Quantifying Consciousness: Electrophysiological Perspective

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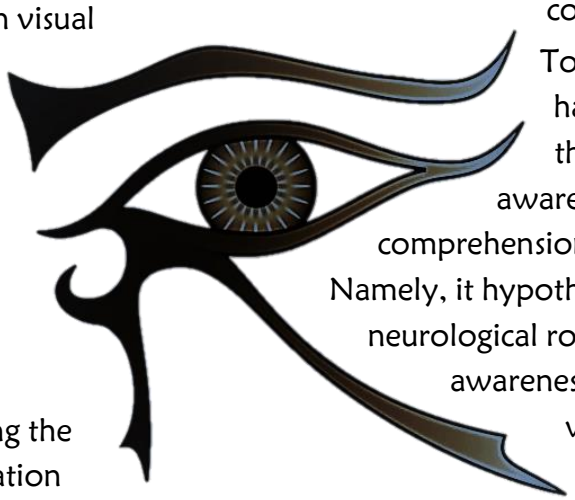
Abstract- This article aims to provide a new electrophysiological metric, namely, brain energy. Based on the literature review, this metric is expected to quantify the human global visual awareness, namely because it suggests the use of binocular rivalry setup.

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 consciousness to the scientific era. 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 speculate and 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. Speculatively, gamma waves may 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). Normal brains, however, might require greater GABAergic action due to their suboptimal detailed consciousness for one stimulus (inhibition before the aforementioned convergence); that's synchronized with imperfect oblivion for the other stimulus. Imperfect oblivion had been be viewed as subconscious brain activities in the literature."

Importantly, I previously speculate that the brain is just a processor 'biological processing wires' to consciousness which might be resided in extra physical dimensions (See reference 11). The speculation also estimates that inhibitory neurons are gates to the consciousness. 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

To neurophysiologically validated the aforementioned speculations, I have to define a new mathematical metric for brain imaging, namely*; Brain Energy*, as shown in the following equation:

$$\text{Brain Energy} = \sum_{k=0}^{n} \int_{T=0}^{T=dominace\ duration} (ERP)^2 \, \text{dt}$$

Where ERP refers to event related potentials, and k 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). Although I don't offer any empirical studies here, however, the aforementioned offered metric seems to produce meaningful information for BR experiments, instead of the conventional ones that are unable to holistically quantify consciousness. By converging the recent scientific reports altogether; it's expected to see the *normalized value of Brain Energy* of 'the longer dominance duration' stimulus is greater than the *normalized value of Brain Energy* of 'the shorter dominance duration' stimulus. Further empirical validations are must; therefore 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).

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