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Review Article

The Binocular Rivalry: The Phenomenon of Interocular or Perceptual Competitions?

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ABSTRACT

We see the magnificence of the nature through our two bare eyes, albeit due to image coherence at the retina, we normally perceive only one sight at a time. That is, monocular stimuli get merged into a single visual impression. When two distinct sceneries are given to our eyes simultaneously (dichoptic projection), we cannot see both images in coherence and can we actively focus on our preferred one. Rather than that, each eye's visual experience rotates between the two exhibited images. Additionally, transient and unsteady blends of image pairs could be visible during transitions. Binocular rivalry is the term used to describe this occurrence of alternating visual impressions. To comprehend its basic process, numerous hypotheses have been advanced to date. Recent breakthroughs have enabled scientists to explain a plethora of fresh facts about binocular rivalry. However, their curiosity has not yet reached a suitable level. As such, this study considers the mechanism and ideas underlying it, as well as its future usefulness in the disciplines of neuroscience and research.

Keywords: Binocular rivalry, Monocular stimulus, Conscious awareness, Visual perception, Visual cortex.

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INTRODUCTION

The binocular integration of images from the two eyes focused on the same object has advantages in enhancing the depth and contrast of perception, the better judgment about the distance of the object allowing the degree of stereopsis or the ability to view the world in three dimensions. However, this advantage is not persistent if the two retinal images are made substantially different. In this condition, there is no mixing of both images, rather the perception is confined to one retinal image at one time for a few seconds and gradually this perception fades away from consciousness and the second retinal image appears. That is, the image from one retina becomes dominant transiently (perceptual dominance) while the image from the other is suppressed and vice-versa. This phenomenon of intermittently reverse conscious visual perception is called binocular rivalry (Blake and Logothetis, 2002). The realization which comes due to visualizing any object gets changed arbitrarily when the two dissimilar stimuli get imaged on the retinal regions of two eyes and this phenomenon continues until the stimuli persist.

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If the dichoptic presentation of an image differs in the contour only, rivalry presents with the shift in contour only, called the binocular contour rivalry. When the image to eyes differs with colors, the rivalry obtained is known as a binocular color rivalry. Likewise, there is binocular luster rivalry for an image perceived by the eyes with different lightness (Pagnoni, 2019). Surprisingly, the image is perceived continuously without reversal when the image is perceived through one eye while blocking the field to the other eye. However, occasionally a blank field or contours of a closed eye can be seen and alternates with the image of another eye of equal stimulus strength. Moreover, when the image is inserted immediately into the blank field or closed eye, the person perceives that image rapidly called flash suppression. How the brain chooses one to the consciousness between the two competing visual signals that have remained a fundamental question? Psychologists as well as the neuroscientists have become curious about the binocular rivalry occurrence specially while inspecting the procedure of finding the visual awareness during last two decades (Yang *et al*., 2014). But still the scholars across globe have not reached consensus with respect to the competitive interactions which is mediating the binocular rivalry. The difference is still persisting in opinion over the matter of discrepant monocular pattern rivals which results from the neural competition taking place among monocular channels.

Neural processing mediating rivalry therefore needs to be discussed as a broader category. In such cases of rivalry competition is taking between the so-called eye rivalry and so-called image rivalry. In this article therefore there is an attempt to review theories associated with binocular rivalry.

RELEVANT THEORIES: UNDERPINNING MECHANISMS

Early theories

Porta was the first to observe the binocular rivalry by reading books with the dichoptic presentation. He found one book can be read at a time and after some time reading shifted to the other book presented to the other eye (Wade, 1996). DuTour first described the concept of the binocular rivalry (Wade, 1996) and reported that he perceived the colors fluctuating from the blue to yellow taffeta presented to each eye. He concluded that our brain could obtain only one of the two retinal images at a time with dichoptic viewing of objects. Before DuTour, Le Clerc (explained by Wade) (Touwen, 1972) and Desaguiliers (Desaguliers, 1716) were also recorded binocular rivalry of color when viewed from bands in the mirror bevels. The phenomenal reversal was explained by DuTour (Dutour, 1760) often called DuTour's phenomenal reversal theory or 'suppression theory'.

The suppression theory revealed that there was no fusion of the two retinal images and there are two retinal corresponding points, one suppressed the other at a moment of time and suppression alternates. This concept remained for a longer period, till the concept of depth of perception came into notice by Panum (Panum, 1940). Wheatstone discovered stereopsis, which revealed that stereo-images can be fused yielding more stability and depth of perception. He further mentioned that when two monocular images in the eye differ in the pattern or contour, they failed to fuse rather perceptual rivalry happens.

This concept is further simplified due to conceptualization of stereopsis. Stereopsis is basically sensing something with depth which happens because monocular information is converging onto the disparity-sensitive binocular neurons (Cumming, 2002; Parker, 2007). With dichoptic presentation, the eye project contradictory information to the same area in the brain. It shows the availability of two things at the same place. This dual image results into confusion state in the mind which is having the characteristics of alternating periods of perceptual dominance. This phenomenon last until eyes view discordant stimuli. There is dissociation between physical stimulation and the conscious visual experience regarding any object. It is therefore the rivalry which meant to classify the neural events associated with cognizant visual awareness (Blake and O'Shea, 2009).

It is significant to mention about the proposition of Helmholtz who stated that rivalry is resulting because the visual attention is getting fluctuated spontaneously. Unlike Wheatstone, Helmholtz felt that the two eyes' inputs really aren't integrated biologically (physiologically). Although the input from the two eyes can be integrated to create stereoscopic depth, this is more likely due to a mental influence than a biological act. This conclusion was reached in part because of the discovery that combining dichoptic hues does not result in an intermediary impression but rather in competition. Helmholtz took these findings to mean that until the last phases of attentional selection, information from either the eye remains apparently available to consciousness (Von Helmholtz, 1925).

Helmholtz discovered that by concentrating to a pattern, he could enhance the prevalence of rivalry, while no effort has been made to transfer attention. These arbitrary variations were supposed to represent the aspect that attentiveness is always changing and deters focus on a single item for not more than just a few moments. Helmholtz found that when two objects were spatially superimposed and presented to the same eye, an equivalent but lower perceptual ability occurred. This phenomenon was later named by Breese as "monocular struggle" (Peal and Lambert, 1962). Although Du Tour's suppression theory was unable to account for monocular rivalry, it was compatible with the Helmholtz's attention theory, which coincided with the subsequent view that rivalry is a broad kind of rivalry of pattern (Alais *et al*., 2000; Leopold and Logothetis, 1996).

MODERN THEORIES

Interocular Competition Theory

Among several investigations and theories to justify the mechanism of binocular rivalry, monograph of Levelt on binocular rivalry has got great importance (Levelt, 1965). The definition of rivalry as a competing mechanical process that involves reciprocity inhibition among the two eyes is the major reason for its lasting relevance and the effect of strength of the stimuli well described with four propositions to explain the central aspects of the phenomenology of binocular rivalry (Levelt, 1965). These could be summarized as:

- It is observed that increased intensity of stimulus for an eye increases the stimulus's perceptual primacy.
- Strengthening the stimulus for an eye has no effect on the average length of perceptual dominance for the stimulus of that eye. Rather than that, it will shorten the mean length of the stimulus of opposite eye's perceptual dominance.
- Strengthening the stimulus to one eye increases the pace of perceptual alternation.
- Increasing the stimuli intensity including both eyes while maintaining equal response strength between them increases the pace of perceptual alternation.

It is inferred from four assertions that when dichoptic patterns are greatly differing, as they do in the binocular boundary competition, they compete straight via reciprocated interocular suppression. Explicitly, the frequency amplitude of a monocular sensory inducement controls the amount to which the contralateral stimulus is suppressed intraocularly. Later, the researchers conducted several studies based on Levelt's model of rivalry with common structure and predictions (Blake, 1989; Lehky, 1988; Matsuoka, 1984; Sugie, 1982). Lehky proposed an example of an interocular competition model stating that the binocular rivalry arises due to the mutual suppression between the right versus left the monocular channels. When one eye's strength of the interacting stimulus is increased, the inhibitory neuron from that eye is activated, which suppresses the monocular image carrying input from the other eye. This inhibition is not last for a longer time and soon gets adapted, allowing the dominance of the suppressed eye (Lehky, 1988).This is true for the chronological dynamics of the rivalry that reveal a significant psychophysical outcome, where increase in the intensity (like contrasts) of one monocular inducement didn't upsurge its predominance, however in its place, decreases the predominance of contending stimulus (Levelt, 1965). These findings were obtained when considerable studies were advanced in neurophysiology along with the finding that binocular neurons combine the input stimulus from both the eyes within the cat striate cortex (Hubel and Wiesel, 1962).

Study reported that the competitive circuit included suppressing response signals to the monocular layer of the Lateral Geniculate Nucleus (LGN) that arise from the primary cortex region (V1) (Lehky, 1988). However, the absence of rivalry in stereopsis put a debate on this finding. To explain for this lack of competition, Lehky, postulated a distinct stereopsis function that evaluates the level of correlation among inputs from the eyes and regulates interocular suppression appropriately. When inhibitory suppression is low, fusion occurs and when inhibition is excessive, competition occurs. Nevertheless, it might very well be used to competing lateral connections between monocular V1 neurons, as Blake suggested in an alternate model (Blake, 1989).

Pattern Competition Theory

Binocular rivalry occurs due to the completion of perceptual nonidentical image formation at the cortex region (V1) that does not happen in the case of interocular competition (Alais *et al*., 2000). The vertical and horizontal pattern rivalry of the right and left eyes are supposed to be due to incompatible representation at the cortical level (Alais *et al*., 2000). This pattern competition is much alike to the interocular competition model of Lekhy (Lehky, 1988) explains the reciprocal inhibition, which would be at the level of pattern representation between monocular inputs at the cortex region V1.

After discussions on many theories from early to modern, the binocular rivalry has been dominated by three issues: the possible locations of the neural rivalry, in respect to the visual manifestations that contend for these integral sites, as well as the integrated processes that coordinates competing relationship across extensive neuronal populations. Binocular rivalry, conferring to one theory, emerges from low-level interocular rivalry among monocular retinal neurons found in the thalamic LGN or the primary Visual cortex (V1) (Tong, 2001). Binocular rivalry, however, is observed later in processing of visual information and tends to reflect conflict across conflicting motifs rather than rivalry between both the eyes (Logothetis *et al*., 1996).

Recently, a cohesive image combining parts of both perspectives has developed, based on the assumption that rivalry includes neuronal conflict at varying levels of the visual pathway (Freeman, 2005; Wilson, 2003). It has been proposed that different cortico-neural synapses handle distinct sorts of visual ambiguity at distinct cognitive levels and that an operative principle may be analogous to a degree (Klink *et al*., 2009; Wade and Ngo, 2013). The major distinction among these perceptive rivalry triggers as

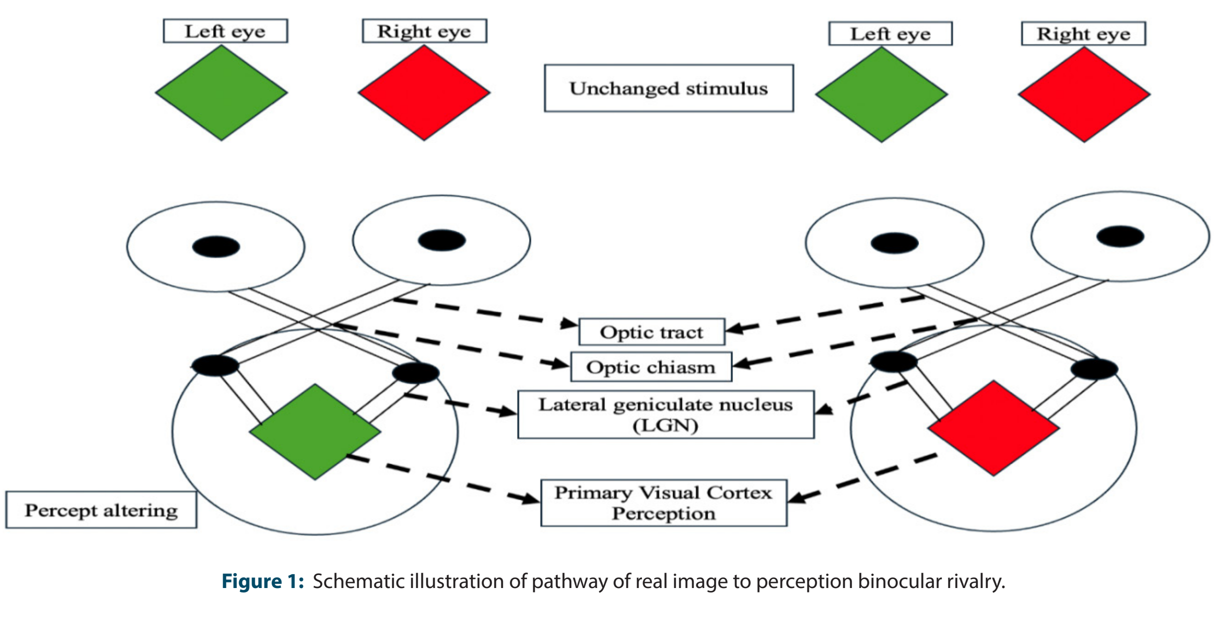

Figure 1: Schematic illustration of pathway of real image to perception binocular rivalry.

well as binocular rivalry is that alternated visualization occurs in the absence of the sophisticated neural architecture associated with binocular vision. Thus, it ignores interocular exchanges and concentrates exclusively on the (cortical) perceptional competition among competing signal understandings. However, it is unknown if inhibiting (part of) a visual input is equivalent to inhibiting comprehension of a perceptual experience while employing visual information, as in binocular rivalry.

In near past studies have shown that attention of the features may suspend this binocular rivalry as rivalry seems to be cease when observers are not interrogating the information on location (Zhang *et al.*, 2011). Study also reported that attention is required to combine the features to one object (Treisman, 1998).

CONCLUSION

In conclusion, the evolution of theories on binocular rivalry-from early concepts like DuTour's suppression theory, Wheatstone's stereopsis and Helmholtz's attention theory to modern models like Levelt's propositions and Lehky's interocular competition-highlight the complex interaction between physiological processes and attentional dynamics. Early theories emphasized alternating dominance between retinal images, while modern approaches focus on reciprocal inhibition, stimulus intensity and cortical-level pattern competition. Together, these frameworks deepen our understanding of how conflicting visual inputs are processed, revealing the intricate neural mechanisms underlying binocular rivalry and the brain's capacity to resolve perceptual conflicts.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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