

Some Vital and Unrecognized Roles of Attention in Quantum Theories of Consciousness

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ABSTRACT

As the quantum theories of consciousness are becoming more and more prominent theoretical models of consciousness, more dimensions of consciousness are being discovered. At the same time, the need to pin-point the element of consciousness is becoming more and more important. Parallel to these researches, several cognitive models of consciousness have also been propounded. With more and more results of cognitive studies, we are coming to know that like consciousness, attention is also a basic function of human psychology and both are very intricately related to each other, some- times even overlapping with each other. Perhaps this has been the reason that the cognitive functions of attention have either been completely over-looked or have been mistakenly used synonymously with consciousness in the theories of the latter. This is especially true for quantum mechanics (QM) theories of consciousness. Because of not taking attention into account, some of the most basic assumptions of QM models of consciousness have been erroneous. In this article, we review the literature of basic theories of QM and at the same time, we will see that several important roles of attention in these theories which have been ignored. This is because in most of the theories, attention has either been completely ignored or has been confused with consciousness, whereas both are two distinct cognitive functions. In this preliminary exploration, we will try to address three basic issues on QM in relation to consciousness: the measurement problem, the quantum reduction or wave function collapse and the free choice of consciousness. We propose that future models of consciousness should take into account the vitality of understanding attention.

Key Words: quantum mechanics, consciousness, attention

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Introduction

Consciousness is undoubtedly the most intriguing mystery of nature. It is thus no wonder that it has been a matter of fascination

and speculation for philosophers, mathematicians, scientists as well as the intelligent lay person alike. Among the scientific theories of consciousness, the quantum mechanical (QM) theories occupy a special position because QM includes dimensions of both philosophy and science as well which together somehow reach to the level of abstractness of conscious experience. Recently there has been a proliferation in these QM theories of consciousness which have undoubtedly revealed several novel dimensions of consciousness for further exploration (Bierman & Whitmarsh, 2006; Penrose, 1994).

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The QM models of consciousness have provided us with several important insights into its scientific as well as philosophical realms. Interestingly, in parallel to these researches on the subject of consciousness, the literature has also proliferated in past few years on a very vital cognitive entity- 'attention'. With these researches in cognitive sciences, several vague aspects of attention have come to the forefront (Posner & Peterson, 1990). However in spite of these advances in researches, attention still eludes a proper definition in first place. These new dimensions of attention have not only helped us to realize that attention is an entity distinct from consciousness, but have also made us re-think the theories of consciousness in first place. With more and more results of cognitive studies, we are coming to know that attention, similar to consciousness, is also a basic function of human psychology and both are very intimately related to each other, sometimes even overlapping with each other (Koch & Tsuchiya, 2007). Perhaps this has been the reason that the functions of attention have been either over-looked or have been mistakenly used synonymously with consciousness while propounding the theories of the latter. This has been especially true for QM theories of consciousness. Because of not taking attention into account, some of the most basic assumptions of QM models of consciousness have been erroneous as we shall explore further in this article. No literature till date has looked into these vital issues in-depth. This has been perhaps because of the gap between cognitive neurosciences and QM. We will appreciate in present review that not only are attention and consciousness two distinct cognitive processes, but are also two distinct neural processes. Further we will see how the faculty of attention poses serious challenges to three of most basic assumptions of quantum mechanical theories of consciousness: collapse of quantum superposition measurement problem and free choice.

In this review, we will address and elaborate some important facts about attention and will see how the theories of consciousness have missed this vital element and the consequences thereof. We will see that because this topic has not been addressed, several of the most basic assumptions have been messed up not only in the science of consciousness but also in the QM as well. In fact, in the earliest descriptions of consciousness by William James

(1890), consciousness was described as a "selecting agency" which selects between different courses of actions. From the psychological perspective, this description clearly fulfills the criteria of something known as 'selective attention' rather than consciousness itself. Similarly, the Copenhagen interpretation describes consciousness as the "observing system". We will see that when the phenomenon of attention comes into play, even the most basic assumptions like measurement problem in QM become controversial especially when seen in the backdrop of the latest cognitive studies. However, addressing all the QM theories of consciousness is out of the scope of this article and thus we will focus only on the three major issues mentioned above while taking an Ariel view at other related topics.

We propose that before propounding any theory of consciousness, the cognitive domain of attention should always be kept in view and the word consciousness should not be loosely used. When loosely used, it could either directly imply attention or any one of its several dimensions instead of consciousness per se.

Attention and Consciousness are Two Distinct Processes

It has to be stressed that like consciousness, attention lacks a clear definition and thus several perspectives exist for the same. For example, Moray (1970) proposed six different meanings for the term attention, whereas Posner and Boies (1971) suggested that attention has three components: orienting to sensory events, detecting signals for focused processing, and maintaining a vigilant or alert state. Throughout this review instead of defining it, we will use the word attention as a cognitive function with multiple dimensions, which includes selecting information, dividing itself and the ability of control, as and when required similar to the prevalent concepts in cognitive literature (Posner & Peterson, 1990; Posner, 1994).

One of the reasons why we often confuse attention with consciousness is our experience with the former entity. On a daily basis we observe that when we pay attention to an object, we become conscious of its attributes; when we shift attention away, the object fades away from consciousness. We thus tend to believe that consciousness is the *process* of attending something. Phenomenologically, however



consciousness consists of a rich experience involving but not limited to sensations, emotions and thoughts at the moment whereas attention is a mechanism by which the stream of consciousness is oriented (Posner, 1994). Several studies have found that attention and consciousness are two distinct entities not only cognitively but also in terms of underlying neural processes. Koch and Tsuchiya (2007) have summarized these distinctions at various cognitive levels and have shown that against the earlier conception that attention and consciousness cannot exist without each other, actually they can very much exist and operate without the presence of the other. In fact, in some instances, top-down attention and consciousness can oppose each other's effects (Koch & Tsuchiya, 2007). Lamme (2004) has reviewed the studies of neurological correlates of visual attention and visual consciousness. From these experiments, separate neural definitions of visual attention and visual consciousness emerge more clearly. Based on the review of these studies, the author suggested that visual attention could be defined as a convolution of sensory-motor processing with memory. Consciousness on the other hand, is generated by recurrent activity between cortical areas. On the basis of these distinct neural processes, Tallon-Baudry has recently proposed a "cumulative influence model," in which attention and consciousness correspond to distinct neural mechanisms feeding a single decisional process leading to behavior (Tallon Baudry, 2012). With this clear distinction as a backdrop, we now move towards the implications in QM models of consciousness.

Attention, Consciousness and the Measurement Problem

Measurement problem is one of the core issues in QM. No wonder it has been a matter of debate ever since the theoretical foundations of QM have been laid (Boughn & Reginatto, 2013). Presently there are several versions of this measurement problem, which we will not go into details of. In this section, we will see how the introduction of the concept of attention makes this issue even more problematic and difficult to conceive. We will avoid the complex mathematical quantum formalism because of the simple reason that this is just a preliminary exercise to bring the element of attention into the scene. In this section we will deal only with the role of consciousness in measurement

process. The issue of wave-function collapse, which is the other important aspect of quantum measurement, will be dealt in next section.

We begin with a simple question: "who exactly is the observer?" Historically, several theorists have understood and described this 'observer position' in different ways. To start with, we find von Neumann (1955), who invoked the concept of "abstract self" of the observer in order to account for state vector reduction; Schrödinger (1935) who spoke of a "mental act"; London and Bauer (1939) and French (2002) introduced the idea of "solipsism" but finally insisted on the crucial human feature of "introspective power"; and last but not least Wigner (1967) advocated the central role of "consciousness" in state vector reduction. However, all these models have been very vague in representing the exact entity of observer. Unfortunately, this vagueness has continued in to the subsequent researches aimed at studying this measurement problem in QM. Ibson and Jeffers (1998) were the first to conceive and conduct these experiments using the double slit experiment design. In this classical study, they asked the subjects to visualize (*observe, by extra-sensory means*) monochromatic light passing through a double slit, prior to its registration as an interference pattern by an optical detector. They used this "visualization" as a representation of consciousness. However, this act is actually a form of attention, popularly known as the working memory. Similarly, Radin et al. (2012; 2013) recently conducted a series of experiments with the model of double slit interference. They tested the conscious collapse hypothesis by asking the subjects to focus their 'attention' towards the double slit in the optical system. Their experiments provided an important outcome which showed that actually the act of observation was associated with difference in results. However, on the flip side of their methodology, through-out their studies they continued to use the words consciousness and attention interchangeably. Therefore these theories and experiments have either assumed that consciousness and attention are the same or that in the process of observation, consciousness comes in contact with the observing instrument directly without any other intervening psychological agent. In this review, we aim to propose that, neither of these is the actual case. Several distinctions between attention and consciousness have been



described above. An important relation between the two is that consciousness can receive information from the environment only when attention selects something for observation, a process popularly known as selective attention (Driver, 2001). Only when the perceptual attention aligns itself with the measuring instrument, does information reaches the conscious awareness.

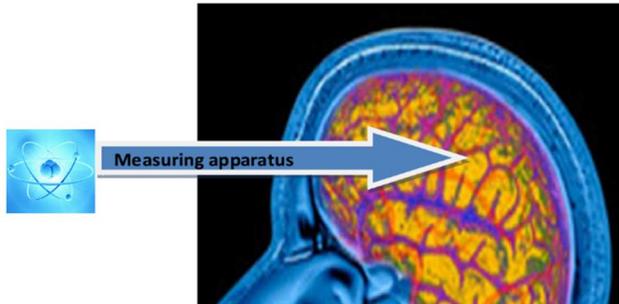


Figure 1. The classical quantum mechanical theories assume that the observation of quantum event occurs directly by consciousness, thereby ignoring the important roles of intervening or mediating psychological agents in between the quantum mechanical event and consciousness.

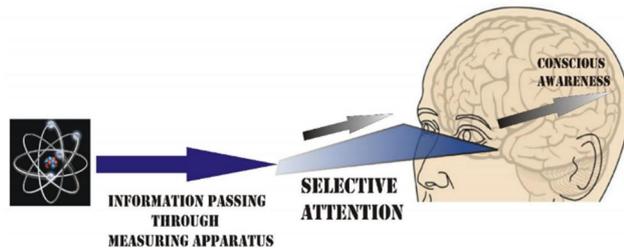


Figure 2. Actual sequence of events involves several psychological events, the most important being the cognitive faculty of attention. Without selective attention, the consciousness cannot receive information regarding any change in environment, including that from the measuring apparatus.

We now turn to the second important question: *“What exactly represents the quantum/classical interface in measurement?”* According to Bohr’s statement of the Copenhagen interpretation, while a (microscopic) system under investigation is described quantum mechanically, the measuring apparatus that observes it must be (or, perhaps always is) described classically. How does one decide which aspects of a system are to be described classically and which to be described quantum mechanically, i.e., what is the location of the quantum/classical divide? Many, including Heisenberg have pointed out that this divide does not represent a discontinuity of physical systems but rather is simply a transition from one formalism to

another (Schlosshauer & Camilleri, 2008). Nevertheless, it has been historically considered as an important aspect of the measurement problem and has been popularly known as the ‘Heisenberg’s cut. This transition is especially important when we look at the event of measurement from the perspective of the object being observed. However, there is another quantumo-classical interface which needs to be addressed in such theories but has seldom been highlighted. This is the interface of quantum events in brain (representing consciousness) and attention itself. This delineation seems very blurred right now because of the abstractness of both attention and consciousness. But addressing this interface is in fact very important because the actual measurement process occurs in the consciousness whereas the attention acts only as a mediator/selecting agency. Also attention is a well-defined cognitive parameter whereas consciousness is an abstract entity.

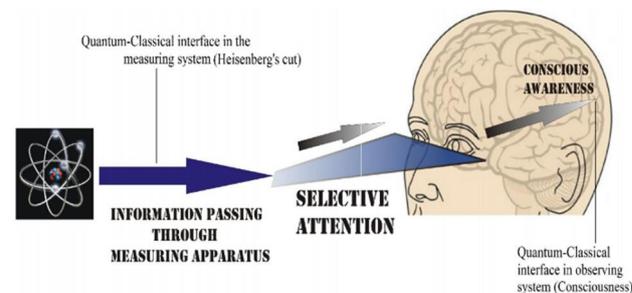


Figure 3. The actual measurement process actually involves at least two quantum-classical interfaces. One is the interface somewhere in the measurement apparatus which has not exactly been delineated till this date, popularly known as the “Heisenberg’s cut”. The second interface is somewhere in the brain at the junction of attention and consciousness. Here attention has been considered as a classical measurement apparatus because it is a less abstract and a better understood cognitive function as compared to consciousness itself.

Now we come to the third important question regarding the very prerequisite of consciousness in the act of measurement. This question was recently addressed and detailed by Koch and Hepp (2006). They have challenged the idea that consciousness carries the burden of the measurement in quantum mechanics with a very strategic thought experiment. They demonstrated that, if one eye of a subject receives a stream of highly salient images, a constant image projected into the other eye is only seen infrequently. This perceptual suppression can be used to evaluate whether consciousness is strictly necessary for the collapse of the wave function (or measurement).



They have even suggested an experiment where an observer is looking at a superimposed quantum system, such as Schrödinger's box with the live and dead cat, with one eye while his other eye sees a succession of salient faces. Under the appropriate circumstances described earlier, the subject is only conscious of the rapidly changing faces, while the cat in the box remains invisible to him. In this instance, what happens to the cat? The conventional prediction would be that as soon as the photons from this quantum system encounter a classical object, such as the retina of the observer, quantum superposition is lost and the cat is either dead or alive. This is true irrespective of whether the observer consciously saw the cat in the box or not. If however, consciousness is truly necessary to resolve the measurement problem, the animal's fate would remain undecided until that point in time when the cat in the box becomes perceptually dominant to the observer. This seems unlikely but could, at least in principle, be empirically verified. This cognitive state is called as divided attention, which we will describe in detail in next section.

Divided Attention, Consciousness and Wave Function Collapse in Brain

Collapse of a wave function, popularly known as quantum reduction (QR) is one of the founding principles of quantum mechanics which is also integral to the measurement problem discussed above. Additionally, quantum reduction is also integral to the problem of consciousness itself because theoretically it is the consciousness of the observer which is carrying out the measurement which also subsequently causes collapse of the wave function. Historically, several theorists have attempted to explain the whole phenomena of consciousness by relating it to the event of wave function collapse. However in these theories, the pre-collapse superposition states have varied from particles (Ghirardi *et al.*, 1986) to quantum gravity or underlying properties of space time geometry, as in the "objective reduction" proposals of Károlyházy *et al.* (1986); Diosi (1989) and Penrose (1989; 1996). Some views like that of Stapp (1993) have even considered the whole universe as a single quantum wave function and that reduction within the brain is a conscious moment (akin to Whitehead's "occasion of experience"— Whitehead, 1929). As per this theory, Reduction/collapse is consciousness, but its cause and distinction between universal

wave function and that within the brain are unclear. Among the most influential quantum reduction theories of consciousness, is that of Penrose & Hameroff Orchestrated Objective Reduction (OrchOR) in which, each OrchOR theoretically correlates with a moment of conscious experience (Hameroff & Penrose, 1996; Hameroff & Penrose, 2013).

The Penrose (1989; 1994) theory brought consciousness into physics in a very unique way, by directly approaching the super positioned objects as actual separations in underlying reality at its most basic level (fundamental space-time geometry at the Planck scale of 10^{-33} cm). The OrchOR phenomena in brain relies on the objective reduction of the superposition in brain microtubules by a conscious experience. In simpler words, the conscious experience is a consequence of the "collapse" of the state-vectors which are the non-conscious quantum brain states preceding a conscious moment.

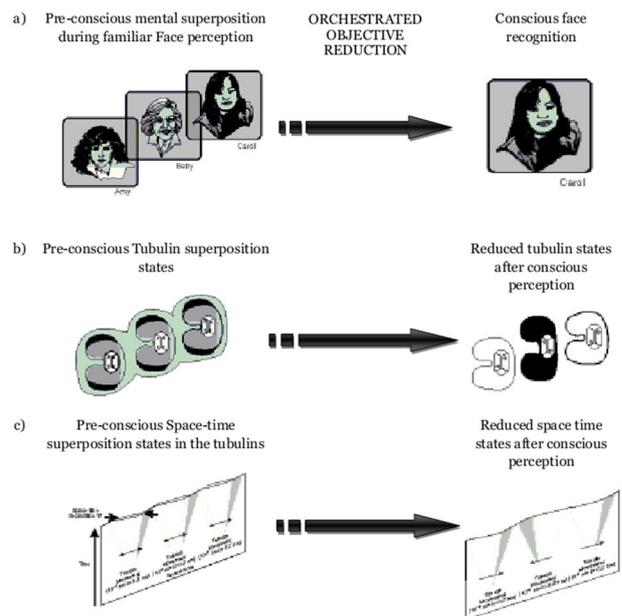


Figure 4. OrchOR events in conscious experience. a) Cognitive facial recognition. A familiar face induces superposition (left) of three possible solutions (Amy, Betty, Carol) which "collapse" to the correct answer Carol (right), b) (left) Three tubulins in quantum superposition states prior to 25 msec. Reduced states of the tubulins after the OrchOR (right), c) Fundamental space-time geometry view. Prior to OrchOR (left), space-time corresponding with three superposed tubulins are separated as Planck scale bubbles: curvatures in opposite directions. Conscious experience causes Orch OR and an abrupt selection of single curvatures (and a particular geometry of experience).

But on an important note, the authors have kept some exceptions to this OrchOR in the form of "split-brain" patients or others with



“cognitive disorders” (Hameroff, 2012) as mentioned by the authors themselves:

“Entangled superpositions leading to OrchOR and moments of consciousness are seen as sequential, only one “consciousness” occurring in the brain at any onetime (except perhaps for “split-brain” patients, or those with other cognitive disorders).”

The authors have kept this exception because of their apprehension that the assessment of consciousness in split-brain patients or those with severe cognitive disorders is much more difficult (or even impossible to conceptualize) as compared to normal individuals. In addition to these abnormal conditions, there is a normal cognitive state which is also a challenge for theories of consciousness similar to cognitive disorders as addressed above. This is the state of “divided attention”.

Divided attention can be defined as the ability to simultaneously attend to more than one activity (McDowd & Craik, 1988). These skills are required for occupations or tasks that demand skills in attending to several

simultaneously occurring stimuli which include can of vital importance in crucial tasks like flying (Gopher, 1992; Gopher *et al.*, 1994) and surgical tasks (Rosser *et al.*, 2004). In addition to these complicated tasks, divided attention is also required for the performance of a number of everyday activities such as walking (Bootsma van der Wiel *et al.*, 2003; Mezler & Oddsson, 2004) and driving (Howard & Connell, 2005; McKnight, 2003). Historically, there have been several popular examples of individuals using divided attention in their day to day activities with great and often astonishing efficiencies. Early investigators attempted to explore the limits of consciousness by combining diverse tasks while introspecting on their performance. Paulhan (1887) recited one poem while writing another, or while executing mathematical calculations. Solomons and Stein (1896) and later Downey and Anderson (1915) practiced reading stories while writing at dictation, and noted the changes that occurred in their conscious awareness of the act of writing. The psychological state of divided attention is baffling because it challenges the presumption of the unitary nature of attention as well as consciousness.

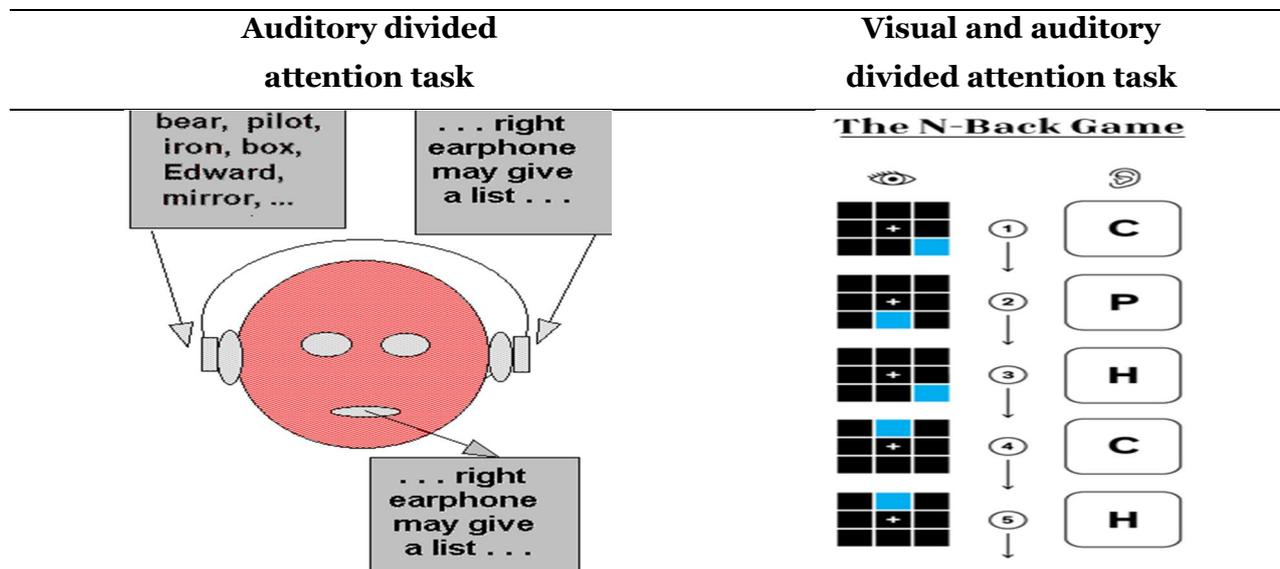


Figure 5. Two of the dual task paradigms. The left image shows a dual auditory task. This task delivers two different auditory stimuli simultaneously in the two ears. The subject has to then reproduce the words spoken to him. The image on right shows an auditory-visual dual task. In this task, a visual and an auditory stimuli are delivered to the subject simultaneously. Then the subject is asked to reproduce the auditory and visual stimuli.

An experimental example of cognitive task utilizing divided attention is in the dichotic listening experiments where two different stimuli are presented to the two ears. In such

instances, most subjects do manage to hear the mention of their own names (Moray, 1959), sexually explicit words (Nielson & Sarason, 1981), and words they had learned to associate

with electric shock (Dawson & Schell, 1982)—even when these are irrelevant stimuli spoken in the unattended ear. It has been observed that many subjects in this situation could tell that something odd had occurred in the unattended ear when the speech in that ear was switched from ordinary English to English played backward (Wood & Cowan, 1995). Similarly, several forms of visual dual task paradigms have been designed to assess the divided attention. For the sake of simplicity, we will not go into the details of these paradigms. Many of these paradigms present two visual stimuli, one at center and one at periphery (Williams, 1988; Williams, 1989). A commonly used dual task paradigm is the *n-back task* which uses simultaneous visual and auditory stimuli and depends on the identification of both these stimuli.

Theories such as the resource allocation theory (Kahneman, 1973) propose that there is a unitary pool of resources or attention that needs to be divided among multiple tasks and when the demand exceeds the available resources, performance on either one or both the tasks decline.

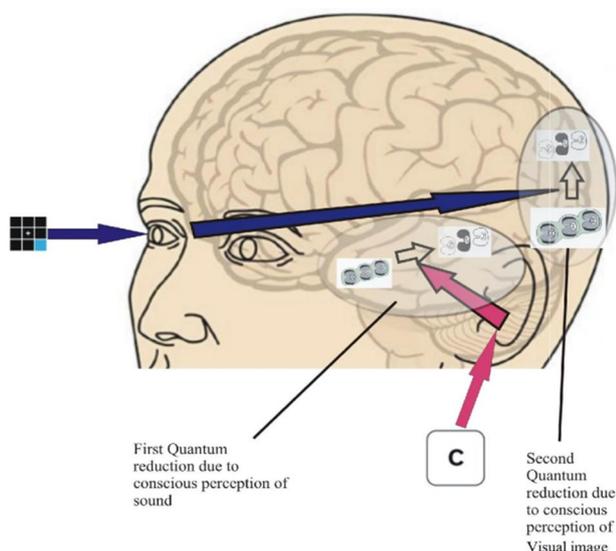


Figure 6. The double quantum reduction model in a dual auditory-visual task. In this model, we propose that when two stimuli are perceived simultaneously in divided-attention task, there are actually two quantum reductions at two different periods of time. This will imply that the divided attention is actually selective attention rapidly alternating between the two stimuli. Thus at a given point of time, consciousness acts through attention for only one sensory stimulus. Thus there are actually two quantum superpositions and reductions at two points of time.

Divided attention is also a unique state from the perspective of QM because it makes the depiction of the underlying reduction difficult to conceptualize. What exactly happens when the person attends (consciously) multiple stimuli simultaneously? Will there be multiple reductions? Or will it result in a single reduction for two multiple states of superposition (for two different stimuli) in the brain? Because of a lack of adequate scientific probing of these phenomena, presently there is no theory/concept to answer this question. Thus for the sake of initiating this discussion, we will consider both of these options (Figure 6 and 7). Which one of these models does actually apply to the QM reduction theory of “Divided attention” task cannot be answered right now but definitely this subject is an important substrate for further discussions on the reduction models of consciousness in future.

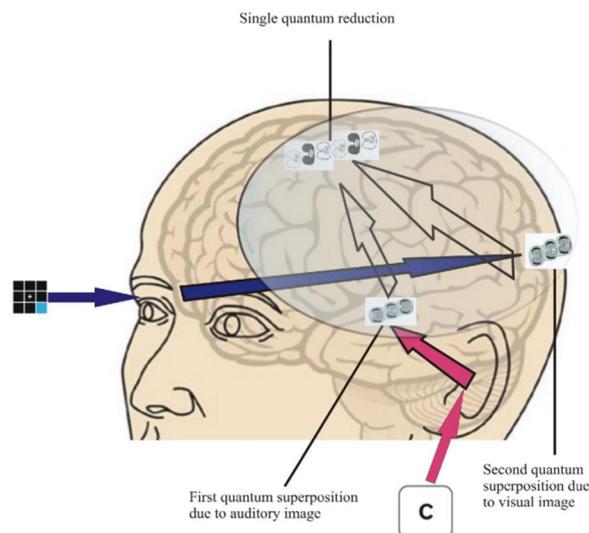


Figure 7. The single quantum reduction model of dual task perception. In this model we propose that actually the auditory and visual images formed are two different quantum superpositions in brain occurring simultaneously and finally they reduce to a single state as conscious perception occurs to both of these stimuli at the same time. As per this model, there is a simultaneous perception of auditory as well as visual image in our consciousness which is in turn a unitary experience. However, the exact location of this quantum reduction in brain will be a matter of speculation given that the superpositioned states of visual and auditory stimuli are occurring in two different lobes of brain.

Attention Dependent Consciousness: A Challenge to Free Choice Theory

The ability to have a ‘free choice’ has been universally considered as a defining attribute of consciousness (Libet, 1999). The concept of free choice has also been a central theme in

quantum mechanical theories of brain. As early as 1890, William James described in his book that “consciousness is at all times primarily a selecting agency. It is present when choices must be made between different possible courses of action.” From Von Neumann to recently propounded quantum zeno effect by Stapp (Schwartz *et al.*, 2006), the property of free choice has been addressed by almost all the researchers working in theoretical domains of QM. In the model of von Neumann, the free choice is a central ability of the observing agency which differentiates it from the observed agency. His theory placed this Free-choice property of whole quantum world in to the Process 1 psychophysical event in the brain of the conscious agent, while placing the conscious choice of which probing question to pose in his stream of consciousness. That is, the conscious act of choosing the probing question is represented as a psychologically described event in the agent’s mind, which has been named by von Neumann (1955; p.421) the “abstract ego”. This choice is physically and functionally implemented by a Process 1 action in his brain. The psychologically and physically described actions are the two aspects of a single psychophysical event, whose physically described aspect intervenes in the orderly Process 2 evolution in a mathematically well-defined way.

Bohr emphasized that the laws of quantum theory should continue to be valid in biological systems, but that the latitude introduced by the severe constraints upon observation imposed by the demands of sustaining life could permit such concepts such as “teleology” and “volition” to come consistently into play (Bohr, 1958, p.10 and 22). Wheeler (1978) described an interesting thought experiment in which the measurement choice (by a conscious human observer) was delayed until after the electron or other quantum entity passed through the slits, presumably as either wave or particle. Wheeler suggested the observer’s delayed choice could retroactively influence the behavior of the electrons, e.g., as waves or particles. The experiment was eventually performed (Kim *et al.*, 2000) and confirmed Wheeler’s prediction; conscious choices can affect previous events, as long as the events had not been consciously observed in the interim. This ability of free-choice provides consciousness with the ability of independence.

However, cognitive studies of attention have provided some results which seem to challenge this view. Recent studies have provided enough evidence that awareness may not always have the free-choice in s selection the stimulus. This event cannot be considered as the same event which has been described in QM experiments. None the less, these are events in cognitive neurosciences which depend on free choice of consciousness. Instead of consciousness making the free choice, consciousness actually depends on attention for several perceptual experiences. Here we will give some examples of the dependence of consciousness on attention.

Bottom-Up vs Top-down Modulation of Attention

Top-down modulation of attention is the ability to shift and modulate attention by the means of higher cognitive functions like emotion and consciousness (Polich & Criado, 2006). Although top-down attention is not a prerequisite of consciousness (Koch & Tsuchiya, 2007), but it does seem that consciousness acts by top-down attention: It is the property of volition or voluntary control of attention (Pashler 1999; Posner & Peterson, 1990). However common day to day experiences as well as cognitive studies prove that this top-down attention control can be overridden: salient and powerful stimuli can capture attention and direct us away from the task at hand. Attention thus captured is described as *exogenous attention*, because it is driven in a bottom-up fashion by stimuli generated outside oneself (like the sound of the breaking glass, strong color). These exogenous cues are actually very useful in day to day situations: little children on field trips and prisoners in work-release programs wear brightly colored shirts for the same reason. This bottom up modulation of attention poses important challenge to the concept of free choice. Especially, the original hypothesis of the free-choice in probing into physical systems by Von Neumann (1955) seems to fall apart with this finding of bottom-up attentional modulation. As the choice to attend or to not attend may be very much modulated by environmental factors instead of the consciousness itself, so the choice of probing into physical systems (for example orienting the attention towards a physical object) may not be with the consciousness itself, but could actually be with the environment



itself (the external cues in the bottom-up attention modulation) may not always be. For example, the act of choosing between to see the cat or other visual stimuli may not be in the individual conscious capability rather could be more dependent on the salience of the task/object.

In fact, bottom-up processes are often measured by how much a stimulus interferes with (Theeuwes, 1991; Folk *et al.*, 1992) or facilitates (Treisman and Gelade, 1980; Yeshurun *et al.*, 2009) the performance on an attentional task and salient stimuli are thought to “capture attention”, thus depriving consciousness of its freedom to choose what to see, in spite of the task at hand.

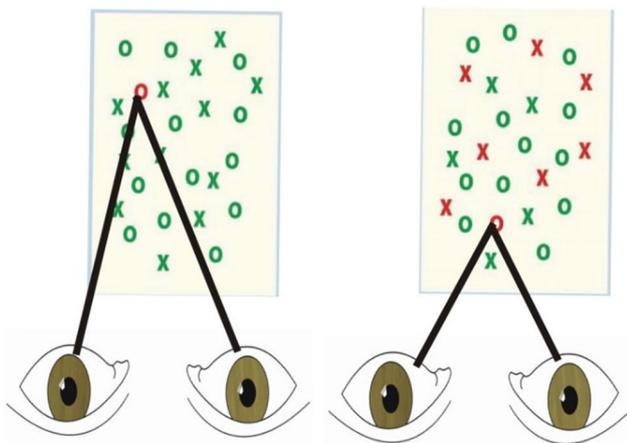


Figure 8. Task 1 (left). Identify the odd image. The red circle gets identified reflexively and many a times unconsciously. It is because of the color salience of the red circle as compared to other images in the task. This is called as bottom up modulation of attention and does not depend on analysis of choices. Instead it happens automatically. **Task 2 (right).** Identify the odd image. Here also the odd image is the red circle. But it is difficult to identify and requires lot conscious effort. This is called as top-down modulation of attention and requires careful selection amongst available choices.

Hemispatial neglect and other attention related blindness

Another important example of the dependence of consciousness on attention is the clinical condition of hemispatial neglect and similar forms of inattentive blindness. Hemispatial neglect is a condition of deficit of attention in which one entire half of a visual scene is simply ignored. The reason for failure in selecting the information in such cases is not that they are blind on that side or any neurological interruption in flow of visual information. Rather, they do not seem to be able to orient the attention toward information on the side of the

scene before them and to attend it. This condition is usually seen in the lesions of right hemisphere. Clinically patients may leave food uneaten on the side of their plate, fail to groom the affected side of their face, or miss words from the left of a printed page while reading (Robertson & Marshall, 1993). Neglect may affect awareness for contralesional inputs in other sensory modalities as well (e.g., audition, touch), but most research has focused on the visual deficits. Although neglect has been observed after damage to a number of brain areas, the region most commonly affected is the inferior parietal lobe (IPL) (Vallar & Perani, 1986). If it is pointed out to them, they may then go back and fill in the missing information; but, left to their own devices, they apparently do not select information from the left side. This shows that the awareness of stimuli is intact but the stimulus is ignored because of deficits in attention-related mechanisms. Another interesting aspect of this disorder is that some patients with parietal lesions do not show any deficit at all for an isolated visual event on the affected side. Their deficit only emerges when stimuli are presented concurrently on the left and right sides, in which case the more contralesional event now goes undetected. This phenomenon is known as “extinction” (Bender, 1952), and it has been taken as an evidence that parietal damage causes a problem with selective attention rather than sensory processing or consciousness (Driver *et al.*, 1997). Whereas single inputs can be attended normally, thereby entering awareness, bilateral simultaneous stimuli compete for limited attentional capacity, with the more ipsilesional of the two inputs winning the competition and gaining exclusive access to awareness (Ward *et al.*, 1994).

The neglect is not restricted to visual information (further demonstrating that it is not a visual problem per se)—such patients may also ignore sounds or touch delivered to the left side or even fail to detect smells delivered to the left nostril. In fact, several studies have revealed that unconscious processing goes on in neglect patients (Nagamura *et al.*, 2012).

From these descriptions, it can be clearly seen that inattentive neglect presents a serious challenge to the concept of Free-choice of consciousness. The ability of the person to attend the stimulus when pointed out or when provided separately on the side shows that consciousness is intact but the patient is not able to be aware of the stimulus because of the

disability of attention in acting properly. Additionally, the missing left half of these patients "spontaneous drawings" shows that even the volitional choice of these individuals may not be free, which instead may depend on the involved attentional processes. These findings clearly show that to be aware or not for a stimulus depends a lot on the presence of attention. Thus consciousness may not have a free choice in the act of probing into the measuring apparatus thus contradicting the Copenhagen model of consciousness (Von Neumann, 1955).

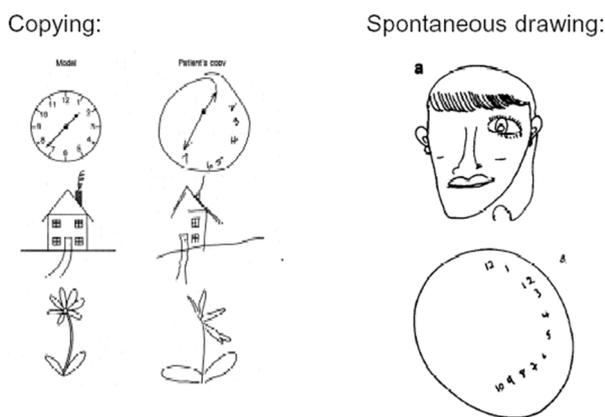


Figure 9. An example of copying and spontaneous diagrams in hemispatial neglect patients. Note the missing left-half of almost all the diagrams. These diagrams show that both the Copenhagen and Bohr interpretations of free-choice in choosing the observation or measuring instruments may not be applicable in these patients where there is paralysis of the cognitive functions of attention.

Conclusion

The QM models of consciousness have provided some very important insights into the world of consciousness. However, attention is an important cognitive function which is intricately related to consciousness. Additionally, its properties at times seem like that of consciousness itself although both are very distinct cognitive and neural processes. Due to these reasons, most QM theories of consciousness have either ignored attention outrightly or have confused attention with consciousness. Our review shows that prevalent QM theories of consciousness need to incorporate attention for at least three basic issues: measurement problem, quantum reduction and free choice. We are of the opinion that by not including the phenomena of attention, these theories have oversimplified the whole subject of consciousness and have actually ended up giving theories of attention at

several points. These erroneous assumptions can be avoided by taking into account this cognitive entity of attention while propounding theories in future.

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