Towards a Coherent Application of the Beck-Eccles Quantum Trigger

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ABSTRACT

Prior to the 20th century, the strictly deterministic laws of classical Newtonian physics made the integration of a non-physical entity such as volition into a scientific model of brain dynamics a seemingly impossible task. However, the probabilistic laws of quantum physics discovered in the 1920's have provided researchers with a valuable new tool, allowing them to account for non-physical entities like volition while still maintaining scientific rigor. One of the greatest challenges that researchers in this field have faced is the application of the atomic-level laws of quantum physics to the study of macroscopic objects. This paper contributes to this line of research by examining the Beck-Eccles quantum trigger model from a neuropsychological processing perspective. Specifically, experimental results from several recent studies of the effects of mindfulness meditation on attentional skills are considered. These results strongly suggest that volition can be used to induce significant changes in the brain's ability to maintain focus on a single stimulus. In addition, it is shown that the gradual nature of the induced changes is very much consistent with the contention that the Beck-Eccles trigger functions only at an atomic level, and that nonlinear dynamics, and more specifically the principle of self-organization, are needed to apply the trigger's effects coherently on a macroscopic level.

Key Words: Quantum Trigger, Coherence, Volition, Mindfulness

DOI Number: 10.14704/nq.2018.16.9.1537 **NeuroQuantology 2018; 16(9):14-19**

Introduction

The development of the theory of quantum mechanics in the early 20th century has added an important new perspective to the long-standing debate between monist and dualist approaches to the study of the mind-brain relationship. One of the most important obstacles that researchers in the rapidly-developing field of quantum neuroscience have had to deal with is the question of how best to apply quantum principles coherently on a macroscopic level. The goal of the present paper is to contribute to this line of research by examining a specific model, namely the Beck-Eccles quantum trigger model, from a neuropsychological processing perspective.

Historical perspective

It has been nearly 400 years since French philosopher and mathematician René Descartes (1637) proposed his well-known distinction between the mind and the brain. Since that time, there have been countless research papers proposing myriad perspectives on the mind-brain relationship. In general, neuroscientists have tended to support monist models which deny the existence of the mind. Such models typically invoke the principle of causal closure, and more specifically the law of conservation of energy, in order to exclude the possibility that the non-physical mind can interact with the physical brain. Conversely, psychologists and philosophers have tended to favor dualist models which maintain

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 04 May 2018; **Accepted:** 27 July 2018

that the mind is a real entity, distinct from the brain, whose existence cannot be ignored. An interesting development in this long-standing debate occurred in the 1920's, when physicists such as Bohr, Heisenberg and Schrödinger determined that unobserved subatomic particles behave according to probabilistic laws, as opposed to the deterministic laws of classical Newtonian physics. The unpredictability of quantum events led many researchers to investigate possible applications of quantum theory to the study of the mind-brain relationship. Of the various models that have been proposed over the years, the model of Beck and Eccles (Eccles 1986, Beck and Eccles 1992, Beck 2008) has been singled out in several recent studies (Atmanspacher 2015, Georgiev and Glazebrook 2014[1]) as being the model that is the most compatible with the principles of quantum mechanics, as they are currently understood. One of the principal reasons for this compatibility is related to the application of quantum principles at a macroscopic level. Simply put, the probabilistic equations of quantum mechanics only apply to subatomic particles, such as electrons orbiting an atomic nucleus. In macroscopic objects, the quantum properties of individual atoms tend to balance each other out, with the result that the object as a whole behaves according to the laws of classical Newtonian physics. Despite numerous attempts on the part of various researchers to develop models of "quantum coherence", there is still no firm evidence to suggest that quantum principles can apply on a macroscopic level. As will be seen in the next section, the Beck-Eccles model is unique in the sense that it applies solely at the atomic level, and Beck and Eccles explicitly exclude the possibility of applying their model at a macroscopic level.

The Beck-Eccles quantum trigger

The starting point of the Beck-Eccles model is the process of exocytosis, which is the release of a neurotransmitter molecule at a nerve terminal. It has been well established in the literature that exocytosis is one of the principal processes involved in communication between neurons. Beck and Eccles note that exocytosis as a whole is a macroscopic process, explainable using classical physics. However, they also note that the arrival of an electrical impulse at a nerve terminal is a necessary, but not a sufficient, condition for exocytosis to occur, and they cite evidence that suggests that the probability of exocytosis upon arrival of an impulse is approximately 0.4. Beck and Eccles go on to argue that, given the organizational structure of the brain, exocytosis could not possibly be regulated stochastically, and that some sort of stable regulator must therefore be present. They propose a model according to which exocytosis is regulated by atomic-level reactions, such as electron transfer between molecules of the synaptic membrane. Because these reactions alter the charge separation across the membrane, they represent a very plausible regulation mechanism for exocytosis. In addition, because the reactions in question are atomic-level processes, they obey the probabilistic laws of quantum physics. Beck and Eccles go on to show that a quantum mechanical trigger, based on quantum tunneling of a quasiparticle across a potential energy barrier, is a very plausible regulator for exocytosis. They also show that, because the trigger obeys probabilistic quantum laws, human volition could be added to the list of factors that affect the probabilities associated with the trigger mechanism, without violating any physical laws.

As I have already mentioned, one of the primary advantages of the Beck-Eccles model is that it applies only at the atomic level, thereby avoiding the complex problem of quantum coherence. Needless to say, this feature of the model has an associated drawback. Specifically, the Beck-Eccles quantum trigger can do nothing more than regulate exocytosis in individual neurons. In order to explain brain dynamics, it would obviously be necessary to explain how the model could apply coherently to thousands of neurons. Unfortunately, Beck and Eccles make little mention of this issue. According to Eccles (1986: 411) "mental events act on probabilistic synaptic events in a manner analogous to the probability fields of quantum mechanics", and according to Beck and Eccles (1992: 11360), "the mental intention (the volition) becomes neurally effective by momentarily increasing the probability of exocytosis in selected cortical areas". In the most recent version of the model, Beck (2008) goes a step further, expressing confidence that ongoing research in the field of

[1]It should be noted that, while Georgiev and Glazebrook (2014) agree with the basic structure of the Beck-Eccles model, they do not agree with all of the details of the model. Specifically, they argue that the insensitivity of the model to temperature variation is problematic, and they propose a modified model which they claim resolves the temperature variation problem. Given the complexity of the arguments involved, I will leave open the question of whether the proposed modification of the model is necessary.

non-linear dynamics, and specifically the principle of self-organization in biological systems, will soon be able to deal successfully with the coherence issue. Beyond these simple statements, no details are provided.

A processing model

In this section, I would like to attempt to obtain a clearer picture of how the principle of self-organization alluded to by Beck (2008) might manifest itself, by considering the Beck-Eccles model from a neuropsychological processing perspective. One of the first attempts to integrate volition into a processing model can be found in the work of neuroscientist Benjamin Libet. In a unique series of experiments conducted in the early 1980's (see Libet 1999 for an overview), Libet attempted to determine the neurological mechanisms associated with performing a voluntary action. The results of Libet's experiments showed that, when a person performs a voluntary movement, a readiness potential (representing brain activity in preparation for movement) appears on average 550 milliseconds before the movement. Approximately 350-450 milliseconds after the appearance of the readiness potential, the person becomes consciously aware of the intention to perform the action. There is then a period of 100-200 milliseconds during which the person can choose to "accept" or "veto" the action corresponding to the readiness potential. If the person decides to "veto" the action, then the action will not take place. In short, the results suggest that, even in the case of a voluntary movement, the readiness potential is created by the brain, and although volition can be used to "veto" the movement, it cannot be used to create a readiness potential independently of the brain. For this reason, Libet's model is often referred to as the "free won't" model of volition.

In the years since the publication of Libet's model, there have been considerable advances in the field of neuropsychology, allowing the concept of volition to be studied from a much more comprehensive perspective. An area of the brain that has particularly attracted the attention of researchers is the prefrontal cortex (PFC), which, from an evolutionary perspective, is the most recent addition to the mammalian brain, and which appears to perform many of the brain's most complex functions. In particular, there is considerable evidence (Diamond 2013, Hazy *et al.,* 2007) to suggest that the PFC functions as the brain's "executive centre", receiving and processing information from many, or perhaps all, other areas of the brain.

Given that the PFC is constantly receiving and processing stimuli from many sources, a question that has stimulated much recent research is how the PFC allocates its limited processing resources. In other words, what factors can influence which stimuli the PFC "pays attention to" and which stimuli are "ignored"? In this regard, several authors (Ciaramelli *et al.,* 2010, Katsuki and Constantinidis 2014) have highlighted an important distinction between "bottom-up" and "top-down" attention. Bottom-up attention is based on the stimulus itself. A bright light or a loud noise, for example, will tend to attract the attention of the PFC more than a stimulus which lacks such salience. Top-down attention is a much more complex phenomenon. According to Katsuki and Constantinidis (2014: 509), top-down attention refers to "internal guidance of attention based on prior knowledge, willful plans, and current goals". Clearly, volition would be included in this category.

Another important development related to the allocation of resources by the PFC is the identification of a "default mode network" (Garrison *et al.,* 2015; Mak *et al.,* 2017). The regions that are most commonly mentioned as being part of this network are the medial PFC, the posterior cingulate cortex and the angular gyrus. As the name suggests, this network is believed to be responsible for the functioning of the PFC in situations where no specific cognitive task is being performed.

The developments in neuroscience described in the preceding paragraphs have allowed for the creation of much more comprehensive models of neuropsychological processing. Given that the ultimate goal of this paper is to determine how volition could manifest itself on a macroscopic level, I would now like to examine the role that volition might play in such a processing model. Specifically, I would like to consider an example of top-down attention where volition is used to "override" the default processing mode of the PFC. An example of such a process can be found in the recent literature on mindfulness meditation. Mindfulness is defined by Kabat-Zinn (2003: 145) as "the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment". There is considerable evidence to suggest that this type of meditation has beneficial effects in the treatment of conditions such as anxiety (Kabat-Zinn *et al.,* 1992) and depression (Teasdale *et al.,* 2000), among others. Although there are several different techniques associated with mindfulness meditation, one of the most common, especially for novice meditators, involves focusing attention on a single stimulus, often the sensations associated with breathing. Given that this technique clearly involves using volition to focus for an extended period of time on a single stimulus, and thereby "override" the default tendency of the PFC to regularly switch attention from one stimulus to the next, it may provide insight into how volition can influence brain activity on a macroscopic level.

Several recent studies have shown that mindfulness meditation improves the ability to focus on a single stimulus and ignore distracting stimuli. For example, Moore *et al.,* (2012) investigated the effect of meditation on attention by examining performance on a Stroop task (Stroop 1935), a test commonly used to measure attentional control. A group of novice meditators performed the test three times: before learning mindfulness meditation, after approximately 8 hours of meditation, and again after approximately 16 hours of meditation. When compared to a control group, EEG data for the meditators showed an increase in activity in areas of the brain which have been shown to be directly related to the performance of the task in question. There was also a decrease in activity in areas which have been shown to be devoted to allocation of resources by the PFC, which suggests an improvement in processing efficiency. It should be noted, however, that these changes in brain activity were not accompanied by improvements in task performance.

A similar study conducted by Allen *et al.,* (2012) compared performance on a Stroop task in a group of novice meditators before and after a course involving approximately 20 hours of mindfulness meditation. In this study, fMRI data showed significant increases in brain activity in the dorsolateral PFC, which has been shown to play an important role in executive processing. In addition, behavioral data showed significant improvement in task performance after completion of the meditation course.

There are also several recent studies which show that improvements in attentional ability continue to occur over much longer periods. For example, a study by Lutz *et al.,* (2009) examined performance on an attentional blink task (Raymond *et al.,* 1992) and a dichotic listening task (Tiitinen *et al.,* 1993), as well as EEG data, in a group of meditators with an average of approximately 3000 hours of meditation experience. Data were collected before and after an intensive three-month retreat consisting of an additional 1000 hours of meditation. Despite the level of previous experience of the meditators, both the task performance data and the EEG data showed significant improvements over the course of the additional 1000 hours of meditation.

A quite different study, conducted by Brefczynski-Lewis *et al.,* (2007), examined fMRI data during mindfulness meditation from three groups of volunteers. The first group consisted of novices who had performed approximately 7 hours of mindfulness meditation. The second group consisted of experienced meditators with 10,000 – 24,000 hours of meditation experience, and the third group consisted of experienced meditators with 37,000 – 52,000 hours of experience. The data from this study yielded several interesting results. First, the novice group showed increased activity in areas that correspond to the default mode network, which is characteristic of an inability to maintain focused attention. The second group showed less activity in the regions corresponding to the default mode network, and greater activity in regions that have been shown to correspond with focusing attention. Interestingly, the third group showed less activation than the other two groups in all of these areas. Brefczynski-Lewis *et al.,* attribute this finding to the fact that the highly experienced meditators in this group had developed the ability to "effortlessly" maintain attention.

While there are clearly methodological differences between these studies, the results, when taken together, reveal several interesting trends. First, the results clearly indicate that mindfulness meditation improves the ability to focus attention on a single stimulus. Specifically, in the performance of a task that requires focused attention, meditators show an increased ability to make less use of the default mode network and more use of areas of the brain that apply specifically to the task at hand. They also show a more efficient use of the brain's processing resources. A second interesting aspect of the experimental data is the gradual nature of the changes that take place. Specifically, the data from novice meditators suggest that, when one begins using mindfulness to improve attentional ability, approximately 8 hours of meditation is needed produce noticeable changes in brain activity, and approximately 20 hours of meditation is needed to produce noticeable improvements in attentional task performance. In addition, the results obtained from experienced meditators show that, even after several thousand hours of mindfulness meditation, noticeable improvements in the ability to maintain focused attention are still occurring.

I would now like to consider these experimental results from the perspective of the Beck-Eccles quantum trigger model. While the results do not directly support the model, they are certainly consistent with it. As I mentioned in the previous section, the quantum trigger can only alter the probability of exocytosis in individual neurons, and some type of self-organization is required to extend the changes coherently to large numbers of neurons. This aspect of the model is definitely consistent with the finding that initial attempts by novice meditators to use volition to "override" the default mode network and maintain attention on a single stimulus yield negligible results, and that several hours of repeated efforts are necessary in order to produce noticeable changes. The model is also very much consistent with the finding that, among experienced meditators, changes in brain activity and task performance continue to occur even after thousands of hours of meditation experience.

Summary and Outlook

In this paper, I have attempted to shed light on the manner in which the Beck-Eccles model of quantum brain dynamics can be extended from the atomic level to the macroscopic level. Specifically, I have presented data from several studies of mindfulness meditation which suggest that volition can be used to effect significant changes in the brain's ability to maintain focused attention. I have also shown that the very gradual nature of these changes is quite consistent with the idea that initial attempts to use volition to influence brain activity can only alter the probability of exocytosis in individual neurons, and that macroscopic changes in brain activity can only be achieved through a lengthy process of self-organization. Although there are still many unanswered questions and many details that remain to be worked out, it is my hope that the ideas presented here will prove beneficial to researchers in neuroscience, neuropsychology and quantum physics, as they continue to work towards a better understanding of this fascinating aspect of the mind-brain relationship.

Acknowledgements

The author would like to thank Ashraf Ahmed, Vatche Deyirmenjian and Andrew Meyertholen, as well as the NeuroQuantology Editorial Board, for their helpful comments and suggestions.

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