned to the visual field originate from the cortical areas that are responsible for other aspects of vision that help orientate a person with the external world at any given moment.

Vision is more complicated than simply deciphering an image at face value. Perception of the external world consists of complex information that is received from all the senses, which allows one to more fully understand what is being seen and how to respond. This includes depth, space, location, distance, color, and motion (see Fig. 2). We propose that the process of vision is tripartite, in that it has three components that allow a person to make sense of the world. We have termed these primary, secondary, and tertiary processes of vision. The primary process of vision in the retina is the ability to integrate it with the cortex through retino-geniculo cortical oscillations to micro-calibrate the individual discs in each of the photoreceptors with cortical functions. This allows an "idling" to take place within the retina during a resting state that coincides with the "internal visual space". The secondary process of vision in the retina is the phototransduction of the image that is focused on the discs. Phototransduction leads to the process of chemical photoisomerization, which takes place in 10^{-12} s [1], just before lateral inhibition occurs. Tertiary process of vision is the retina's integration or synchronization with higher cortical areas allowing one to place the objects in a pre-calibrated photoreceptor that can detect the placement, motion, along with other aspects of vision, thereby allowing the cognitive orientation of vision to occur.

The physiological role of lateral inhibition was previously proposed as being the mechanism of action in "bringing" the cortical faculties to the retina [4]. Sensory experiences rise to consciousness within 200–500 ms [2,3], and we suggest that during this brief period, lateral inhibition is taking place. This would allow for an instantaneous view and recognition of the erect external visual field that is perceived as a vividly detailed and accurate image. The contention is that the external space is condensed into an internal microscopic reflection of the biological world. The brain acts as a magnifier in that it utilizes the biological components of the condensed external world and with the help of gamma waves, the miniature internal reflection is projected it back to where it originally came (the scientific meaning of 'reflection').

Gamma oscillations as the secondary role in vision

Gamma oscillations are responsible for: 1) regulating visual stimuli responses, 2) mediating external sensory response in the visual cortex, 3) synchronization of neural population response, 4) selective sensory signal amplification and enhancement, and 5) information regulation [10]. Furthermore, in the early visual cortex, the spectral properties of gamma oscillations are dependent on spatial frequency, contrast, and movement, and in the early medial visual cortex, gamma response is "the only component that is sensitive to the visual motion of the stimulus" [11]. In addition, more motion-specific information is transferred by the higher gamma frequencies [11]. This supports our theory that gamma oscillations serve a secondary purpose in the brain, which is to connect the visual system with the brain to provide a person with the ability to perceive motion that affords a unified visual experience.

Gamma waves that are higher in strength and volume allow communication among the retina, thalamus, and various areas of the cortex. Gamma rhythms usually occur in the frequency range of 30–80 Hz and are "modulated by sensory input and internal processes (working memory and attention)" [12], thus frequency varies with function. For example, processing visual information needs "millisecond-precise" interaction between neurons, which is mediated via synchronization of gamma oscillations in the range of 20–60 Hz [13], although oscillations are not needed for vision due to their absence from stimuli [14]. Perception, attention, and memory formation occurs with synchronization