Neural Recruitment in Subjective Time Perception in a Non-local Model and the Psychological Nature of Attention

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ABSTRACT

We propose that attention is a purely psychological faculty without any corresponding neural centre, though it operates on neural assemblies for its functional aspects. An algebraic attention function is proposed to account for time perception removing the divergence of neural recruitment in the exponential attention function proposed earlier. The equation for subjective time is derived with the non-divergent recruitment. The inherently non-local nature of our model is discussed. The nonlocal nature of attention is discussed in view of recent experimental data indicating instantaneous correlations between spatially separated neural assemblies derived from the neural stem cells of the same individual as well as between human subjects.

Key Words: attention, time perception, neural recruitment, non-local communication, universal field of consciousness

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Introduction

All perceptions essentially have both a psychological and a physiological (neural) aspect. Two broad categories of perception can be there: (1) Internal perception depending on memory, without any corresponding driving physical input signals (Pradhan, 2010; 2012; 2014). This happens e.g. in dream and in analysis of thoughts and ideas stored in memory. In these cases there are just the neural activities and corresponding psychological perceptions. (2) External perceptions depending on physical input signals from sources external to the nervous system. The external physical signal is received by the senses and converted to neural signals that go to form a definite neural correlate in the brain. In a framework for a generalized Fechner law developed by Pradhan, both the Stevens law and the Fechner law were unified as being responsible respectively for encoding and decoding of information for perception (Pradhan 2017). The encoding of the physical information into neural correlate is assumed to happen via a power law as given by Stevens while the decoding of neural correlate for perception takes place via Fechner logarithmic law.

Attention is essential for perception (Corbetta and Schulman, 2002). At the conscious level, it can be willful, voluntary, top-down and goal-directed. When external cues such as disturbances draw the attention, it is reflex, involuntary, bottom-up and stimulus-driven (Mangun, 2003). But the question we pose is: Is attention also a perception itself? Do we perceive attention as we do other physical or psychological stuff? Just as we can bring our attention onto sensory inputs or on memory storages, can we similarly focus our attention on attention itself? In the sensory and memory inputs, there are definite neural correlates excited which make it possible for attention to be focused on them but we cannot focus

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attention on attention itself. Of course, we know whether we are attentive or not and we can willfully alter the intensity of attention. Further, if it were one of the external or internal perceptions, it could be decoded by logarithmic law applied to a neural correlate of attention.

Attention has been experimentally found to be associated with activation of definite brain areas that have been associated with neural mechanisms of attention (Cohen, 2014; Posner and Peterson, 1990; Peterson and Posner, 2012). Neural network models have been proposed and studied in relation to the functional aspects of attention (Fan and Posner, 2004). The basic question is: how can attention, having theses supposedly different neural correlates in different brain regions attend upon other neural correlates of perception (corresponding to the object of attention) in the same brain, as if one part of the brain were focusing on another part? What or who directs such attentional neural correlates to observe perceptional neural correlates, and how? This *reductio ad absurdum* will land us in a realm that has to be beyond the physical brain *i.e.* in the psychological (Boyer, 2011). That such a possibility of juxtaposing nonlocal psychic phenomena and physical brain operations has to be addressed with seriousness has recently been advocated in a Brain-mind operational architectonics framework (Fingelkurts *et al.,* 2019).

Here, we arrive at certain definite conclusions about the purely psychological nature of attention in the process of analysis of time perception. Like will, attention is a voluntary function of the psyche and though it may be affected by external and internal factors, it is not determined by them.

Attention and time perception

Recently we have proposed an equation for subjective time duration (Pradhan and Tripathy 2018a) which incorporates attention as a function (Pradhan 2015). The attention was modeled as:

$$a(t) = \begin{Bmatrix} 1, \textit{full attention} = a_{\max} \\ 0, \textit{no attention} = a_{\min} \end{Bmatrix} \quad ...(1)$$

Unless specifically directed to a task the attention lies between zero and one. Taking account of the proportionality with objective time interval, frequency f of neural processing in a particular assembly the dependence on neural recruitment $N(t)$ as per Fechner Law, the subjective time interval is given by:

$$ds = K \ln \frac{N(t)}{N_0} dt \quad ...(2)$$

where K is a proportionality constant; N_0 is the minimal neural recruitment for that perception which is attained with full attention: $a(t) = 1$. Decrease of attention leads to excess recruitment $N'(t)$ given by (Pradhan and Tripathy, 2018a):

$$N'(t) = -N'_0 \ln\{a(t)\} \quad ... (3)$$

where N'_0 is that attentional excess recruitment for which the attention falls to $\frac{1}{e} = 36.8\%$ of its maximum value. The total recruitment then becomes:

$$N(t) = N_0 + N'(t) \quad ... (4)$$

The attention function is then given by (Pradhan and Tripathy, 2018a):

$$a(t) = \exp\left[-\frac{N'(t)}{N'_0}\right] \quad ... (5)$$

But for its minimum value $a(t) = 0$, it requires $N'(t) = \infty$ *i.e.* it diverges, which is not tenable since the total number of neurons in a brain $N(t)$ is finite. One way out is to assume that once the excess recruitment N' becomes equal to N'_0, the attention falls to the value $\frac{1}{e}$ *i.e.* 0.368 and then the perception can be assumed to sufficiently blurred by lack of attention and thus, that can be taken to be the effective minimum that rescues it from the divergence. The huge number of neurons ($\sim 10^{10}$) in the human brain can be effectively taken to be infinite compared to the small number of neurons excited in any particular perception. Or else, we have to give up the exponential attention function altogether in favor of another suitable function satisfying the criteria.

Removal of Divergence of Neural Recruitment

To address the divergence of neural recruitment for minimum attention we introduce the quantity N_{max} for the maximal neural recruitment which can, in principle, be the total number of neurons in the brain and in place of the exponential function above, we propose an algebraic attention function which has the desired properties *i.e.* $a(t) = 1$ *for* $N(t) = N_0$ *and* $a(t) = 0$ *for* $N(t) = N_{max}$:

$$a(t) = \frac{N_{\max} - N(t)}{N_{\max} + N(t) - 2N_0}$$

$$\Rightarrow a(t) = \left[1 + 2\frac{N(t) - N_0}{N_{\max} - N(t)}\right]^{-1} \quad ... (6)$$

such that $N(t)$ is given by:

$$N(t)=\frac{2a(t)}{1+a(t)}N_0+\frac{1-a(t)}{1+a(t)}N_{\max} \quad ...(7)$$

The excess recruitment is then given by:

$$N'(t)=\frac{1-a(t)}{1+a(t)}(N_{\max}-N_0) \quad ... (8)$$

The subjective time interval then becomes:

$$ds=\frac{1}{n}\sum_{i=1}^{n}w_iK_if_i(t)\ln\left[\frac{2a(t)}{1+a(t)}+\frac{1-a(t)}{1+a(t)}\frac{N_{\max}}{N_{io}}\right]dt \quad . (9)$$

This gives us the revised equation for $s(t)$:

$$s(t)=\frac{1}{n}\int_0^t dt\sum_{i=1}^{n}w_iK_if_i(t)\ln\left[\frac{2a(t)}{1+a(t)}+\frac{1-a(t)}{1+a(t)}\frac{N_{\max}}{N_{io}}\right]dt \quad (10)$$

The constant K_i is the proportionality constant for the *i*th assembly. The frequency f_i of the neurons in the *i*th assembly may vary with time for longer durations and for multi-tasking (Fan *et al.,* 2007). The weight factor w_i determines the relative importance of the assemblies in determination of the perceived duration.

Regarding the ranges of $N_{\max}$ and N_0 we note that the maximum value of the former can be of the order of $\sim 10^{10}$ for human brain which is the total number of neurons in the brain while the minimum value of the latter can be 2 (Pradhan, 2017).

Non-locality of the model

Einstein Locality derives from the second postulate of Special Relativity that no physical signal can travel faster than light in free space (Einstein *et al.*, 1935). Let A and B be the positions of two neurons in an assembly or the locations of two different neural assemblies. A local communication by using any physical signal from point A to point B (separation R_{BA}) in flat space has to have a time delay of $T_{BA}\geq\frac{1}{c}R_{BA}$, where $c\sim 3\times 10^8\ m/s$ is the speed of light in vacuum and the equality holds for signals that travel with this speed. At any instant of time, starting from point A, any other point C is reachable through physical signals if it is within the future light cone A, outside which the point C is said to be space-like separated from A. A violation of this special relativistic locality criterion is termed non-locality. But, it is an experimentally established fact that non-local correlations, though not communications, do exist in quantum systems that had once interacted in the past to become entangled. Instantaneous correlations have been experimentally observed between space-like separated entangled quantum systems (Aspect *et al.*, 1982; Aspect *et al.*, 1982; Tittel *et al.,* 1999). Note that non-local correlations observed are all instantaneous effects between spatially separated subsystems that once shared a common quantum state, as if there were an agency simultaneously connecting the two in a mysterious manner.

Nerve signals across the synaptic cleft can be transmitted at most up to speeds of 120 m/s by chemical neurotransmitters like acetylcholine across chemical synapses (20 to 40 nm gap) while neuro-electrical signals along the axon of a particular neuron or across electric synapses (2 to 4 nm gap) can move at speeds close to that of light (Hormuzdi *et al.,* 2004). Thus nerve to nerve transmission is always local communication and neural information propagation across thousands of synapses is involved in all neural processes. If, as is usually supposed that all information is frequency-encoded (Binding by Synchrony), then there can be different neural assemblies with the same frequency at different locations (*e.g.* visual and auditory cortices while enjoying the symphony of a live orchestra performance involving many instruments and performers at the same time) but without an underlying (or overarching) pervasive agency that connects both of them simultaneously, there is no way they could be bound together to produce the result. Thus simultaneous processing of information from multiple spatially separated regions of the brain is characteristic of the perceptual process (Feldmen, 2013). Such simultaneity is also what the experimentally observed non-local quantum correlations in entangled systems imply (Gao, 2016). In this sense, the perceptual process is a fundamentally non-local process by the perceiving consciousness that simultaneously exists at all locations in the brain and does the actions of integration, classification and Interpretation etc.

Our current model, based on neural recruitments is, in this sense, inherently non-local since temporal perception here is taken to be the result of the mean of the integrated instantaneous total neural recruitment in different assemblies over the objective time interval. Therefore the model is quantum mechanical too since such non-locality is a feature of quantum mechanics (Pradhan, 2012). Further, there is no classical solution to the neural binding problem (Feldman, 2013) that can explain simultaneity without violating special relativity. Quantum mechanics too violates special relativity but there is an underlying explanation in terms of nonlocality in entangled systems. We propose that it is the pervading consciousness in the brain that is simultaneously present at the location of all assemblies which can perceive and bind together the qualia associated with the neural correlate. This integrating consciousness (or abstract ego) in us that perceives (von Neumann, 1955) takes account of all the neural oscillations all over the brain in all the assemblies simultaneously (Reynolds and Desimone, 1999) by virtue of its pervasive presence and our model bases itself on this non-locality as a fundamental fact associated with the brain and its connection to the cognizing consciousness, the ego (Pradhan, 2010; 2014).

Note that we don't consider the details of the non-local neural networks involved (Wang *et al.,* 2018), rather we deal with the instantaneous recruitments and frequencies of the assemblies involved. This is because there are essentially two distinct aspects to the binding problem: (1) Integrating the distributed neural input from various assemblies also known as the Neural Binding problem (NBP) and (2) the unitary psychological output as a perception (Mind Brain Connection). The nonlocal networks postulate different interaction schemes connecting spatially separated neurons which can at best explain how the binding of the distributed neural inputs together is achieved, but not the why of it nor its aftermath i.e. perception. And, neural binding in itself is not sufficient to account for perception unless it is interpreted and perceived by the pervading consciousness (Mould, 2016). The neural networks are thus merely the algorithms for generation of definite neural correlates. They don't as such explain perception. Therefore, taking such network output as the neural input for perception, we try to find out the psychic output in terms of only the recruitments and the corresponding frequencies.

Non-local communication among spatially separated neuronal basins having neural assemblies cultured from the neural stem cells of the same host has been experimentally observed (Pizzi *et al*., 2004; Thaheld, 2005). Thus it is evident that irrespective of the neural network architecture that are interconnecting the neurons within and without the neuronal assemblies, the total neural recruitment at any instant can be taken to be a measure of neural information processed which is proportional to the estimated time. We further hypothesize that this particular reasoning may be applicable in case of other kinds of perception, and not just time perception.

In the psychophysical interpretation of quantum theory (Pradhan, 2012), quantum non-locality among entangled systems has been explained as being due not just to the objective fact of the systems having shared a common past at some point or at least having interacted at some point in the past, but to our knowledge of the same. Here, the two basins did contain the neurons cultured from the neural stem cells (NSCs) of the same host, which means that they shared a common past (Thaheld, 2010).

Psychological nature of attention

Spatial and Temporal attention have been associated with definite neural correlates (Coull and Nobre, 2008; Coull *et al*., 2004; Griffin *et al.,* 2002) in experiments using PET & fMRI, as well as in more general functions using EEG, MEG and MEEG (Kida and Kakigi, 2015; Crottaz-Herbette and Menon, 2006). If that were the case, attention should then be decodable by a logarithmic function and not by an exponential or an algebraic function of the neural recruitment as proposed by us. Further, it is presence of excess neural recruitment due to noise (unwanted or intruding external or memory signals) that reduces concentration, but willful reduction in concentration need not necessarily cause excess neural recruitment in the absence of noise (Pradhan and Tripathy, 2018b). Again it is not necessarily true that excess neural recruitment always must lead to loss of attention since even in noisy places one can focus on definite tasks by virtue of willful concentration. In such cases noise does produce the corresponding neural correlates but they are not paid attention to and thereby are not decoded for their perception.

Of the many aspects of attention, the functions of alerting, orienting and executive control have been observed to be associated with increase or decrease of different rhythms of neural oscillations but none can be conclusively said to be associated with attention *per se* (Fan *et al*., 2007).

Thus the attention-associated neural recruitments observed in these experiments are not the causes of increase or decrease of attention; rather they are the effects of the corresponding alterations in attention, which is a purely psychological faculty.

Taken as a psychological faculty, attention is dependent on another psychological faculty, namely, interest: the more the interest, the more is the attention. These experiments were designed for modulating attention to measure the corresponding effects and the subjects were well aware of the task of focusing attention. Their willingness to participate in the attention tasks was there as a result of the interest in them in the experiments. Interest is necessary for increased attention. Interest, in its turn, depends on yet another psychological factor, namely, attitude (Pradhan 2010). A strong like or dislike in the event or object or process leads to increased attention, while indifference or lack of interest leads to decrease of attention. The attitude in its turn depends on the instincts and urges in the psychological make-up of the subject on account of the stored experiences of pleasurable or painful experiences in the memory.

Psychological Non-locality and attention

Nonlocal correlations between brain electrical activities of spatially separated human subjects have been experimentally observed (Grinberg-Zylberbaum *et al.,* 1994; Wackerman *et al.,* 2003; Standish *et al.,* 2004). These have been termed Biological non-locality (Thaheld, 2003; Josephson and Pallikari-Viras, 1991), but their true explanation lies in the psychological nonlocality of an underlying all-pervading consciousness that connects all minds (centers of perception). What is instrumental in these processes is the attention of the interconnected individuals on the definite modes through which voluntary communication is to be established. Goal-directed attention does the trick (Thaheld, 2010) and thus attention is nonlocal as a psychological faculty. Here there is no previous association between the individuals apart from the fact of their having agreed to take part in the experiments, which could be independent choices. But the attention on the possible transmission of signals through their brains from one to the other by the subjects enables them to establish non-local communication channels through the intermediary of the underlying field of consciousness which is simultaneously in contact with all the individual centers of consciousness and as such is the common source of all of them.

For the universal field of consciousness which acts through all the brains at all times. The total access recruitment may indeed be infinite effectively, in which case the exponential attention function equation-5 may be appropriate.

As an aside, direct brain to brain interface (BBI) (Rao *et al.,* 2014; Jiang *et al.,* 2018) using noninvasive brain computer interface (BCI) and computer brain interface (CBI) respectively at the sender and the receiver ends (Grau *et al* 2014) are more reliable communication systems than the aforementioned non-locality which has been established only as positive statistical correlations (Persinger *et al.,* 2003; Rechards *et al.,* 2005; Sakkalis, 2011; Manolea, 2015). However, the dependence on computers as mediators at sender and receiver ends makes such communication rather indirect, contrary to their claims of "direct" brain to brain communication.

Conclusion

We have tried to establish attention as a purely psychological faculty with no neural counterpart, though it operates on all neuronal assemblies depending on the definite task. Our reasoning follows an approach following from the generalized Fechner law that assumes that the decoding from neural to psychological happens via the Fechner logarithmic law for any perception, whether from sensory or memory inputs. A divergence in the maximal neural recruitment for the minimal attention in our earlier proposal has been removed by a new algebraic function. Whether the extreme values (0 and 1) of the attention are practically attainable in specific subjects depends on possible future experiments.

The non-locality of attention as a psychological faculty is quite evident from the existing experimental facts in the sense that coherence of brain states between spatially separated observers are patent in all the investigations with appreciable effect size. These imply that a person by focusing attention on another person at a distance can send and receive thought signals through such coherent brainwaves. The detailed mechanism of such thought transference processes will be matter for future research. In addition to spatial non-locality temporal non-locality can also occur where a particular observer can relate to his or her own past being at the same physical location of his or her body and utilizing temporal coherence of current brain states with retrievable psychic states even of previous incarnations as graphically detailed in many real life instances by eminent psychologist and past-life therapist Dr. Brian L. Weiss (Weiss 1988). A hat or a shoe or a garden or a scenery or any such particular experienced event in this life that somewhat tallies with a similar past life experience throws the patient back into that in its own preserved memory in many of the patients successfully treated in Weiss's accounts. These do point to more interesting psychical research in future which will unravel many more secrets of the world that is spread before us in space and time as an physical unfoldment of invisible psychological potentials through the instruments of matter, energy and information.

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