Quantifying Consciousness: Electrophysiological Perspective

Ahmad Yousef[1]

[1]School of Computational Science and Engineering, McMaster University, Hamilton, Ontario, Canada

*Correspondence: mohamas2@mcmaster.ca

Abstract- This article aims to provide a new electrophysiological metric, namely, brain energy. Based on the literature review, this metric is expected to quantify the human global visual awareness, namely because it suggests the use of binocular rivalry setup. The article also offers simple ways to build up binocular rivalry experiments.

Introduction

Binocular rivalry, a phenomenon of visual perception in which human visual awareness alternates between different images presented to each eye, is an outstanding psychophysical approach to quantify consciousness. Importantly, both kinds of attention, automatic and voluntary, help in increasing the awareness dominance duration of the corresponding stimulus. In another word, attention controls human global consciousness.

Strength (Levelt, 1965), saliency (Engle, 1956), spiral motion (Malek, 2012), higher spatial frequency (Fahle, 1982), duchenne expressions (Malek, 2018), are all having 'catchy' visually stimulating features, namely, they all trigger automatic attention; therefore they all dominate the visual awareness over 'non-catchy' ones. Voluntary attention to certain details to a certain stimulus also elongates the awareness dominance duration of the stimulus (Lake, 1978).

Time (the awareness dominance duration) had been used as a metric to quantify human visual awareness by vision scientists, however, this metric should be supported by physiological metrics to help scientists to convey awareness to biological science. But what is the best physiological metric for consciousness?

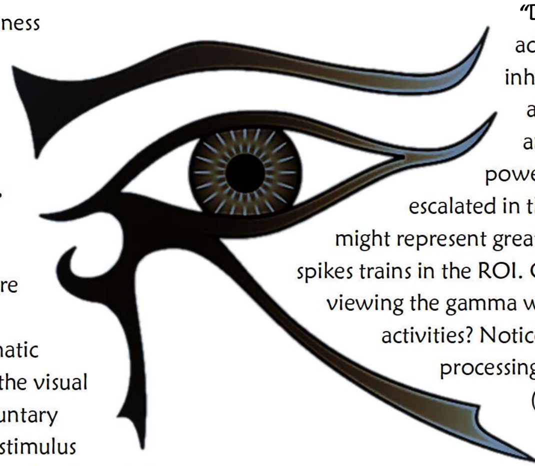
To answer this question, we have to understand how the human visual awareness works (for fulsome comprehension; see reference 11). Namely, it hypothesized that the neurological roads of the visual awareness, especially for those which are triggered by external stimulations, are started from the photoreceptors and ended by the final inhibitory neurons. Now, let's see a specific example and try to generalize it, namely, let's study the autistic brains. Three interesting facts about the autistic brains:

1- They have hyper-systemizing, hyper-attention to detail and sensory hypersensitivity (Baron-Cohen, *etal.* 2009).

2- They have reduced GABAergic action, (Robertson, *etal.* 2016).

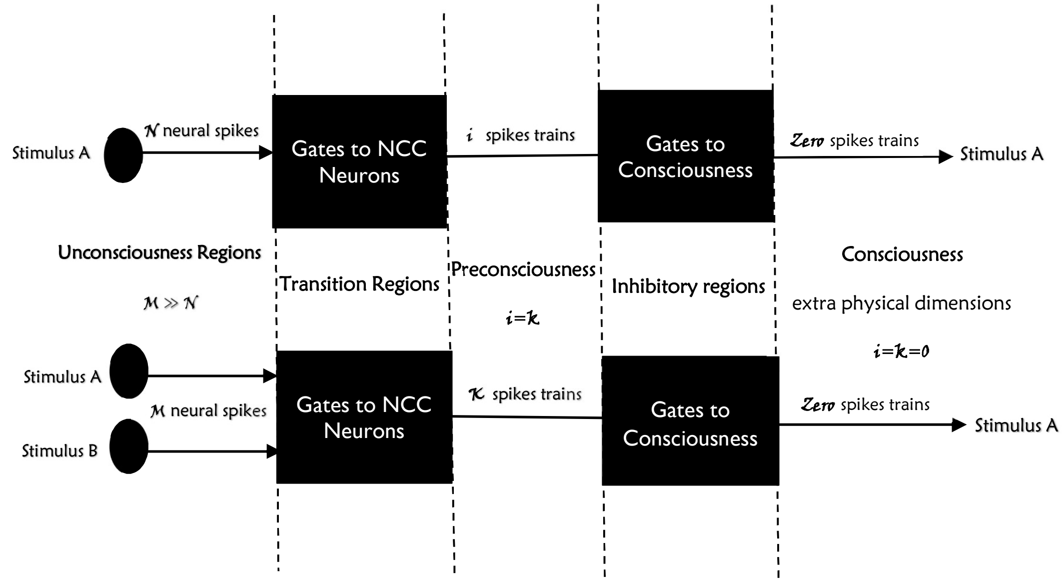
3- They have longer dominance duration in binocular rivalry (BR) experiments, (Robertson, *etal.* 2013). Autistic brains also have higher spectral power of peak gamma frequency due to their slower switching rates; this is an indirect conclusion to (Fesi, *etal.* 2015) findings.

The aforementioned facts may allow me to hypothesize & say the following statement:



"Due to the lack of GABAergic action, early stages cortical inhibition might not occur in autistic brains in BR experiments; and therefore, the spectral power of peak gamma waves is escalated in these areas. Gamma waves might represent greater numbers of 'asynchronous' spikes trains in the ROI. Could it be the reason of viewing the gamma waves as conscious brain activities? Noticeably, those neurological processing roads to the visual awareness (spikes trains) are assumed to converge eventually, and thus, the need of GABAergic action will be minimized. To minimize the GABAergic action, a possible scenario can be proposed for autistic brains: They might have greater processing roads to the visual awareness for certain stimulus (perfect and fulsome detailed consciousness); synchronized with retinal inhibition for the other stimulus perfect oblivion; namely, M=N in the unconsciousness regions; see the infographic diagram in the following page. Normal brains, however, might require greater GABAergic action due to the possible suboptimal detailed consciousness for one stimulus (inhibition before the aforementioned convergence); that might be synchronized with imperfect oblivion for the other stimulus; namely, M > N in the unconsciousness regions. Imperfect oblivion had been be viewed as subconscious brain activities in the literature."

Comparison between the visual awareness generative processes of 'Stimulus A' through Normal vision (up) and Binocular rivalry (down)



Importantly, I previously hypothesize that the brain is just a processor 'biological processing wires' to consciousness; the awareness however might be resided in extra physical dimensions (See reference 11). The hypothesis also estimates that inhibitory neurons are gates to the consciousness, and therefore, the human awareness is a product of too many parts of the brain; namely, physiological investigations in consciousness should have holistic considerations. Detailly speaking, greater spikes trains might lead to better processed details, while shorter ones might lead to weaker processed details. Namely, longer spikes trains might eventually create greater details and fulsome consciousness; shorter ones create weaker awareness, but very short ones due retinal or subcortical inhibition create minimal to no awareness about the stimulus. Because highly informative awareness might be a product of fewer inhibitory neurons 'due to the convergence of spikes trains', therefore, the awareness that's produced by
a fewer gates 'narrower neurological channel to consciousness' will access the awareness for longer dominance duration in binocular rivalry settings.

Brain Energy: The Metric

The neurophysiological validation can be concluded from the available literature; however, to tighten the aforementioned hypothesis tightly, a new mathematical metric for brain imaging may be defined, namely*; Brain Energy*, which can be described as follows:

$$\text{Brain Energy} = \left\{ \sum_{h=0}^{n} \int_{T=0}^{T=dominace\ duration} (ERP)^2 \ \mathrm{dt} \right\}_{25Hz \longrightarrow 150Hz}$$

Where ERP refers to event related potentials, and h is the number of the channels of the EEG system. Importantly, different kinds of brain imaging techniques has different metrics, that should be wisely used to estimate accurate *Brain Energy* values. Consider a high density EEG system with 256 electrodes; each electrode will detect localized *Brain Energy* that can be estimated by integrating the $(EPR)^2$ over the time whereas the starting time is the onset of the awareness of a certain stimulus (t=0), until that stimulus disappear from the awareness (t=dominance duration). The *Brain Energy* can be estimated by summing up of all of the 256 localized *Brain Energies.* Advisably, the data should be filtered by taking gamma waves only into measurements consideration. Detailly speaking, since attention has some control over consciousness, the gamma waves filter should be so wide up to 150Hz (see reference 12). Moreover, alpha waves should be removed for two reasons; it peaks when gamma waves are minimized (see reference 14), and it proportionally correlated with the rivalry switching rate (Katyal, etal. 2019). Namely, alpha waves will strength the value of brain energy despite it's not responsible for intensifying the human visual awareness; therefore, it should be removed. Although I don't offer empirical studies here, however, the aforementioned offered metric seems to produce the most meaningful physiological information for BR experiments; the conventional metrics, however, are unable to holistically quantify the awareness.

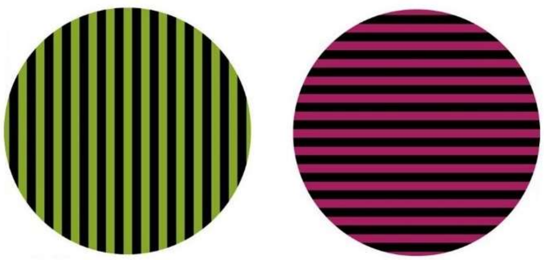
By converging the recent scientific reports altogether; it's expected to see the *normalized value of Brain Energy* of 'the longer dominance duration' stimulus being much greater than the *normalized value of Brain Energy* of 'the shorter dominance duration' stimulus. After several empirical validations; scientists may confidentially say;

greater/weaker inhibition of brain activities due to greater/weaker GABAergic action lead to shorter/longer spikes trains and therefore weaker/greater fulsome consciousness.

Progressively, quantifying consciousness should be a very important procedure in medicine, because it might help the practitioners to have estimated interventions in critical cases (reference 15).

Binocular Rivalry Installation

Readers can experience binocular rivalry just by moving their eyes towards the page until the two following circles seem to merge. To have a better experience, open the stimulus on portable devices.



Courtesy of Jame W. Kalat, 2005. Introduction to psychology, seventh edition

Scholars who would like to have perfect setup; the most efficient, simplest, and cheapest installation is as follows:
1- Purchase 9.25 diopters for prism correction base-out glasses from any optics shop. Scientifically speaking, that equals to 5.28 degrees visual angle (DVA); namely, it represents how many degrees does the stimulus subtend on the retina.
2- Create a splitter, using cartoon and glue gun to prevent the interference of light rays among the two circles. The splitter, and the stimuli should be adjustable based on the equation of the visual angle. Assume that human subjects are comfortable to view the computer screen 50cm away, this should be the length of the splitter. Now, by substituting in the following equation, we can calculate the diameter of each circle, and the spacing for the splitter: $5.28\ (DVA) = \tan^{-1}\frac{x}{50}$; where x is in centimeters. For this case the diameter of each cycle, plus its corresponding spacing would be exactly 4.62 centimeters.

Essential Notification

Scholars who have high density EEG machines and would like to collaborate are welcome to contact the author. Scholars who have low density EEG systems are advised to use compressive sensing techniques (see reference 16). Scholars who have issues with binocular rivalry setup or want to access a copy of the current codes for brain energy metric, with gamma waves filter are welcome to request it directly from the author. Scholars who struggle in comprehending any part of this article are also welcome to directly contact the author.

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