Meditation and the Neural Correlates of Consciousness:

A No-Cognition Paradigm

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Abstract

This research investigates the neural correlates of consciousness (NCC) through a novel "no-cognition" paradigm that employs the unique capacity of meditators to prevent cognitive reactions to stimuli. It also uses the innovative ability of machine learning to decode perceptual content from brain activity to test a prediction about the temporal dynamics of consciousness.

Within neuroscience, the exact parameters of NCC is a matter of contention. For cognitively based theories, the NCC entails activity related to cognition in the frontal cortex in addition to perceptually related processing in the occipital and temporal cortex. This is opposed to sensory-based theories that mainly focus on the occipital and temporal cortex.

Using electroencephalography, the experiment tested the neural responses of a group of advanced meditators and non-meditative controls. A comparison of the groups across no-task and task conditions evaluated whether the P3b component is an NCC, as predicted by the cognitively based global neuronal workspace theory (GNWT), or constitutes a neural correlate of cognitive processing related to task relevance. We also tested GNWT's prediction that consciousness arises 300–600 ms post stimulus.

Our results appear to provide evidence that the P3b component is not an NCC, but is instead a neural correlate of cognitive processing related to task relevance, as demonstrated by the P3b's presence in the task condition and disappearance in the no-task condition. For decoding, we found that accuracy remained above chance until 500 ms in both conditions when comparing between stimulus categories and individual face stimuli, which is consistent with GNWT's temporal predictions about consciousnes's ignition. Overall, this data implies that some facets of the competing theories are valid, while other aspects are invalid, thus suggesting that cognitivist and sensory based theories should be integrated, instead of entirely opposed to one another.

Chapter 1: Introduction

This research project is based on a multidimensional experiment. Its primary aim is to investigate the neural correlates of consciousness through a novel "no-cognition" paradigm that involves advanced meditation practices. In addition, the project studies the capacity of meditators to prevent cognitive reactions to stimuli. Finally, it tests the innovative ability of machine learning to decode perceptual content from electroencephalogram recordings.

Currently, the major aim of the neuroscience of consciousness, as formally defined in the seminal article by Crick and Koch (1990; 1998), is to understand the "neural basis of consciousness." To this end, and as an initial step, Crick and Koch proposed that the scientific community should work to isolate the neural correlates of consciousness (NCC).

Following Crick and Koch's suggestion, the overarching goal of this study is to better isolate potential NCC from closely related cognitive processes. Before approaching these issues empirically, however, we need to address a few fundamental questions: what precisely is consciousness and what exactly are NCC?

What is consciousness?

If one reads the current literature on the topic, it quickly becomes apparent that consciousness has no standardized definition, both colloquially and within the formal fields involved in consciousness science. This situation is readily gleaned from explicit statements of this fact (Weise, 2018; Van Gulick, 2018; Nunn, 2009; Wu, 2018). For instance, the standard textbook *Consciousness: An Introduction* states on page one, "Part of the problem is that 'consciousness' has no generally accepted definition in either science or philosophy despite many attempts to define it" (Blackmore & Troscianko, 2018, p. 1). Evidence of this lack of agreement includes the use of the word "consciousness" to refer to several different phenomena or disparate aspects of the same phenomena. In 2009, Ram Vimal conducted a review in which he investigated the various meanings ascribed to consciousness in recent literature, scientific and otherwise, from Eastern and Western schools. He was able to draft a "by no means exhaustive" list of 40 relevant and relatively distinct definitions in use (Vimal, 2009). Wiese (2018) and Van Gulick (2018) cite the presence of fierce debates about seemingly fundamental aspects of consciousness (phenomenal consciousness vs. access consciousness, levels of consciousness, the distinction between conscious and unconscious perception) as additional inferential evidence that there exists little consensus within the field. Wiese concludes that "consciousness is not a unitary concept" (2018).

This lack of a standardized definition, however, is not necessarily seen as an immediate problem by all scholars in the field. For example, Crick and Koch in their previously mentioned call to arms decided against formulating a conclusive definition because of the relative nascency of the field and its evolving knowledge. To them, attempting a definition would be premature and would lead to a notion that is "either misleading or overly restrictive, or both" (Crick & Koch, 1990). In contrast, they reorient the reader back towards one's own intuitions and folk theories by emphasizing that "everyone has a rough idea of what is meant by consciousness." Presumably, that "rough idea" is broad enough to effectively include and help one navigate the varied aspects of consciousness presented in scientific studies. The issue here is that Crick and Koch avoid explicitly defining consciousness, although they proceed to suggest a potential NCC for visual awareness, the operationalization and logic of which implicitly contains their ideas of consciousness and NCC. In our view, the two operations are not mutually exclusive. To state one's underlying rationale is however important, otherwise the enterprise will lack clarity. If researchers do not offer precise details on their approaches to consciousness, those details will eventually have to be decoded by readers who wish to reach a better understanding. Chalmers (2000) did exactly that as he tried to make sense of Crick and Koch's article.

In agreement with Vimal (2009), the stance taken here is that failing to define one's personal use of consciousness and NCC will only lead to more gaps in knowledge among researchers. Moreover, without presenting explicit definitions, the field will have difficulties working on the same set of issues and achieving results. This being said, at this initial stage we will refrain from proposing a conclusive definition, although we will employ a provisional definition. As Blackmore and Troscianko (2018) state, there is no formalized operationalization of consciousness, yet they remark, “The term is most broadly used to mean the equivalent of subjectivity or personal experience” (p. 2). A review of the field proves this assertion true, with a number of major authors and papers drawing on similar conceptions (Block, 1995; Boly et al., 2017; Chalmers, 2000; Koch, 2018). For philosophers and researchers adopting this definition, it is also very common to employ the expression “what it is like” to describe their understanding of consciousness. In 1974 Thomas Nagel coined this now famous phrase to address the personal experience of being conscious (Nagel, 1974). Consciousness is “what it is like” to experience the cold of snow or the sight of a blue sky, for example. In this sense, this notion of consciousness appears to overlap with folk conceptions of consciousness that emphasize first-person experiencing. In this research project we will provisionally employ this definition of consciousness.

What are the neural correlates of consciousness?

David Chalmers formally defined the NCC as “a minimal neural system N such that there is a mapping from states of N to states of consciousness, where a given state of N is sufficient, under conditions C, for the corresponding state of consciousness” (Chalmers, 2000). In Chalmers’s statement, the minimally sufficient criterion works to cleave off irrelevant neural systems, specifically overestimations of the NCC. In this way, one can isolate the NCC from extra-cognitive processes, such as short-term memory or conceptual labeling, for example, that might get activated consistently in response to certain stimuli, but are not minimally sufficient or relevant for conscious perception of those stimuli. Similarly, one might be able to separate the NCC from “background conditions” (Boly et al., 2017; Koch et al., 2016) – such as proper cell hydration, oxygen flow, and others – that are clearly necessary for any proper functioning of the brain, but that by themselves are not sufficient for conscious precepts. The separation of the NCC from background conditions can be achieved by omitting to declaring those conditions as a “necessary” criterion for the NCC.

By crafting his definition, Chalmers aimed at a general notion that could be modified to target various levels of specificity in regards to the NCC, depending on the particular focus of the research. According to Chalmers, consciousness studies tend to concentrate on a range of specificities: A) the general neural correlate of consciousness vs. unconsciousness, or B) more specific types of sensory awareness, such as auditory and visual consciousness, or C) the most fine-grained type of conscious experience, that is, a specific conscious precept, such as a specific face or house. It is the latter and the most-specific version of the NCC – termed the neural correlates of conscious content – that will be the focus of the current investigation, particularly the NCC for specific visual stimuli. Thus the definition we employ here is the one Chalmers modified from his original version, "An NCC (for content) is a minimal neural representational system N such that representation of a content in N is sufficient, under conditions C, for representation of that content in consciousness" (Chalmers, 2000).

Why correlates and not causes? The "hard problem" of consciousness

Why, one might wonder, are we speaking about investigating the neural correlates instead of the neural causes of consciousness? Would it not make more sense to aim directly at the causal mechanisms behind consciousness in order to explain the phenomenon, as is standard in the scientific community?

There are essentially two reasons for this distinction. First, it is difficult to directly manipulate the neural circuits in question to establish causality in humans, as this requires direct access to the brain. As a consequence, neuroscience research in humans often relies on methods that do not causally affect the brain, such as EEG, which is employed here, MEG, and fMRI. All these methods involve manipulating behavior or external stimuli and then observing correlations between sensory inputs or motor outputs and the measured neural activity patterns. Due to less stringent ethical codes, animal research commonly employs direct manipulation of the brain. The data from this research, however, is limited, since at present scientists cannot communicate with animals, thus making it difficult to gauge whether or not manipulation alters the animal's conscious experience, or if animals have consciousness at all.

Second, even studies that involve direct manipulation of the brain with electric stimulation and that then appear to give rise to conscious precepts are criticized as not presenting sufficient evidence for the neural system in question to be considered a cause of the conscious content. Schalk et al. (2017) offer one example. Their research found that stimulating the "color-preferring region" (hV4 and V4α) gave rise to rainbow-like patterns, while stimulating the fusiform face area gave rise to the appearance of parts of faces and face distortions. But within these types of experimental paradigms, it is difficult to ensure that stimulating one region of the brain electrically will not trigger downstream brain activity that then gives rise to consciousness.

A more fundamental issue is that it does not seem intuitive or evident how and why consciousness arises from seemingly unconscious matter or, phrased differently, how one can relate one's subjective private experience of the phenomenal world to the experimental and quantifiable world of objective phenomena. This view of the explanatory gap between the NCC and conscious precepts has been elevated by Chalmers, who coined it the "hard problem" of consciousness (Chalmers, 1995). Philosopher Nagel states on the topic, "It is a phenomenon quite unlike any other in the physical world, and, if nothing else, even imagining a way in which it might possibly be explained is difficult" (Nagel, 1974). This issue of the hard problem is not only relevant at the level of folk intuition, but also has a logical basis.

Since we cannot directly measure subjective experience, we must depend on external indicators. These external criteria, however, are not experimentally determined, because we do not have experimental entrance to the independent variable, that is, consciousness. Therefore, it is not possible to understand whether external measurements reliably capture the same construct as consciousness. As Chalmers notes, relying on these external criteria involves taking an "epistemological leap." Because the external criteria have not been experimentally connected to consciousness, a neural system that is correlated to external criteria cannot conclusively be said to be a correlate of consciousness (Chalmers, 2000).

There are differing opinions on how tractable this hard problem truly is. Some believe that, even if we were to understand the entirety of the nervous system and all of its mechanics, the hard problem would still not be resolved (Nagel, 1974). Others, such as Crick and Koch (1990), simply "believe that the problem of consciousness can, in the long run, be solved only by explanations at the neural level." To them there appears to be no hard problem.

In this research, we do not take a position on whether the hard problem will ultimately be resolved through neural explanations. However, we do think that the exploration of the potential neural substrate of consciousness should be continued, as it *might* lead to a resolution of the hard problem, even though it currently appears as if we are missing an extra explanatory step for achieving this goal.

The frontal debate and theories of consciousness

In the field of consciousness, many propositional theoretical models have arisen that differ over which domains of the brain and what types of neural activity constitute the NCC. The theories can be classified into three subcategories depending on their predictions whether 1) the neural activity is based around sensory-processing neocortical areas in the temporal and occipital cortices, or 2) the activity occurs within the frontal and prefrontal cortical regions that is related to higher-order cognition, or 3) aspects of both. Essentially the predictions are based on how much their theoretical conceptualizations integrate cognition with consciousness as a core dimension. It is this critical issue of contention that our research will investigate further. This debate has been termed both the prefrontal debate and the debate between cognitive vs. non-cognitive (sensory) theories of consciousness. Two quintessential articles that review and summarize this debate are Boly et al. (2017) and Odegaard, Knight, & Lau (2017).

In her review, Boly et al. (2017), makes the claim that frontal regions, especially the prefrontal cortex (PFC), are not necessary for basic sensory consciousness. She backs her claim by citing different neuropsychological studies, some of which involve widespread prefrontal lesions while consciousness is maintained, and others in which electric stimulation to posterior zones caused changes in conscious content by inducing distortions and hallucinations, while stimulation to the PFC did not. There are also no-report studies appearing to show that some previously identified frontal activity in consciousness research is actually not part of the NCC, but is related to additional cognitive processes involved in performing the reporting task. Finally, there are meta-analyses that point to content-specific NCCs being located in posterior zones. In contrast to Boly et al., Odegaard et al. argue for frontal regions being necessary for consciousness. They assert that PFC lesions indeed affect subjective perception, that PFC activity does reflect specific perceptual content when analyzed with more powerful imaging and analysis, and that PFC involvement in studies of perceptual awareness is not solely driven by cognition required by tasks.

Two prominent theories of consciousness that uphold divergent positions on the relevance of frontal regions to sensory consciousness are Integrated Information Theory (IIT), which does not hypothesize that activity in frontal cortical regions are NCC for basic perception, and Global Neuronal Workspace Theory (GNWT), which posits key nodes in prefrontal cortex as part of essential neural networks supporting every conscious experience (Dehaene, Lau, & Kouider, 2017).

IIT derives its axioms about consciousness from the essential properties of phenomenal experience, from which it then extrapolates the requirements for the physical substrate of consciousness. Based upon its axioms, IIT proposes that the physical substrate must have a maximum of intrinsic cause and effect power and must be structured, specific, integrated, and exclusive (Tononi et al., 2016). This approach is unlike most theories that use cognitive psychology and experimental data as their starting points. IIT is also unique in that it provides a mathematical framework for evaluating the amount of consciousness within a system. From its rather abstract axioms, IIT derives postulates that allow one to make real-world predictions about the NCC that can be tested. These predictions include that posterior areas of the brain are sufficient for experience, that activation patterns in the brain are continuous and content specific, that synchrony of neural firing for consciousness is between high- and low-level sensory areas, and that decoding of conscious content is most accurate when analyzing data from posterior regions. IIT focuses on the posterior cortices because they possess a grid-like structure that allows for maximal cause-effect power, compared to the more random connectivity within regions such as the PFC.

From the above discussion, it is evident that IIT does not consider the PFC to be necessary or sufficient for consciousness. This is because IIT does not consider higher-order cognition as being necessary for consciousness.

GNWT, as described in Dehaene et al. (2017), states that what is commonly termed consciousness actually comprises two types of information-processing computations. One computation consists in making sensory information globally available, so that the information can be accessed and responded to by cognitive and motor systems. The second is the reflexive reviewing of these computations, so that there is a subjective sense of certainty or error. While these theoretical notions immediately convey that for GNWT consciousness is deeply intertwined with cognition and computation, they also indicate that the variety of predictions about the NCC that GNWT makes are in direct opposition to the IIT model.

From this conceptual framework, GNWT makes a variety of predictions about the NCC that are in direct opposition to IIT. These predictions include: activations of the frontal cortices that control cognitive processes necessary for experience; conscious content being decodable from frontal cortices; synchrony between the frontal cortices and high-level sensory areas during conscious experience; and the temporal dynamics of neural activity for conscious content are from 300 to 600 ms (Dehaene et al., 2011).

No-report and no-cognition paradigms

A potentially powerful tool to address the conflict between IIT's and GNWT's predictions – whether certain frontal cortical activity is related to cognition and conscious perception or only cognition – is "no-report" or "no-cognition" paradigms. As stated above, and reviewed in Boly et al. (2017), mounting evidence from no-report studies appears to show that some frontal activities, previously believed to be NCC, are instead part of supplementary cognitive operations related to performing a task.

In this study we endorse the viewpoint that some proposed frontal NCC are overestimations due to cognitive processing provoked by the research methodology. By subscribing to this view we do not imply that there is no activity in frontal regions that might be identified as an NCC. We only suggest that a degree of the brain activity – previously cited in empirical studies – might index post-perceptual task-related cognition rather than processes related to consciousness per se. This is because not all types of frontal activity can be identified with EEG. Thus, there may still be other activity within the frontal cortices that are NCCs.

Researchers in consciousness studies generally need to know if an experiment participant was aware of a stimulus or not. A common and effective way to ascertain this information is by having participants report whether they were aware of the stimulus. Unfortunately, in order to report what one is aware of, participants must use a number of additional cognitive systems, such as categorizing if a stimulus is relevant for a response, holding the response in short term memory, and preparing motor systems to implement the response. Thus, the activity related to cognition and performing the task becomes consistently entangled with the neural response related to consciously perceiving the stimuli, causing researchers to overestimate the neural correlates of consciousness.

To resolve this problem, no-report paradigms have been developed by a number of research groups. In certain contexts, it has been found that conscious contents can be accurately predicted from physiological measures, such as eye movements in binocular rivalry paradigms, for example. Binocular rivalry involves presenting a different image to each eye in the same retinal spot, but unintuitively the images do not blend together to create a sum. Instead, they act as rivals vying for access to awareness. By measuring eye movements during a report condition, it was found that eye movements are highly correlated with whichever image is conscious. For example, if one presents an image moving left and an image moving right in a binocular rivalry experiment, participants will first be aware of and follow the leftward moving object, then the rightward, and then back to the left (Safavi et al., 2014). Thus, knowing that the eyes correlate with conscious perception, one is able to remove the report condition from the methods.

Previously, researchers discovered that during report-based binocular rivalry experiments the contents within awareness were correlated to activity within the frontal, prefrontal, and occipital cortices. After the development of the no-report version, however, the situation became less clear. As Block (2019) details, some no-report binocular rivalry studies using fMRI did not find the PFC to be correlated with phenomenal content, while a study that was able to insert electrodes into the cortex of monkeys found the opposite (cite papers here). These conflicting results have been interpreted as potentially deriving from the more sensitive nature of intracranial electrodes as opposed to fMRI. As mentioned previously, Odegaard et al. (2017) also argue that current brain imaging and functional mapping methods are not sensitive enough to capture the neural activity in the frontal cortex that can be correlated to conscious content.

Seeking better clarity, Block (2019) calls for the field to focus on the creation of no-cognition paradigms, as well as presenting his own modification of a binocular rivalry experiment for this task. Independently from Block, we also formulated the idea of using a no-cognition paradigms in order to isolate the NCC from potential cognitive processing, building off of the gnawing feeling that participants may still be cognitively reacting to the stimuli, at least minimally, even in no-report paradigms.

The original idea behind the current study was to seek out advanced meditators in order to have a population that could reliably enter into a mental state in which there is little to no conceptual proliferation in reaction to the presentation of stimuli. Using electroencephalogy, the brain activity of these specialized meditators would then be compared to a non-meditator control group, which would also be presented with the same stimuli. Additionally, both groups would take part in a task condition in which they must respond to the stimuli, thus making the stimuli task relevant and likely to include post-perceptual cognition. This novel approach is one of the first no-cognition experiments attempted and the first to experimentally test and investigate meditators' ability to prevent cognitive reactions to stimuli.

Meditation techniques and no-cognition

Attempting a formalized definition of "meditation" confronts difficulties similar to the ones we discussed when addressing definitions of "consciousness," and for many of the same reasons. To begin with, the word "meditation" is prescientific and has been loosely used to denote a wide variety of phenomena and practices from a broad array of traditions that are often seemingly at odds with each other. Prior to the mainstream introduction into the West of meditative practices imported from the Eastern world, the meaning of "meditation" was derived from the old French word "meditacion," which means "thought, reflection, study" (*Online Etymological Dictionary*, n.d.). This meaning is diametrically opposed to some of the actual practice of meditation, which does not presume reasoning. Currently, in the wake of the movements of spiritual seekers in the 1960s and 1970s as well as more recent trends of pop-mindfulness, mainstream ideas of meditation follow this line of meaning: meditation implies training one's attention while seeking to avoid discursive thought for the purposes of tranquility and compassion.

Within the domain of neuroscience research, investigators have sought to formalize categories for relatively distinct meditative practices. Standard models comprise "focused attention" (FA) (which is characterized by the "cognitive focus and re-focus of attention toward a particular mental object") and "open monitoring" (OM)(which is characterized by "nonreactive monitoring of the content of experience from moment to moment, with a calm awareness of any thoughts or sensations"), later also adding "automatic self-transcending" (Berman et al., 2015, p.2; Raffone et al., 2010; Travis et al.; 2010) Although these categories are a helpful first step, they fail to capture degrees of nuances present within each meditative practice. Also, they neglect to account for all practices that do not fit within the above bounds. Ultimately they are unable to recognize that meditative practices cannot be seen as isolated, solitary instances to be studied in a lab, but are instead inseparable from broader spiritual views and goals as well as from one's own ideas of how to live one's life and conduct oneself outside of formal meditative practice. That being said, in order to retain a degree of standardization and thus comparability of data, we will adopt "automatic self-transcending" (ATS) as the definition closest to the meditative techniques we are interested in testing. ATS involves techniques “designed to transcend their own activity,” which means that the techniques being employed should extinguish the very effort that initiated them, thus leading the meditator to transcend spiritual effort while experiencing uncontrived rest. Technically, practices placed in the categories of FA and OM can also lead to their own transcendence. However, the definition of ATS appears to make transcendence more immediate.

In considering extra-cognitive processing of sensory stimuli, our research aimed to exploit the unique capacity of meditation to lead to states of little-to-no cognition. Our initial plan involved having meditators enter into a state in which there was absolutely no cognition or conceptuality. The issue here is that this level of no-cognition cannot be directly attempted through effort, as this effort itself serves to stir up the self-perpetuating motion of seeking and grasping, both of which involve cognition. Additionally, it is not possible to recognize that one is in a state of no-cognition while it is occurring, as some level of cognition is required for such a reflexive recognition to arise, thus one can only infer in retrospect that one entered that state.

Because of these theoretical and objective constraints, the feasibility of studying such extreme states in the lab came in doubt. (Some of these concerns were also raised by meditators during the experimental design phase of this project.) We quickly realized that our original goals were too ambitious; the population of skilled meditators who might be able to achieve such states was too limited for an undergraduate thesis. Therefore, a more attainable goal was formulated in our research design. We would ask meditators to rest in a state of non-proliferation of thought about the stimuli being presented, as opposed to requiring absolutely no cognition. Ideally, meditators in this state would not conceptually label the stimuli, or hold the stimuli in working memory, or think about the stimuli. Instead, they would simply view the stimuli with basic sensory perception. The mediators would sense the visual input without reactivity when the stimuli appeared and disappeared, thus enabling the parsing of basic perception from extra-cognitive factors. This criterion served as our working definition of the aspect of meditation that we were investigating. This type of meditation fits within the ATS categorization more than FA or OM, because it does not involve continuous concentrative focus on a single object and does not require reflexive monitoring or allow for thought such as in OM.

Initially it was decided only to pool participants from the Zen traditions of Buddhism. This was not because we believe that Zen practitioners are more capable than those from other traditions. Practical concerns regarding the ease of recruitment guided our decision along with the desire to increase standardization by limiting any confounding variables across different spiritual traditions. As we proceeded with our research, however, this criterion had to be relaxed to encompass all of Buddhism, since it was difficult to find a sufficient number of participants at Zen centers only.

As a word of caution, we should emphasize that the overall soteriological goal of Buddhism is not to eliminate thought completely, and that meditators do not usually train for this type of ability purposefully. Our intention in eliciting exotic states of consciousness was the belief that this artificial condition would nevertheless help us analyze more typical aspects of perception and cognition. As the greatly esteemed Sixth Patriarch of Chan Buddhism, Huineng, cuttingly stated, “There is also a class of foolish people who sit quietly and try to keep their mind blank. They refrain from thinking of anything and call themselves ‘great.’ On account of their heretical view one can hardly talk to them” (Chan, 2017).

Neuroscience research into these matters has investigated meditation along these lines. The study “‘Thinking about Not-Thinking’: Neural Correlates of Conceptual Processing during Zen Meditation” (Pagnoni et al. 2008) tasked Zen meditators and non-meditative controls with meditating on their breath. During the meditation, a lexical decision-task of actual vs. made-up words was distributed throughout in order to check whether meditative practices enable meditators to dampen distracting cascades of conceptualization when presented with stimuli. Answers were quantified by monitoring with fMRI the activity of brain regions that were proposed to be part of the default mode network (DMN). (The DMN has been identified as being correlated with cognitive mind wandering when not engaged in a task. Many of the DMN regions related to automatic distracting thinking are found in the PFC.) The results of the study endorsed the researchers’ prediction that practicing meditation allows for increased ability to control spontaneous mental activity. Neurally, when compared to controls, meditators demonstrated a reduction of the continued automatic semantic processing that followed answering the questions, as shown by reduced blood oxygenation in regions proposed to be part of the DMN. This study provides an experimental basis for the notion that meditation can help attenuate the automatic cascade of conceptual associations related to a stimulus. Our research, however, will be going a step further. We are looking to prevent as much conceptualization as possible in reaction to the stimuli, in contrast to simply reducing cognition after an initial distraction.

Electroencephalography (EEG) and ERPs

This experiment used electroencephalography (EEG) in order to investigate the neural correlates of consciousness. EEG is a method that monitors electrical activity in the brain by placing electrodes on the scalp. These electrodes passively collect changes in voltage over time from aggregates of neurons. The resulting electrical measurements are then called the electroencephalogram (Luck, 2014).

At each electrode location, the electrical potential will produce a distinct waveform. The waveform is composed of the neural responses related to particular sensory, motor, and cognitive events, along with electrical noise produced by parts of the body beyond the brain and external appliances. Because the EEG consists of this jumbled aggregation of activity coming from many sources, it is complicated to separate out specific neural responses. Hence, in many cases EEG is a rough assessment of neural activity and is not employable in its unrefined state to quantify many of the brain's very specialized neural operations. Nonetheless, it is feasible to distill some neural responses out of the whole EEG through the use of basic averaging algorithms along with other techniques. Through averaging, voltage unrelated to the stimulus neutralizes itself, while neural responses directly related to the stimulus event persist. These consistent neural responses are termed event-related potentials (ERP) to highlight that they consist of electrical potentials in response to an event (Luck et al., 2012).

In the vast majority of incidences, ERPs are the product of postsynaptic potentials (PSPs) that are generated from neurotransmitters attaching to receptors, and thereby altering the movement of ions across the postsynaptic membrane. This ion flow produces a microscopic electrical dipole. As an individual neuron's PSP is microscopic, only when dipoles from hundreds upon hundreds of equivalently aligned neurons are added simultaneously can one measure ERP waveforms. When the region's neurons are not aligned, their dipoles will neutralize and distort each other. Eventually, these summated dipoles – when collected and processed – create ERP waveforms that are made up of voltage peaks, waves, and components.

An ERP component is a distinct intracranial emitter of voltage produced by a particular neurological process. We may pay attention to the crests of the waves, but these peaks often do not reflect the individual ERP component, because waveforms are usually composed of multiple components.

The specific ERP component that will be used in this research is the P3b.

P3b

The P3b is a subcomponent of the P300 ERP. The P300 ERP was thus named because it was found to peak in the positive direction around 300 ms post-stimulus in the original study (Chapman et al., 1964). Later studies, however, tend to report that it arises between 350–600 ms. The exact function of the P300 is not ascertained, but we know that it is highly sensitive to the probability of task-relevant stimuli (Luck, 2014; Luck et al., 2012).

Within the P300 wave, there is not only the P3b subcomponent, but also the P3a, which is more frontally prominent, while the P3b is more present across the parietal scalp. Although its scalp distribution is parietal, the P3b is known to involve generators in the frontal lobe. A number of other distinctions separate the two, but one major difference is that, while both respond to unpredicted stimuli, the P3b arises only when the stimuli are task relevant.

Our reasoning for investigating the P3b is that, as Michael Cohen et al. (2020) argue, it constitutes "the largest and most replicable piece of neural evidence cited by cognitive theories as an NCC." The prior mentioned GNWT, in fact, makes the specific prediction that the P3b is a signature of global broadcasting that leads to consciousness. A number of recent no-report studies, however, have reported the P3b's complete disappearance. Unfortunately, these experiments have been subjected to methodological criticisms. These elements make the P3b a good candidate for parsing the claims of cognitive versus sensory theories of consciousness (Pitts et al., 2014, Cohen et al. 2020). One example of these no-report studies is Michael Cohen et al. (2020), which found that the P3b was not present for unseen stimuli or for task-irrelevant stimuli. This suggests the P3b may not be a neural correlate of consciousness, but instead a neural correlate of a cognitive process related to reporting.

Decoding

A recent type of analysis that has become increasingly popular due to improvements in computer technology is decoding. The aim of decoding methodology is to assess if a machine-learning algorithm can at above-chance levels predict the content of which a person is aware based solely on patterns of their neural activity. Successful decoding provides powerful evidence that the neural activity being investigated is a potential NCC, as opposed to being a content-free support process. Decoding attempts to answer whether the neural signal contains information about the condition, while standard analysis considers whether ERPs are distinct from each other depending on the various conditions (Grootswager et al., 2017; Bae et al., 2018).

The procedure for decoding entails training a classifier algorithm (using a subset of the total data) to link brain activation patterns to stimuli or experimental conditions. In the next stage, the classifier employs the residual data to test if it can accurately predict the experimental conditions, as a quantification of how distinct the scalp voltage distributions are for each condition.

Decoding can also be deployed to assess the temporal dynamics of the mental processing of visual stimuli and object categories. We followed this type of decoding assessment, and used the entire scalp's data to test the time course, as opposed to investigating whether a singular neural component represents conscious content.

The purpose of our analysis is to analyze the differences in cognitive activity between a mediator group and a control group and between task and no-task conditions in regards to the specific stimuli, as will be discussed in more detail below.

Analyzing the time course of decodability also allows us to test a previously mentioned prediction of the cognitively-based theory of conscious GNWT, which proposes that the temporal dynamics of consciousness occur ~300–600 ms post-stimulus.

Outline and rationale of the experiment

To test if the P3b is a neural correlate of consciousness, if decoding follows the same time course as was suggested by GNWT, and if meditative practice leads to the attenuation of cognition, we developed the following experimental methodology.

Our intention was to recruit approximately 25 advanced Buddhist meditators and 25 age and sex-matched controls with minimal meditative experience. These initial goals were relaxed to 12 participants in each group and sex and age matching was dispensed due to general recruiting difficulties.

Creating the sample criteria for advanced meditators posed a challenge. We sought to ensure that participants were qualified and could access the mental state that was requested. This is difficult to evaluate, however, because one cannot access another's first-person experience, and this is already an esoteric subject. Thus we employed a number of checks and balances. The initial recruitment step was to describe the state of non-proliferation that we are aiming for, and then directly ask meditators whether or not they felt they could manage such a task. The second step was that they must meet the demographics' criteria: they must have meditated consistently at least one hour daily on average for more than five years. The final check occurred when answering the questionnaire after the no-task condition, which assessed if the meditators were consistently able to enter the requested state. This questionnaire will be discussed more below.

The criteria for the controls was more simple to define. It consisted of never having taken a class on meditation, never having gone on a yoga or meditation retreat, never having meditated consistently for more than a week, and only having done less than 10 hours of meditation in the last five years.

These participants would then be taken through first a no-task and then task condition. Within both conditions, stimuli were flashed at the center of a screen. These stimuli consisted of the faces of the past four presidents, Gabor patches, and blank squares. The presidential faces were chosen as they are highly recognizable for the average American and carry conceptual and emotional baggage, thus posing a challenge for meditators and controls to not engage with them conceptually. In the no-task condition, both groups were instructed to maintain a relatively quiet mind, however, meditators were additionally instructed to enter the prior mentioned state of non-proliferation. The blank squares were used as a reference stimulus and the Gabor patches as a stimulus that does not have many prior associations.

Immediately after the no-task condition, two types of memory tests were performed. First, we administered a written free-recall memory test, which assessed the degree of recall detail to make sure the meditators had truly seen the stimuli, as opposed to withdrawing inward and blocking out the world.

Next was the recognition memory test, whose purpose was varied. It was employed because we were concerned that the meditators would not be able to explicitly remember the stimuli if they were in a non-cognitive state, but that a forced-choice recognition test might elucidate unconscious learning. Thus, if the meditators systematically failed the free recall but still performed highly on the recognition test, this could be evidence that a lack of explicit memory was due to participants not conceptually interacting with the stimuli, as opposed to withdrawing their senses. Additionally we performed this test out of curiosity, seeking to learn if the groups would differentially recall the stimuli.

Next a questionnaire was given that gauged if the participants were able to prevent mind wandering and conceptualization about the stimuli, as well as the subjective experience of the participants. This was analyzed with the intention of gaining insight into the nature of this type of meditation and the phenomenal experience of the meditators, as well as allowing us to understand consciousness and cognition from another perspective, i.e., the first-person perspective, in addition to answering whether a participant's data meets the experiment's criteria.

Next, was the task condition. In this condition, both groups were tasked with categorizing the faces and Gabor patches with button presses, while ignoring the blank squares. This condition was inserted so that we could contrast the results of the no-task condition with a reference.

Hypotheses

As stated previously, this research's main aim is to investigate the neural correlates of consciousness through a novel "no-cognition" paradigm that involves advanced meditation practices. Drawing upon this no-cognition paradigm and the structured comparisons between participant groups, as well as conditions and stimuli, we make a number of predictions.

The foundational predictions for the specific experimental hypotheses is that the P3b is not a neural correlate of consciousness, but of stimulus-related cognition, and that meditation can help attenuate the automatic cascade of conceptual associations related to a stimulus.

The first hypothesis is that within the no-task condition the meditators will show little-to-no P3b activity, while the non-meditators, not being able to totally prevent the constant subtle or even explicit conceptualization about the stimuli, will show much larger amounts of neuronal activity, including the P3b.

Our second hypothesis is that during the no-task condition there will be larger amounts of P3b and extra-cognitive activity in response to the faces of the presidents within the non-meditator group and potentially some participants in the meditator group, as opposed to the

Gabor patches and blank squares, due to the conceptual and emotional baggage connected to these men.

Our third hypothesis is that the P3b will appear in both groups during the task condition. As a corollary hypothesis, we predict more P3b activity for both groups in the task condition compared to the no-task condition.

As for decoding, we hypothesize that within the no-task condition the groups of stimuli as well as individual stimuli within these groups will be decodable for longer time periods in the case of the non-meditators as compared to the meditators. This hypothesis assumes that the non-meditators will be conceptualizing the stimuli and holding them in their minds, even after the stimulus disappears. Prior evidence that content can be decodable from working memory can be found in Bae and Luck (2018).

Our fifth hypothesis proposes that within the task the stimuli will be decodable for fairly equal lengths of time between groups, as they both must perform the same stimulus-relevant task. (Although as the meditators have been practicing mindfulness diligently for many years, this may still shorten their decoding due to curbing superfluous cognitive activity.) The corollary hypothesis is that, for both participant groups, decoding will be significant for longer during the task condition compared to the no-task condition. These analyses will also help us evaluate GNWT's temporal predictions for the ignition of consciousness, however we are not predicting an outcome.

Unfortunately, due to the COVID-19 pandemic, the meditator sample was too small to be compared with the control subjects statistically. So, in the appropriate places, the participant groups were pooled together so that between condition statistical comparisons could still occur.

Chapter 2: Methods

Participants

This study tested two groups of participants: one group of advanced Buddhist meditators who could enter the requisite state of mind and one group of control participants who did not have meditative experience. Within the meditator group, we had four participants and within the control group we had 8, with the total then being 12 participants. The age range of the meditator and control groups was 34-74 and 18-23 respectively. When asked to estimate total hours meditated, meditators responded with an average of 18,000 hours. When the controls were asked to roughly calculate the total time they meditated within the last five years, the average was 1.875 hrs. Meditators also estimated the length of time they had been consistently practicing. The average was 15.33 years, with an average of 20.167 hrs of meditation per week.

The meditator group was gathered from Buddhist centers within the greater Portland area, and the non-meditative group was recruited from Reed College and the greater Portland area. IRB approval for this experiment was gained from the college in the form of an addendum for a prior federal research grant. Before beginning the experiment, all participants were informed of the general procedure and gave their consent in the form of a signature.

Stimuli

The stimuli consisted of four faces, four Gabor patches (oriented gratings), and a blank square. The four face stimuli were grayscale photographs of the past four presidents of the United States of America: William J. Clinton, George W. Bush Jr., Barack H. Obama II, and Donald J. Trump. The photographs were gathered from the official presidential portraits released by the White House, and were further edited using Adobe Photoshop. The faces were resized to 7.193 degrees of vertical visual angle, when sitting approximately 70 cm away, and positioned inside of a gray square (RGB: 128, 128, 128) of 8.008 degrees of vertical visual angle. The faces were then shifted to shades of gray by using Adobe Photoshop's grayscale feature and the luminance of the faces was equalized by averaging the luminances of all of the faces through the Matlab code SHINEtoolbox with MATLAB (Willenbockel, V., et al., 2010). Figure 2.1 shows the four face stimuli.

The four Gabor patches were made with the Cogsci Online Gabor-patch generator, as created by Sebastiaan Mathôt (Mathôt S., n.d.). The orientations of the patches were set to 30, 75, 120, and 165 degrees, and all were 94 pixels in size, with a Gaussian envelope consisting of 12 pixels of standard deviation, a frequency of 0.21 cycles/pixel, 0 pixels for phase, the same background color as for the faces, and color one set to RGB: 255, 255, 255, and color two set to all zeros. The patches were additionally shifted to shades of gray by using Adobe Photoshop's grayscale feature, and resized to match the height and width of the faces as closely as possible. The Gabor patches are provided in figure 2.2.

The blank square stimulus was simply a square of the same gray color (RGB: 128, 128, 128) and size (8.008 degrees of vertical visual angle) as the background frames containing the faces and Gabor patches.

A red fixation dot was continuously presented at the center of the screen during all task conditions.

For the recognition memory test conducted after the first half of the experiment, all of the above stimuli (besides the blank square) were presented, as well as eight additional foil faces and eight additional foil Gabor patches. The eight foil faces were split into sets of twos, with each set relating to one of the four president stimuli. Within each set, one of the faces was a novel picture of the same president at a slightly different angle and/or facial expression, while the other was conceptually or perceptually related to each president. These pictures underwent the same editing and formatting process as the original four faces. Face foil stimuli are provided below in figure 2.3.

The eight foil Gabor patches followed the same schema. For each original Gabor patch, there was one novel patch of a different orientation (0, 45, 90, and 135 degrees), as well as a version of the original Gabor patches but with zig-zagged lines instead of straight. All of these patches underwent the same edits as the originals in terms of being shifted to shades of gray by using Adobe Photoshop's grayscale feature and then being resized. The purpose of having different foil stimuli for each real stimulus was to help assess the level of detail in subjects' incidental memory for task and task-irrelevant stimuli. Foil Gabor patches are in figure 2.4 below.

Finally, the background for all conditions and trials, including the detailed memory test, was a gray screen (RGB: 102, 102, 102).

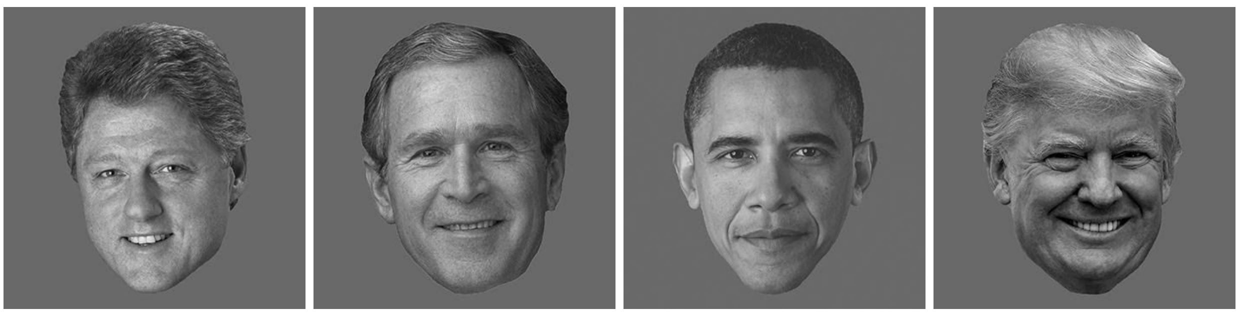

Figure 2.1: The four face stimuli used in the main experiment (not drawn to scale here)

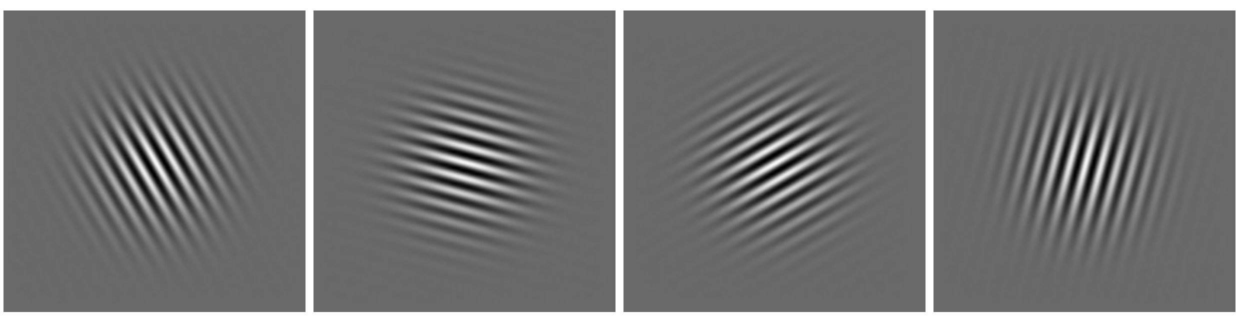

Figure 2.2: The four Gabor patches (oriented at 30, 75, 120, and 165 degrees) used in the main experiment (not drawn to scale here)

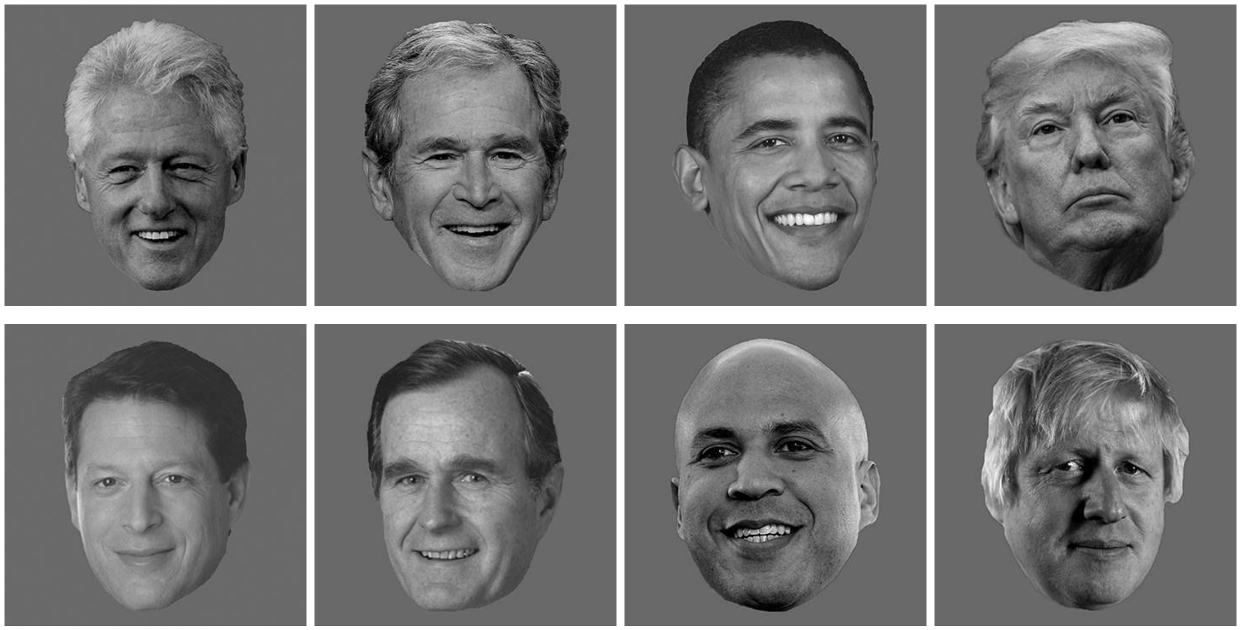

Figure 2.3: The additional foil face stimuli used in the recognition memory test

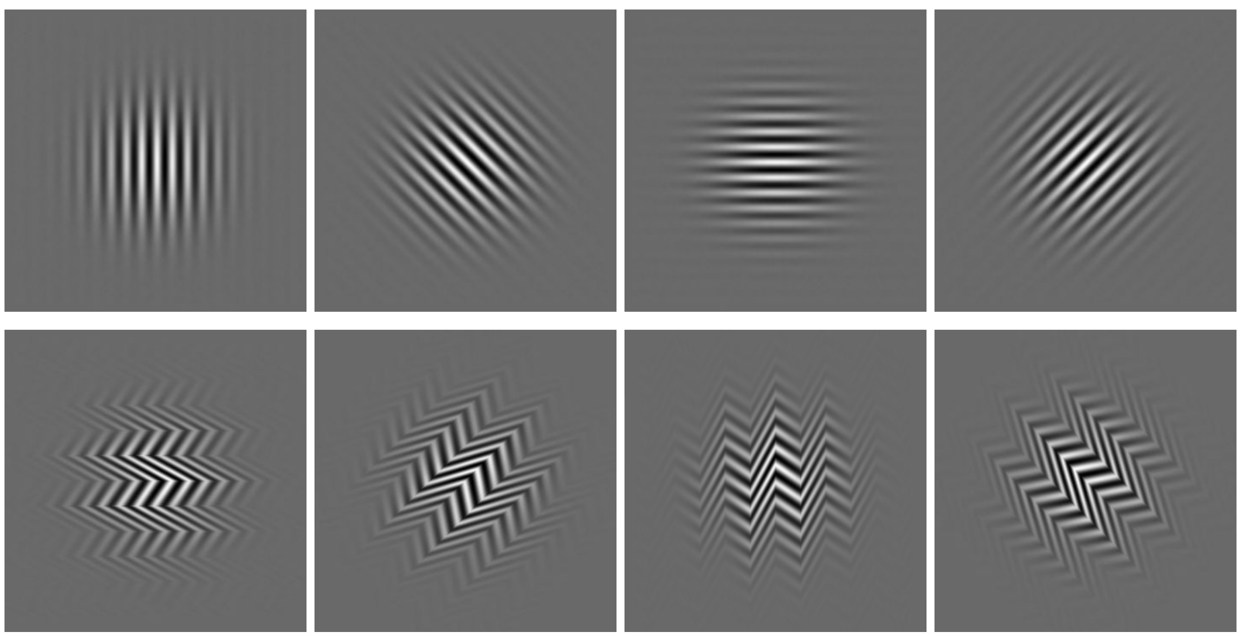

Figure 2.4: The foil Gabor patches (top: oriented at 0, 45, 90, and 135 degrees) and the zig-zagged versions of the original orientations (bottom: 30, 75, 120, and 165 degrees) used for the recognition memory test

Procedure

Before the experiment began, participants were asked to answer a few demographic questions as well as queries about their meditative experiences that were specific to their group (See appendix I).

Participants were seated approximately 70 cm away from a computer screen in an electrically shielded, acoustically attenuated booth. Using the program Presentation (Neurobehavioral Systems, Berkeley, CA), all stimuli were presented for 200 ms directly at the center of fixation, followed by a blank inter-stimulus interval. This interval had a range of 1200-1400 ms because of a randomized jittered period that lasted between 8.3 and 200 ms, but only in multiples of 8.3 ms. Before each stimulus presentation block commenced, there was a 7 second anticipatory sequence in which the fixation dot was shown.

A brief (approximately 60 s) practice session was performed in order to pre-expose subjects to the stimuli and limit any novelty-based ERPs that may be elicited towards the beginning of the experiment. A total of 36 stimuli were shown during the practice in random order – 12 faces total (3 repeats of each face) and 12 Gabor patches total (3 repeats of each patch) and 12 blank squares.

For both groups of participants, the instructions (appendix II) simply asked them to keep one's eyes on the fixation dot, while pictures were flashed on the screen, and to be aware of the pictures so that our research group may better assess their brain activity. They were also told that the specific content of the pictures was not important. Where the instructions differed between groups was that the non-meditators were asked to try and keep a quiet mind, while the meditators received an additional instruction requiring them to enter into a state of non-proliferation, within which stimuli cease to elicit cognitive reactions.

The no-task condition comprised five blocks of stimuli presentation with 30 second rest breaks between each block. Breaks consisted of a simply blank background. Within each block, there were 120 pictures shown in a randomized sequence. The 120 pictures consisted of the four faces, the four Gabor patches, and the blank frame, as mentioned above. Each individual face and Gabor patch were shown 10 times, and the blanks were shown 40 times, thus each category (face, patch, blank) was equiprobable (33%) as were each individual face and patch (8.3%). In total across the five blocks there were 600 stimuli shown, with 200 being faces, 200 being Gabor patches, and 200 being blanks, with each of the four faces and Gabor patches being shown a total of 50 times. Before the no-task condition started, the participants were instructed of the extended length of the session and of the lack of break periods.

Immediately following the no-task condition, participants from both groups were given a surprise free-recall memory test in which they were asked to describe in as much detail as they could the pictures presented during the preceding blocks of trials. Participants were given the option of writing or drawing their answers.

Once the free-recall test was completed, participants were given a recognition memory test. As stated previously, in this recognition test the four faces and four Gabors from the actual trials were interspersed with 16 other images that did not appear during the trials. The participants were instructed to indicate ‘yes’ or ‘no’ (via button box) as to whether or not they had seen the exact image on screen within the trials. All faces and all Gabor patches were presented together in separate sections of the recognition memory test. The order of presentation of the sections was counterbalanced across participants.

Following the recognition memory test, both groups received questionnaires that asked non-group and group-specific questions about the participants’ experiences in the no-task condition. For example, participants were asked “Did you feel like you clearly perceived the stimuli flashed on the screen during the experiment, regardless of whether you could remember them when tested afterward?” Also, “Were you able to consistently enter into the state that was requested? Can you describe the consistency?” (Texts of the different questionnaires are provided in appendix III).

Next, participants completed the second main phase of the experiment: the task condition. The presentation of stimuli in the task condition was identical to the no-task condition. The only differences between the task condition and the non-task condition were that participants were now instructed to press buttons to discriminate between the categories of stimuli. The task was to press one button for faces, a different button for Gabor patches, and no button for blank squares. If the participant failed to respond in time before the next stimuli appeared, they were told not to worry and simply respond to the stimuli now on the screen. Both groups were again told to have a relatively quiet mind and keep eyes at fixation. They were also informed there would be no memory test after this condition. The meditator group had one additional line of instruction stating that they should not enter into any special states, such as in the no-task condition. (See the instructions in appendix IV.) Button assignments were counterbalanced across participants. Before the main phase of the task condition, the participants were made to do a practice trial for this section that was identical to the previous practice program, except for the pressing of buttons. Following this phase, the actual task condition commenced, which had a total of 600 stimuli like in the no-task condition. It also had the same formatting as the no-task condition. The experiment ended after this phase.

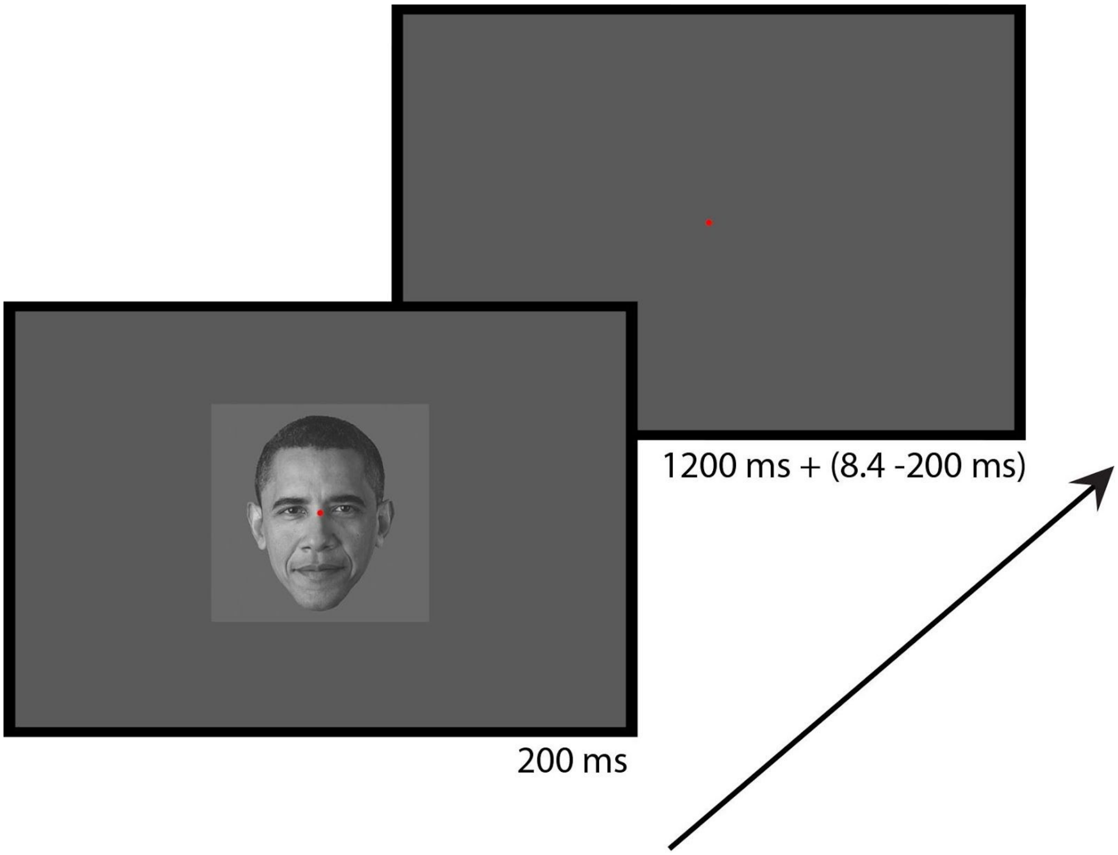

Figure 2.5: This figure shows the general sequencing of the stimulus presentation. Stimulus duration was always 200 ms, followed by a variable inter-stimulus interval of 1200-1400 ms.

EEG recording

This experiment used a custom made EasyCap 64-electrode cap (Brain Products, Garching, Germany). Of the 64 electrodes, one electrode, the vertical electrooculogram, was placed underneath the left eye for the purpose of logging eye-blink artifacts. Another two electrodes – the horizontal electrooculograms – were situated horizontally next to each eye in order to log horizontal eye movement artifacts. Finally, one electrode was placed on the left mastoid and an electrode for online referencing was placed on the right mastoid of the participant. Impedance levels were kept below 5 kΩ. Data was acquired at a 500 Hz sampling rate, amplified by 2 x 32 channel Brain Amp Standard amplifiers (Brain Products, Garching, Germany) and filtered with a 0.1 Hz high-pass, and 150 Hz low-pass hardware filter.

Questionnaires

Questionnaires were given to the participants after the no-task condition. Based on the answers to questions 4, 5, and 6 (see appendix 3), the ability of meditators to dampen cognitive reactions was assessed. If any of the meditators stated that they were not consistently able to enter into a state in which they did not conceptually react to the stimuli, their results were excluded from the main EEG analysis.

Questionnaires were also used to address the phenomenal experience of this type of meditation and its practice. They investigated the subject from multiple angles beyond the more immediate goals of the experiment. Interesting and trend-characterizing responses from these questionnaires will be highlighted in a separate section at the end of the results.

Memory tests

Free recall responses were assessed as pass or fail. Passing involved at least minimally detailing the categories of stimuli (faces, Gabor patches, blanks). If one failed, their data would be excluded from further analysis.

The scores for the recognition memory test were calculated for each participant. The grand mean, standard deviation, and range for total number of correct responses to face stimuli and Gabor stimuli for the meditator group, the control group, and the combination of both groups were assessed in STATA (StataCorp, College Station, TX).

Behavioral data from task condition

For each participant in the task condition, correct responses, false responses, no responses, and average response times for each stimulus category were logged and calculated.

The grand mean, standard deviation, and range for each of these measures for the meditator group, the control group, and the combination of both groups were calculated in STATA.

EEG pre-processing pipeline

For the EEG data, the program BrainVision Analyzer Software (Brain Products, Garching, Germany) was used for pre-processing. The first step in the analysis was to reject any no-response or incorrect-response trials from the task condition. Next, the data was segmented into the main conditions of interest (faces, patches, blanks, in the no-task and task conditions) and epoched from -200 ms before stimulus onset to 1000 ms after. A high cutoff filter of 25 Hz was applied. After this, trials containing muscle artifacts such as eye movements, blinks, muscle clenching, yawns, etc. were semi-automatically removed (by applying automatic peak-to-peak amplitude thresholds and visually inspecting the results, and then adjusting the thresholds if necessary). The ERPs were then averaged within each condition, and baseline corrected from -200 to 0 ms. At this point, the relatively clean averaged ERPs were re-referenced to the average of all electrodes. Finally, grand averages were made for data visualization purposes.

ERP statistics

Unfortunately, due to the small number of participants within the meditator group, our originally planned comparison of P3b ERP amplitudes across participant groups was no longer statistically appropriate. Instead, these between group comparisons were performed in a more exploratory way that involved visually inspecting the ERP differences as opposed to a proper statistical analysis.

Although between-subjects comparisons of the P3b were not statistically feasible, within-subject measures were statistically valid when pooling all the participants into one group. For these statistical tests, the P3b was quantified by taking the mean voltage from 300–600 ms from electrodes 1, 4, 5, 6, 12, 13, 14, 15, 16 in the vicinity of channel CPz, as this is the region used in many past studies, including our own lab, to measure the P3b effectively (Cohen et al., 2020). STATA was used to run a 2x3 repeated measures ANOVA with condition (task, no task) and stimulus (blank, Gabor, face) as the within-subject variables in order to assess whether the P3b was present in the task condition, but attenuated or absent in the no-task condition.

EEG decoding pre-processing pipeline

For decoding analyses, the EEG data was again preprocessed with the program BrainVision Analyzer Software. First the data was re-referenced using the average of both left and right mastoid electrodes and then filtered using a high cutoff of 80 Hz. Next the data was baseline corrected from -200 ms to 0 ms. After this, trials containing muscle artifacts such as eye movements, blinks, muscle clenching, yawns, etc. were semi-automatically removed. The data was subsequently filtered with 112.5 Hz, 24dB/oct, high-cutoff filter and downsampled from 500 Hz to 250 Hz. ERPs were then segmented so that each ERP file ranged from -900 ms before stimulus onset to 1300 ms after stimulus onset. ERPs were then pooled into decoding groups based on condition and comparison, and subsequently averaged.

Decoding

For decoding, our planned comparisons were structured to assess our previously stated hypotheses. This partially involved comparing decoding accuracy between participant groups. Due to the small sample size within the meditator group, the original planned analysis had low statistical power, so again it was decided to pool all participants and compare decoding between categories of stimuli and between individual stimuli of the same type within a single task condition.

The first analysis assessed if the machine-learning algorithm could distinguish between faces and Gabor patches in a single condition at levels significantly above chance. As the decoder is only tasked to discriminate between two categories, chance decoding accuracy is 50%. The second analysis evaluated decoding between individual stimuli within a stimulus category within a single task-condition. Chance decoding accuracy was 25% because there were four faces and four Gabor patches.

For decoding, the data was further processed using a low pass 20 Hz filter, and the time zone selected was -300 ms pre-stimulus to 1296 ms post-stimulus, at 20 ms intervals. For the first analysis, the number of iterations employed were 10 and blocks were 7, while for the second the number of iterations were 10 and blocks 3.

The statistics were then performed on the time region of 0 ms to 1296 for a total of 10,000 permutations. These results were then plotted using 80 time points.

The MATLAB toolboxes used during decoding analysis for formatting, decoding, statistics, and plotting were from Bae & Luck, 2018.

Chapter 3: Results

Questionnaires

After reviewing the answers to questions 4, 5, and 6, all participants passed the exclusion criteria except for one meditator. In response to question 6: Were you able to consistently enter into the state that was requested? Can you describe the consistency? this person stated, “I think so to a degree. More consistently towards the end.” This is regarded as a fail, as the participant was inconsistent in achieving the targeted state. However, due to low sample size, data from this participant was analyzed.

Memory tests

The purpose of the free recall memory test was to make sure that the meditators did not withdraw internally in order to suppress reactive cognition about the stimuli. These tests were simply assessed as pass or fail based on whether the participant could name the categories of stimuli presented. All participants performed adequately enough to pass.

For the recognition memory test, the main results for meditators, non-meditators, and a pooled group of the two were:

Table 1: Percentage of total faces correct ($\frac{\textit{correct hit} + \textit{correct rejection}}{12}$)

	Meditators	Controls	Combined
Mean	81.25	88.28	85.94
Std	25	20.14	21.59
Range	25 - 100	25 - 100	25 - 100

Table 2: Percentage of total Gabors correct ($\frac{correct\ hit + correct\ rejection}{12}$)

	Meditators	Controls	Combined
Mean	59.38	71.1	67.2
Std	18.60	25.71	23.84
Range	25 - 75	25 - 100	25 - 100

Table 3: Total percent correct ($\frac{correct\ hit\ (faces + Gabors) + correct\ rejection\ (faces + Gabor)}{24}$)

	Meditators	Controls	Combined
Mean	70.31	79.69	76.56
Std	24.10	24.34	24.41
Range	25 - 100	25 - 100	25 - 100

Overall, faces were much more recognizable than Gabor patches. This is understandable given the importance of faces to humans and the familiarity of the particular faces used here. We would also note that the Gabor portion of the recognition test was difficult even for persons with significant amounts of exposure to the Gabors. These results seem to show that participants were aware of the stimuli and recalled them.

Contrasting the meditators' results and the controls, meditators performed slightly worse, especially in the Gabor condition. These results must be taken with caution, however, as the meditator group is under-sampled, precluding proper statistical comparisons.

Task condition accuracy and reaction times

We analyzed the behavioral data in order to ensure all participants were appropriately engaged in the task and that there were not any systematic differences across stimuli and groups. Participants were expected to perform well as the task was very straightforward.

Viewing the data, one can see that the scores across groups are fairly equivalent and that overall everyone performed well. One can view this data in the following tables.

Table 4: Percentage of correct responses to faces during task condition (out of 200)

	Meditators	Controls	Combined
Mean	96.88	96.44	96.58
Std	4.92	2.43	3.26
Range	89.5 - 99.5	93 - 99	89.5 - 99.5

Table 5: Percentage of correct responses to Gabors during task condition (out of 200)

	Meditators	Controls	Combined
Mean	96.5	95.94	96.13
Std	3.16	3.69	3.38
Range	92.5 - 99.5	91 - 100	91 - 100

Table 6: Percentage of incorrect responses to faces during task condition (out of 200)

	Meditators	Controls	Combined
Mean	3.13	3.44	3.33
Std	4.92	2.41	3.21
Range	0.5 - 10.5	1 - 7	0.5 - 10.5

Table 7: Percentage of incorrect responses to Gabors during task condition (out of 200)

	Meditators	Controls	Combined
Mean	3.25	3.56	3.46
Std	3.07	3.31	3.09
Range	0.5 - 7	0 - 8	0 - 8

Table 8: Percentage of no-responses to blanks during task condition (out of 200)

	Meditators	Controls	Combined
Mean	100	99.88	99.92
Std	0	0.23	0.19
Range	0	99.5 - 100	99.5 - 100

Table 9: Reaction times to faces for correct responses during task (in ms)

	Meditators	Controls	Combined
Mean	486.82	467.36	473.84
Std	78.08	45.16	55.25
Range	411.68 - 593.68	393.69 - 525.97	393.69 - 593.68

Table 10: Reaction times to Gabors for correct responses during task (in ms)

	Meditators	Controls	Combined
Mean	511.37	470.6154	484.20
Std	67.52	40.55377	51.89
Range	431.02 - 593.86	402.98 - 512.04	402.98 - 593.86

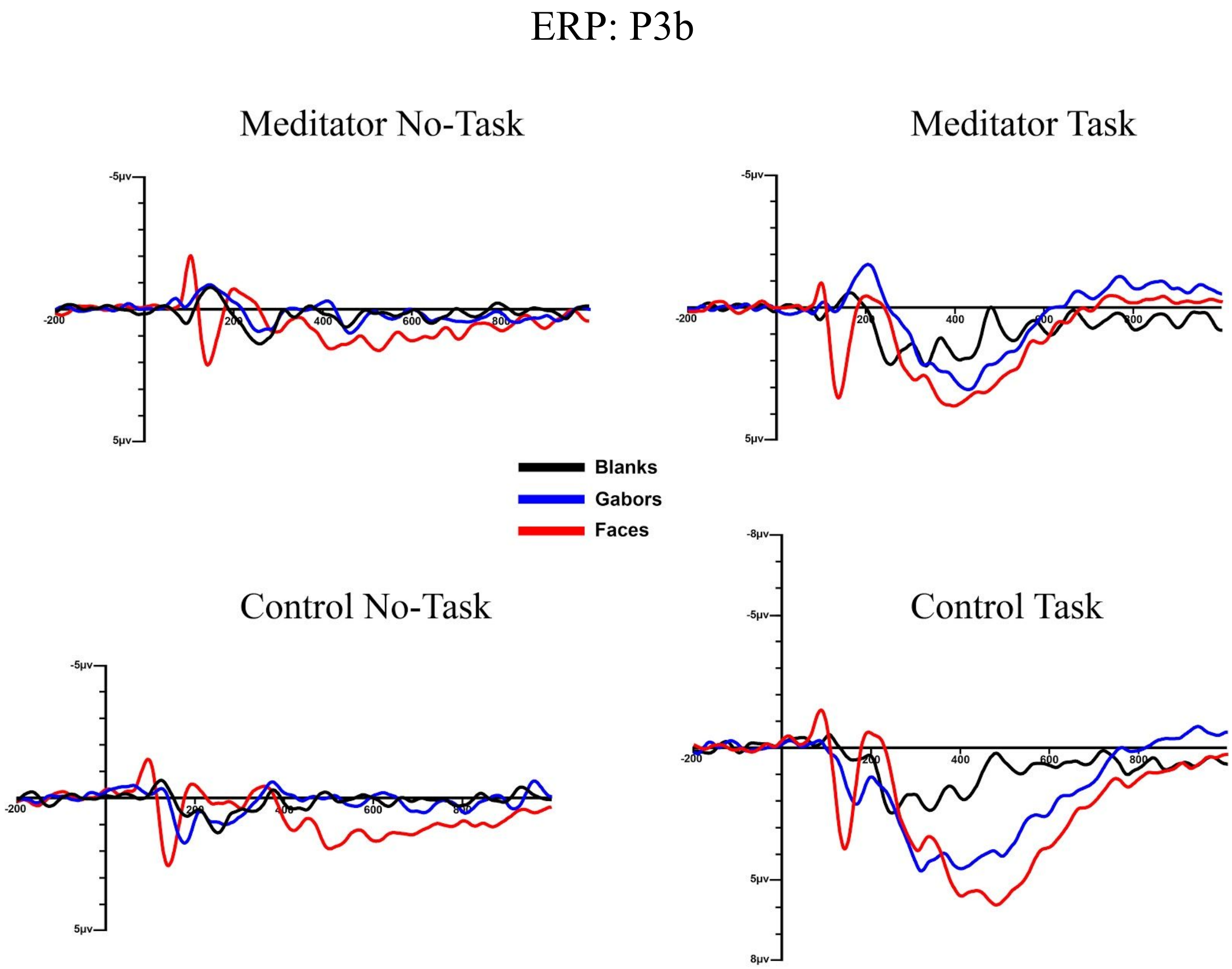

Figure 3.1: This figure shows the grand average ERP waveforms for meditators and controls in both task conditions

We engaged in visual inspection of ERP differences in order to assess between participant group comparisons of the P3b, as opposed to statistical analysis. This was necessitated by the low sample size of the meditator group. The ERPs for the two groups within each condition can be seen in Figure 3 above. Reviewing the no-task figures, there does not appear to be a large difference between groups in terms of waveform. For both groups, the P3b seems largely attenuated if not totally absent, due to the waveforms being clustered around the baseline for the period 300–600 ms, as opposed to in the task condition where they peak in the positive direction. However, in the no-task condition the face ERP, which is more distant from the baseline than blank or Gabor ERPs, could be said to be displaying a slight P3b. This effect was displayed more so in the control group. This potential result is unsurprising considering the salience and conceptual baggage attached to the faces of the presidents. This can be considered additional preliminary evidence toward the notion that the P3b is correlated to stimulus task relevancy, as opposed to consciousness, as even normal controls not in a non-cognitive state displayed attenuated P3b.

Comparing the task condition is where one sees marked differences. Although there are clear P3bs displayed in both groups due to the waveforms peaking in the positive direction, the meditator P3bs appear dampened in comparison to the non-meditators. For the mediators, the highest voltage peak only reached around 3.7 μv, while the highest peak for the control subjects reached around 6.5 μv. This appears to show that meditators may have permanently dampened superfluous cognitive activity due to diligent mindfulness and/or may have less noisy and more efficient cognitive processes right after doing this type of meditation.

No-Task Condition

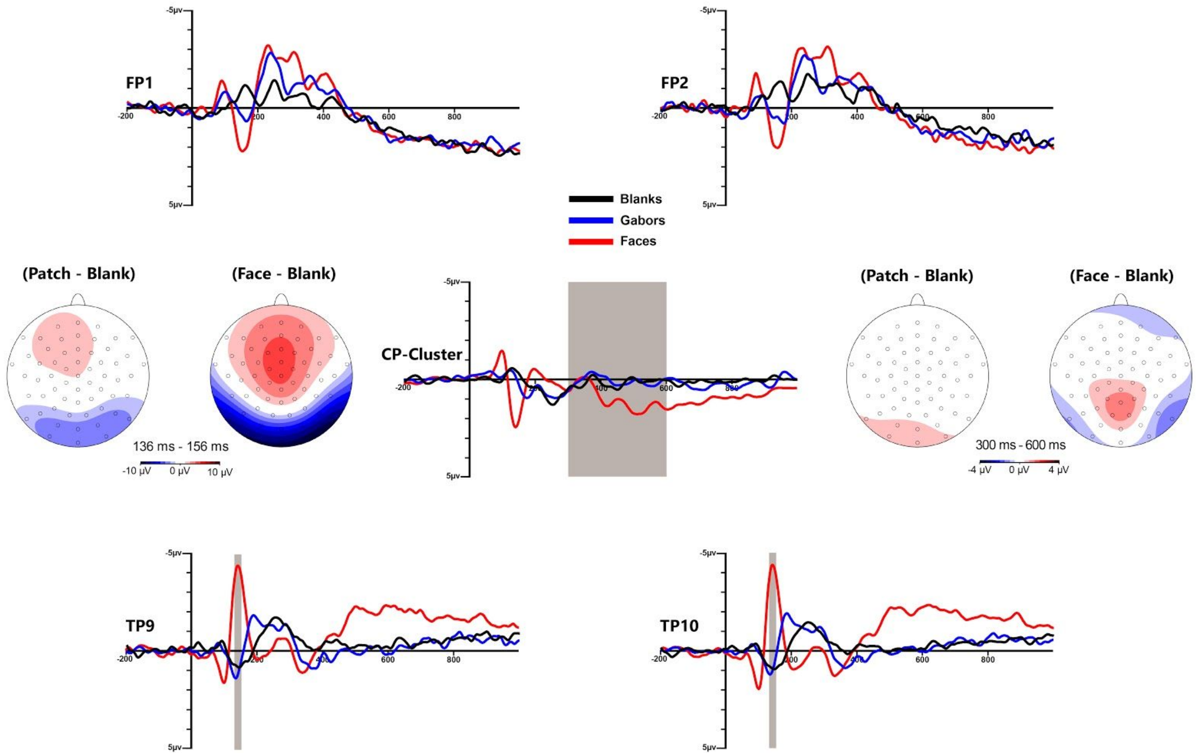

Figure 3.2: This figure shows pooled data for the no-task condition

Task Condition

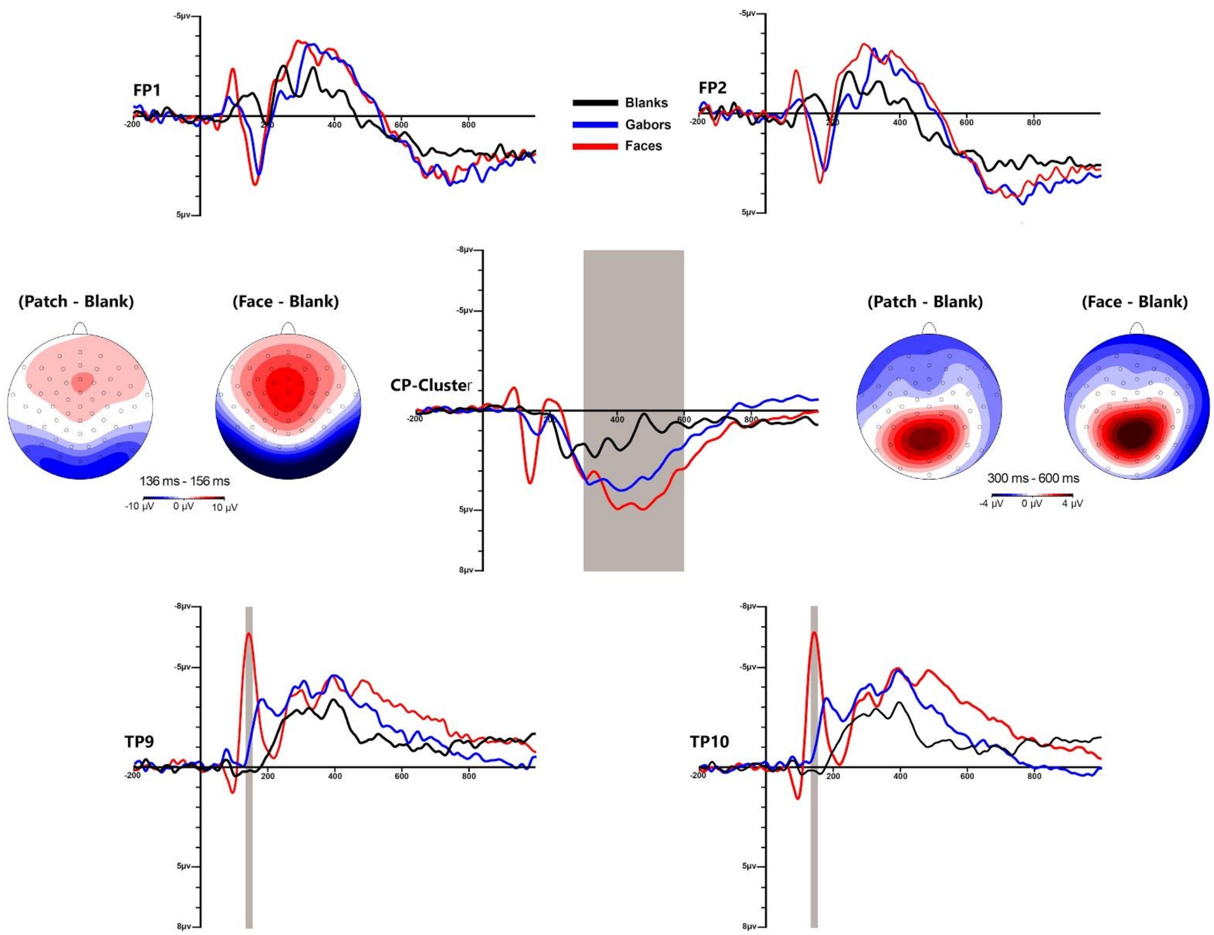

Figure 3.3: This figure shows pooled data for the task condition

Figure 3.2 and 3.3 show grand averaged (N=12, for the pooled group of participants) event-related potentials from 5 of the 64 electrodes that are spatially arranged based on head location (top = frontal electrodes; middle = central electrodes; bottom = posterior electrodes; left is left, right is right) and four difference topographies (patches minus blanks; faces minus blanks) during early (136–156 ms) and late (300–600 ms) time windows for both task conditions.

The bottom two electrodes were 58 (TP9) and 64 (TP10). These electrodes were chosen as they tend to best display the N170 ERP, which was expected to show larger amplitudes for faces compared to non-face stimuli. The N170 is a component of the N1, which is the first negative peak on posterior scalp regions in response to a stimulus. The N1 has a peak latency of 130–200 ms. However, the N1 is particularly large in response to faces, and peaks on average around 160–170 ms. It marks the earliest, strongest, and most reliable difference in amplitude on the scalp between faces and non-face objects. The N170 can be regarded as a quality check because it is known to be purely related to perceptual processes, which should follow the same trends across participants and should not be altered by cognition. Looking at the ERPs for TP9 and TP10, one can see that the red waveform for faces displays a large and early negative peak around 146 ms, unlike the other stimuli; this is the N170.

Directly above the TP9 waveforms, one can see two difference topographies. These topographies display the average electric potential across the scalp across a range of time. The left-hand topographies are mean amplitude differences during the time period of 136–156 ms, which is the time period in which the N170 is maximal, as is signified by the gray bar in the bottom two ERPs. As indicated by their titling, one of the topographies is made by subtracting the average electric potential of the blank stimuli from the average electric potential of the face stimuli, and the other is made from subtracting blank from Gabor patches.

The central ERPs (CP cluster) are relevant for our investigation of whether or not the P3b is attenuated during the non-task condition but present in the task-condition. They were created from the same pool of electrodes clustered around CP that was used to analyze the P3b. As stated previously, the P3b tends to arise between 300 and 600 ms.

Looking at the ERPs between these time points (the region shaded in gray) for the task condition (Figure 3.3), one can see that the two task-relevant stimulus types – faces and Gabors – display large positive peaks during this time window, while the ERPs for the blank square is closer to baseline. These results appear to follow the trend of the P3b, as expected, because it is well established that the P3b occurs during conditions in which the stimuli are task relevant. Shifting focus towards the equivalent graph for the no-task condition (Figure 3.2), each stimulus tends to cluster around the baseline, with the blank being closest to 0 μv.

These results suggest that the P3b is highly attenuated (or completely absent) in the no-task condition, but is present for the same stimuli in the task condition. The difference topographies ranging from 300 to 600 ms, located on the right of both figures, further this notion. This is because one can see that the difference values between faces vs. blanks and Gabors vs. blanks are much greater in the task condition than the no-task condition, further displaying that task-relevant stimuli appear to be eliciting larger positive potentials that follow the characteristics of the P3b.

Using the aforementioned 2x3 repeated measures ANOVA, the expected interaction effect for $p<0.05$ between condition and stimulus was found ($F(2,22) = 19.54$, $p = 0.0000$), as well as for the main effects of condition ($F(1, 22) = 33.76$, $p = 0.0001$) and stimulus ($F(2, 22) = 18.15$, $p = 0.0000$).

A Tukey planned comparison for main effects within independent variable groups (condition, stimulus) was conducted, and all comparisons were found to be $p = 0.0000$. The mean neuronal voltage from the CPz pool was significantly different among categories of stimuli and between conditions.

A Tukey planned comparison was then run for the interaction effects in order to investigate the P3b component. In the no-report condition, it was found that the Gabor patch ($M=0.088$, $p = 1.000$) and face ($M=0.941$, $p = 0.086$) stimuli were not significantly different than the blank ($M= 0.162$), thus confirming that all can be considered generally clustered around the baseline. In contrast, in the report condition it was found that the Gabor patch ($M=3.221$, $p = 0.000$) and face ($M= 4.14$, $p = 0.000$) stimuli were significantly different from the blank ($M= 1.24$), which corroborates what is visually apparent on the graphs. The task-relevant stimuli were significantly different from the task-irrelevant in the task condition. Additionally it was found that comparing across conditions, the faces were significantly different from each other ($p = 0.000$), as were the Gabor patches ($p = 0.000$) and blanks ($p = 0.008$). This final analysis provides evidence that the same type of stimuli can elicit different ERPs based on whether or not they are task relevant. Overall this provides evidence towards our predictions that there would not be a P3b in the no-task condition, while it would be present for the task-relevant stimuli, due to the additional cognitive processing required by the task.

Decoding

When decoding between the categories of faces and Gabor patches, it was found that the machine learning algorithm could at times accurately decode up to about 40% higher than chance (50%) from around 40 ms to 1175 ms in the no-task condition (figure 3.5). A similar trend was seen in the task condition (figure 3.6), however decoding accuracy peaks higher than 40% decoding accuracy, but plateaus less than the task condition. Such a high decoding accuracy was expected, as it should not be difficult to distinguish between the brain activity related to faces versus Gabor patches. Thus this test functioned as our proof of concept. We did hypothesize, however, that the stimuli would be decodable for prolonged periods during the task condition, because the stimuli would be held in mind for longer, as this is required for carrying out the categorization task. In the two graphs below (3.5 & 3.6), the yellow line displays the mean decoding accuracy and its width exhibits the standard error. The shaded gray area defines the region in which the decoding accuracy was found significantly different than chance.

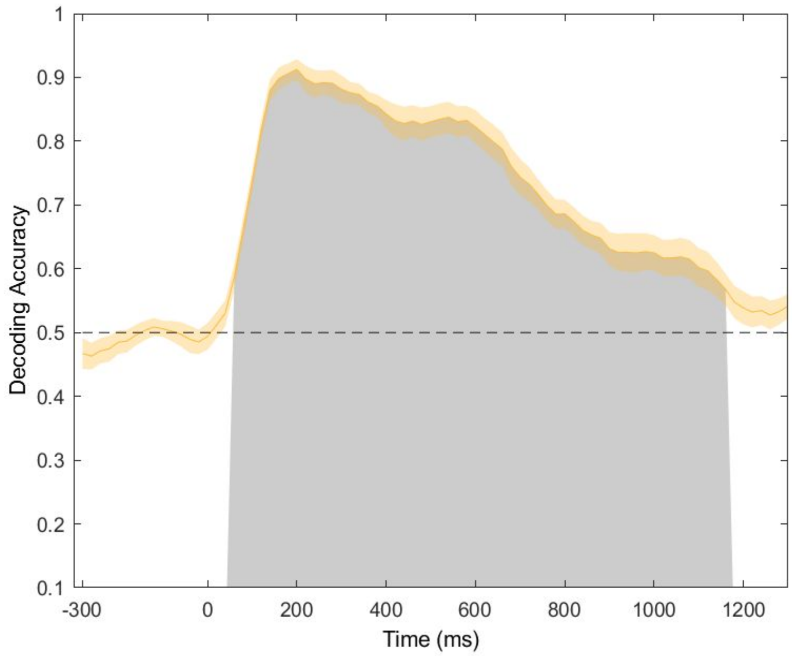

Figure 3.5: This figure shows decoding accuracy for categories of stimuli (faces vs Gabors) in the no-task condition

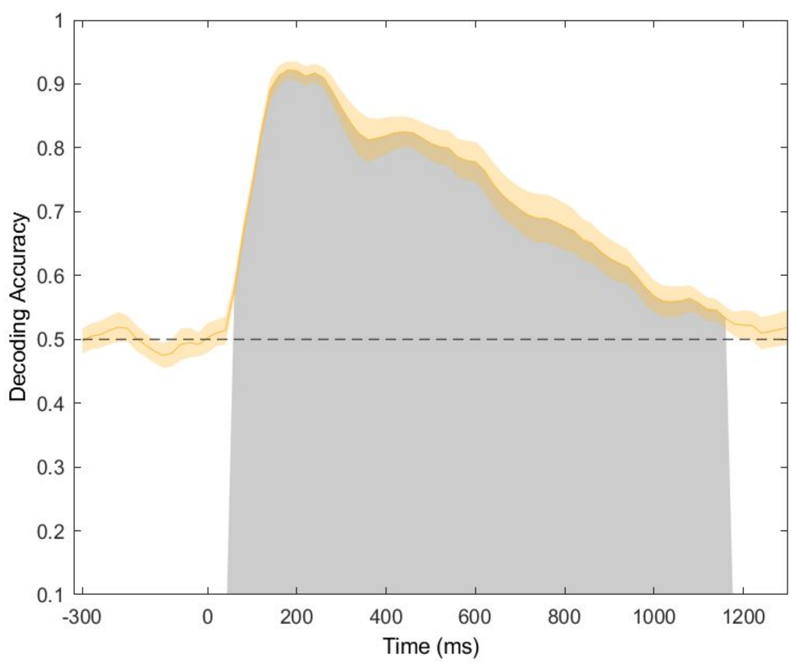

Figure 3.6: This figure shows decoding accuracy for categories of stimuli (faces vs Gabors) in the task condition

Next, we compared decodability between individual stimuli within a category. For faces in the no-task condition (figure 3.7), the highest decodability reached about 36%, while for the task condition (figure 3.8) it was slightly lower. With 25% being chance, these decoding accuracies may seem small, but such accuracies are common in the field and reliably indicate that information was decodable above chance levels (Bae and Luck, 2018). For individual faces, decoding remained significant until 500 ms in the no-task and until 600 ms in the task condition. This follows our prediction about decodability lasting a bit longer during the task condition. The graphs for face decoding are shown below (Figures 3.7 & 3.8).

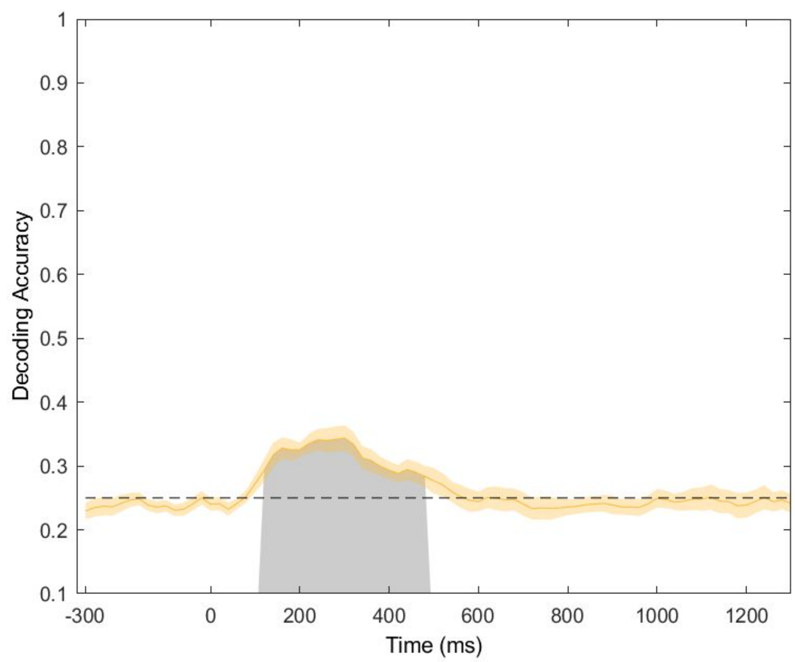

Figure 3.7: This figure shows decoding accuracy for individual faces within the no-task condition

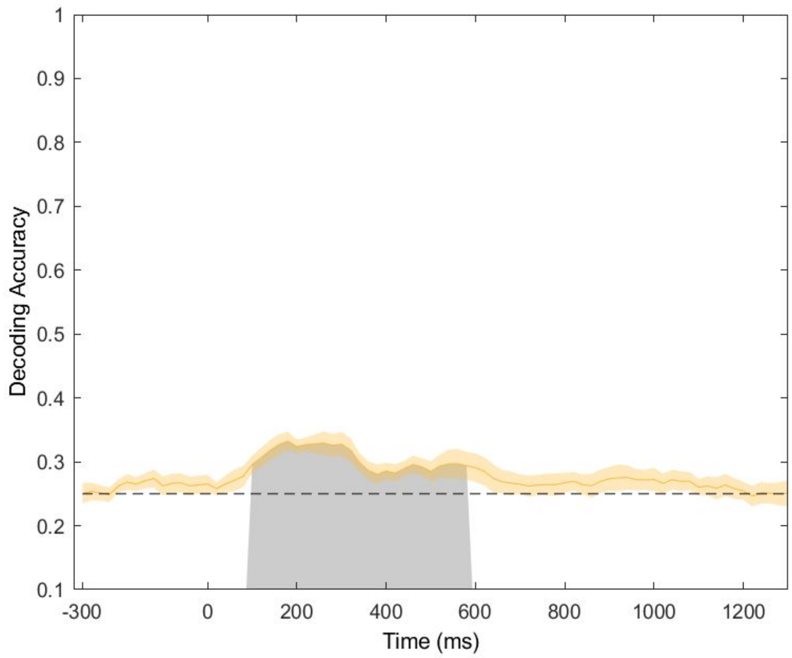

Figure 3.8: This figure shows decoding accuracy for individual faces within the task condition

The decodability for Gabor patches was worse than for faces. In the task condition (figure 3.10), no time points were found to be significantly decodable above chance. While for the no-task condition (figure 3.9), the decoding peaked only 3% above chance and for only 100 ms. This data does not follow the predicted trend of a longer period of decoding within the task condition.

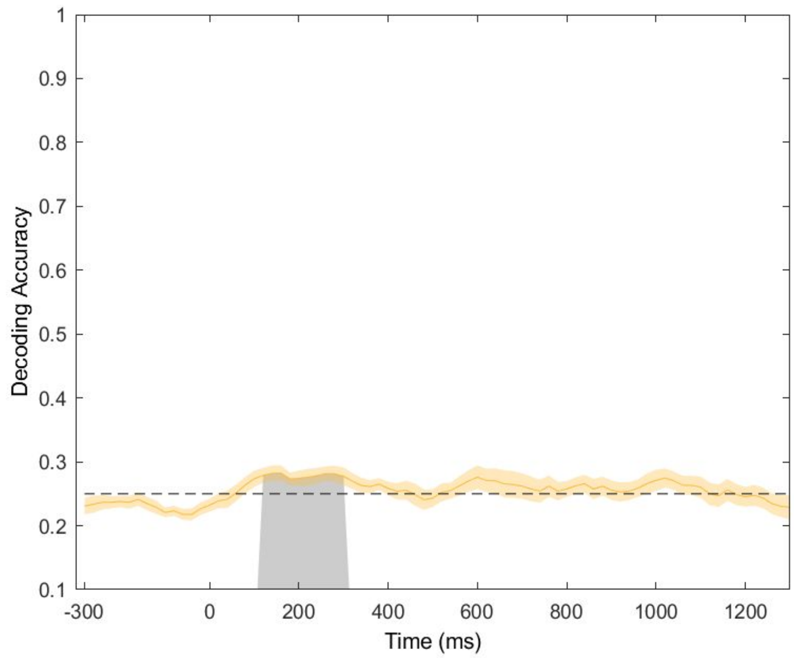

Figure 3.9: This figure shows decoding accuracy for individual Gabor patches within the no-task condition

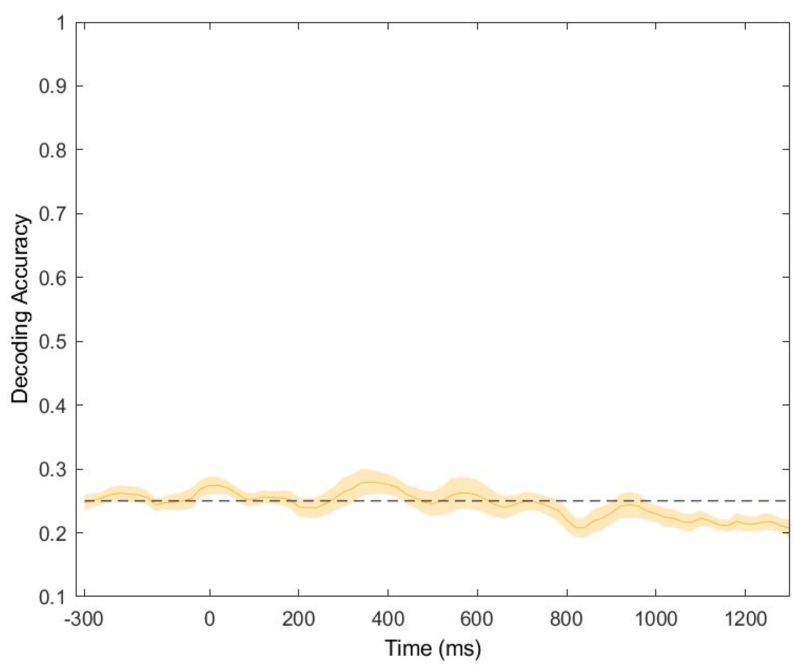

Figure 3.10: This figure shows decoding accuracy for individual Gabor patches within the task condition

Questionnaire interpretive analysis

Questionnaires were given to the participants after the no-task condition to address the phenomenal experience of this type of meditation and its practice. Interesting and trend-characterizing responses from these questionnaires are detailed below.

For the three meditators who claimed they were able to consistently enter the requested state, their descriptions of their experiences matched the prescribed state.

In response to the question asking if participants saw the stimuli clearly, one meditator responded, “Clearly saw the images, wasn't trying to see them in detail or remember them. Allowing them to flash, be seen, and dissolve.” Her account corresponds to the state sought by the experiment. We had hoped that the meditators would simply see the stimuli with sensory perception, allowing the perceptions to arise and fall without interaction or attachment.

One question assessed the distractibility of the meditators and generated a consistent response. According to their introspective reports, these three meditators only thought about the stimuli a few times at most. One example response was: “3-4 moments of internal distraction. The 1st of which was the longest (a few face images long).” This allows us to be more confident that these meditators were maintaining the requested criteria.

Question 6 asked how the meditators entered the state of non-proliferation. Two meditators responded similarly in stating, “Focused on the dot + the screen in general, relaxed into open awareness w/ dot as focal point” and “focus on dot. Release knowing.” This gives us increased confidence that the meditators were engaging in the same type of aim and practice. The practice appears to start with the initial orientation of the gaze, followed by a release of this initial intentionality into a spacious awareness. This is further corroborated by a description of their state in response to question 7. The meditator said he was “resting in the nature of mind, freely resting.” These words imply a degree of effortlessness and lack of attentional direction. Another mediator, in answering question 7, described the practice as “What are things? state of pre-recognition." This is clearly asserting that this person was able to enter a state of simple perceiving, prior to objectifying the world with conceptuality.

Other interesting comments include that one meditator was experiencing "bodily bliss and relaxation" during the meditation. Another described becoming "aware of the emotional presence of each face, rather than knowing 'who the face was,'" and one remarked, "Flow of images that had an effect on my eyes. Noticed my eyes move slightly to take in the images - especially with human faces." The last two quotes suggest that the meditators were becoming aware of subtle and intermediate aspects of perceptual processing. The final quote suggests that bottom-up attention was being activated, due to the salience of the faces, which was causing automatic adjustment of the eyes. This would be in line with a previous study by Forte et al. (1985), which focused on the phenomenal experiences of very advanced meditators within a visual threshold paradigm. He found evidence that meditation can allow one to become aware of usually preattentive processes. The most striking of which was a meditator claiming he could feel the flashes of light being presented hit his retina.

Chapter 4: Discussion

This research's central ambition was to investigate the neural correlates of consciousness through a novel "no-cognition" paradigm using advanced meditation practices. Our main goal was to better distinguish the neural correlates of perceptual awareness from higher cognitive faculties--a critical topic in the field of consciousness science. This is the subject of a lively debate between cognitivists (who believe at least a minimal level of cognitive interaction with sensory content is necessary for consciousness) and sensory theorists (who do not support that belief). This debate has also been branded the frontalists vs. the non-frontalists, due to the fact that the neural regions related to cognition are located in the frontal cortices..

Our research specifically focused on determining the neural status of the P3b and predicted that meditation would help dampen the automatic cascade of conceptual associations related to a stimulus, thus providing evidence that P3b is not a neural correlate of consciousness.

P3b, the evidence assessed

The first hypothesis predicted that within the no-task condition the meditators would show little to none of the P3b component, while the non-meditators would display much larger amounts of neuronal activity, including the P3b. Our second hypothesis predicted that during the no-task condition the face stimuli would elicit larger amounts of P3b and extra-cognitive activity as compared to the other stimuli. This effect would be seen in the control groups, and potentially minimally in the meditator group.

Unfortunately, comparisons between participant groups were not statistically plausible due to the small sample size. Thus, an exploratory analysis involving visual inspection of the waveforms by participant groups was conducted. After inspecting the no-task condition, both groups appeared to display a largely attenuated, if not totally, absent P3b. This result did not align our first experimental hypothesis, which predicted that the control group would display a P3b due to being unable to prevent conceptualization in the presence of stimuli. This unexpected result could be interpreted as displaying that the P3b is not related to conceptualization when in the presence of general stimuli, but is connected to cognition when we are dealing with stimuli that are required for a task. Indeed, the face waveform for both groups, although still close to baseline, displayed slight P3b activity, as it was more elevated than the other two ERPs stimuli. In the end, however, because the pooled average for both groups did not statistically show that face ERPs were significantly different than the blank stimulus ERPs clustered at baseline, it is unlikely that this difference would be significant for the meditator group, as the difference between their ERPS is presumably smaller than the pool. These results follow our second hypothesis, but because of the small sample size, they are to be considered inconclusive.

In regards to the third hypothesis, the data aligned with our predictions that both groups would display P3b activity during the task, thus providing additional pre-experimental evidence for the notion that the P3b is related to stimulus task relevancy, as opposed to simple perceptual consciousness.

An unpredicted potential effect was observed as well: meditators displayed a diminished P3b relative to non-meditators in the task condition. This suggests that meditators may have permanently dampened superfluous cognitive activity due to diligent mindfulness and that they may have more efficient cognitive processes immediately after engaging in this type of meditation. The results tend to match the introspective claims of meditators about their ability to reduce unnecessary cognition over time.

The above-mentioned corollary hypothesis – that there would be larger P3bs for both groups in the task condition compared to the no-task condition – was statistically assessed, since all participants were pooled. The corollary hypothesis was confirmed statistically.

Overall, these results support the new trend as found in no-report paradigms by showing P3b attenuation when the stimuli are no longer task relevant. This outcome directly contradicts GNWT's claim that the P3b is an NCC. The results also suggest that the P3b may not be a neural correlate of consciousness and is instead a neural correlate of cognitive processing related to reporting. However, simply finding that the P3b is not a neural correlate and is due to cognitive processing is not enough to completely invalidate GNWT and other frontalist/cognitively based theories, even if it seems to elevate non-frontalist theories, such as IIT. In fact, there are other sets of neural activity correlated with cognition located in frontal regions that can be involved in perceptual processing. Furthermore, some of this neural activity cannot be easily studied through EEG (Odegaard et al., 2017).

Decoding

For our decoding analysis, we hypothesized that within the no-task condition groups of stimuli as well as individual ones would be decodable for longer time periods in the case of the non-meditators as compared to the meditators. This hypothesis assumed that the non-meditators would be conceptualizing the stimuli and retaining them in their minds, even after the stimuli disappeared. We also proposed that within the task the stimuli would be decodable for fairly equal lengths of time in both groups, as they needed to perform the same stimulus-relevant task. However, due to sample size, we were not able to test these hypotheses.

The corollary hypothesis, however, was statistically tenable for the pooled group. This hypothesis stated that for both participant groups decoding would be significant for a longer period during the task condition compared to the no-task condition. Additionally, it was also possible to assess GNWT's temporal predictions for the ignition of consciousness, although we did not predict an outcome.

When decoding to distinguish between the categories of face stimuli and Gabor stimuli, accuracy was significantly above chance, from around 40 ms to 1175 ms in the no-task and task condition. Such a high decoding accuracy was expected, as it should not be difficult to distinguish between the brain activity related to faces versus Gabor patches. For individual faces, decoding remained significant until 500 ms in the no-task and until 600 ms in the task condition. Both of these analyses contradict our hypothesis that the stimuli would be decodable for longer periods during the task condition vs. no-task condition. The assumption behind this prediction was that having to report the stimuli category required holding those stimuli within working memory, thus the stimuli were being represented neurally for a longer time. These temporal results follow the predictions of cognitive theories of consciousness such as GNWT, which expects the ignition of consciousness to occur from 300 ms to 600 ms. Both task conditions also display above chance decoding starting at 100 ms. This could simply reflect early perceptual processing, which might contain distinct ERP results, whether or not they are within consciousness. Thus, commencing decoding at 100 ms does not necessarily challenge GNWT. If no-task conditions were shown to reduce decoding to chance around 300 ms, while report conditions extended longer to around 600 ms, this would provide initial evidence that GNWT is wrong in its temporal predictions. One could interpret this hypothetical data as demonstrating that perceptual information (conscious content) occurred from 100–300 ms regardless of task, but then was maintained to accomplish the task in the report condition (e.g., retaining the content in mind for category discrimination) from 300–600 ms. If these were our results, it would appear that information does not require interaction with neural activity related to cognition to arise within consciousness. In our experiment, however, decoding remained above chance until 500 ms in both conditions, which is consistent with GNWT's predicted period of ignition.

The decodability results for Gabor patches can generally be considered ineffective, because in the task condition no time points were found to be significantly decodable above chance, while for the no-task condition the decoding peaked only 3% above chance and for only 100 ms.

A possible explanation for the low decoding accuracy results in relation to individual faces and Gabors might be found in Bae and Luck's work (2018), upon which we based our research. In their study, participants were instructed to remember the orientation of a teardrop as precisely as possible over a 1300 ms delay period and then orient another teardrop to match this remembered orientation. Within our study, participants only had to discriminate between faces vs Gabor patches, as opposed to between individual stimuli within each category, as was done in Bae and Luck. This lack of required discrimination among these stimuli potentially explains why the decoder was not able to discriminate considerably above chance for individual faces and Gabors. If we were to rerun this experiment, but changed the task to discriminating between individual stimuli, then decoding results would probably be higher.

Criticisms of the experimental methodology

The major problem of this study was the unfortunate small sample size of the participants. This prevented us from testing many of our most significant experimental inquiries. Fortunately, this problem is easily remediable in future research. We do not, however, recommend revisiting the experiment and testing the same queries, as it is not necessary to use advanced meditators to show that the P3b is attenuated when the stimuli are not-task related.

Another methodological issue the thesis confronted, which is common in meditation research in general, was ensuring that meditators were qualified and able to access the mental state that was requested of them. One serious challenge is the difficulty for an outside person to accurately evaluate the practice of the meditator, as one cannot access another's first-person experience. This means that researchers will often have to rely on the introspective reports of participants, which can bring with it all sorts of biases and confounds. In this study, however, the comparison between meditators and controls was rather bluntly designed to capture non-conceptuality as a quality of meditation, as opposed to a precisely defined practice. Therefore, the issue was not as problematic within this investigation. If researchers are to focus on precisely defined practices, however, very detailed instructions would be required to fully elucidate the requested state and to prevent variation. Sampling meditators from the same tradition would also be critical.

Another problem in this kind of experiment is boredom inducing noise that can have a distorting effect on the data. A common challenge with designs that involve no-task conditions is that participants will become disinterested and unengaged. Boredom then induces alpha waves within a person's brain activity, which can act as a noise and thus distort the ERP waveforms. This was a consistent issue with our data and might have attenuated the statistical power of the experiment by reducing distinctions in the ERPs. Due to potentially lowered statistical power, research of this type may need more participants to achieve meaningful results, thus necessitating the expenditure of more time and money. Here, no person's data had to be thrown out due to alpha, however many were borderline. The issue does not seem easy to resolve, as no-task conditions are simply boring for the average person. Telling participants to be more engaged can diminish alpha waves temporarily, but participants will soon get tired again. Promising an extra payment that is dependent on the alpha waves a person displays might motivate participants to stay alert, however, we did not attempt this solution.

Future research

As mentioned above, we are not proposing to revisit the experiment and test the same sets of queries. We believe that it is not necessary to use advanced mediators to show that the P3b is attenuated when the stimuli are task irrelevant. We do suggest, however, a follow-up study on the unexpected result of meditators displaying a diminished P3b relative to non-meditators within the task condition. Our experiment was not not able to statistically evaluate this result. A possible interpretation of the unpredicted outcome is that meditators may have permanently dampened extra-cognitive activity due to practicing continuous mindfulness and may have more efficient cognitive processes immediately after meditating. One could try a similar methodology as our experiment, but only test the task condition and employ a larger sample of advanced meditators in order to assess if practitioners have a permanently dampened P3b. In order to distinguish the effects of meditating immediately prior to the task from long-term changes due to mindfulness, researchers may also want to include a group of meditators and ask them to meditate for 20 minutes immediately before the task. This type of research could provide important evidence for the long-term benefits of meditation, as well as demonstrate that the average person engages in inefficient and unnecessary cognitive processes.

We also propose investigating more extreme states of meditative consciousness, as we had originally planned. One of these states would be of absolutely no-cognition within which there is no referentiality, as the mind has ceased to objectify the external world into discrete compartments. Another would be the state of contentless consciousness, which is described by Jonathan Shear as "the 'space' of awareness devoid of all the objects such as sensations, images and thoughts that fill our ordinary awareness" (Shear, 2014). This state of contentless consciousness is a crucial aspect of the debate on comparative mysticism, which considers whether religious experiences are a product of one's cultural conditioning, as opposed to expressing the fundamental dimensions of human spirituality and are thus devoid of any content and cultural baggage. The two states, although it would be difficult to find practitioners who can repeatedly enter them, could be utilized to parse between alternative theories of consciousness, as they appear to isolate consciousness from adjoined mental processes at different levels, the one from cognition and the other from all perceptual content. These states may be especially relevant to disprove many predictions of cognitivist theories of consciousness, since the introspective reports regarding them already claim that cognitive faculties interacting with sensory content are not fundamental to consciousness.

In a broader view, we plead for more scientific attention towards esoteric realms that do not necessarily belong to consciousness research. Two worthy topics that we believe will produce paradigm-shifting revelations about human anatomy and humanity in general are the phenomena of autonomous "yoga" and circuits of ecstatic conductivity within the body.

Autonomous or spontaneous yoga (commonly called spontaneous kriyas) is a phenomenon in which the body will begin to do yogic postures (asanas), breathwork (pranayama), and mudras on its own, without any prior knowledge. This phenomenon has deep, fundamental implications for the origins of spirituality and yoga, because it suggests that these actions are innate to the body and beyond culture. This phenomenon also has major implications for how we understand our own autonomy and the inner wisdom of the body.

The second topic is that of ecstatic conductivity in which it is possible to have the experience of what feels to be primordial ecstatic vibration coursing through various circuits within the body. The flow of this "energy" can be influenced by creating closed circuits with various body points, such as the fingers. These circuits appear to align closely with the ancient conceptual maps of the subtle body and chakra systems. A common argument against the existence of this type of experience is that the practices employed to begin feeling these sensations generally involve imagining the sensation first. This would mean that we are dealing with a culturally created experience. However, one can begin experiencing these feelings without any prior attempts or knowledge of their existence. We are not implying that the conceptions of the ancient schools in regards to the chakric systems are in any way correct. We simply mention it to show that this is a well-known phenomenon in some circles and worthy of investigation. We do not make any claims about its metaphysical significance.

Conclusion

This research sought to employ the distinctive mental techniques of advanced meditators, who have developed and refined their methods of mental stillness through years of disciplined study and practice. Their practice of non-proliferation, which divorces perception from cognition, offered a way to address the debates of neuropsychology on the neural correlates of consciousness. It enabled us to experimentally test predictions that differed between cognitivist and non-cognitivist theories of consciousness.

Our research appears to provide evidence that the P3b component is not an NCC as proposed by GNWT, and is instead a neural correlate of cognitive processing related to task relevance, as demonstrated by the P3b's presence in the task condition and by its disappearance in the no-task condition.

For decoding, we found that accuracy remained above chance until 500 ms in both conditions when comparing between stimulus categories and individual face stimuli, which is consistent with GNWT's temporal predictions about consciousnes's ignition.

Overall, this data seems to imply that there are facets in both competing theories that are valid, thus suggesting that the theories should be integrated, instead of being opposed to one another.

Ultimately, investigations into consciousness are important because they help us address many pathologies that affect us, including schizophrenia. Additionally, knowing the neural correlates of consciousness can help us understand if non-responsive patients are in a coma or are immobile and incapable of responding, such as with locked-in syndrome. Ultimately, the question of consciousness is one of the most fundamental questions about existence. It has a relevance that goes beyond mere scientific and even therapeutic pursuits.

Appendix I

Demographics and the subsequent meditation experience questions were on the same paper.

Demographics

Age:

Gender:

Dominant hand:

Non-Meditator-Group Meditation- Experience Questions

Have you ever meditated consistently for more than a week? How long ago was this?

How much time total have you meditated in the last five years?

Have you ever been to a class on meditation?

Have you ever been on a meditation retreat?

Meditator-Group Meditation- Experience Questions

How many years have you been meditating consistently?

How frequently do you formally meditate per week? What is the average length of each session?

Have you been on retreat, if so, how many times overall, and how long was your longest retreat?

Can you estimate how many hours you have meditated total?

Do you identify as belonging to a certain meditation tradition or lineage, if so, which?

Appendix II

These are the instructions for the no-task condition. The sentence marked with (M) is the only sentence that differed between the meditator and control group instructions, in that it was only present for the meditators.

"During this practice and subsequent portion of the experiment, we will be flashing different pictures in the center of the screen. Your only task will be to keep your eyes on the red dot at the center of the screen. The specific content of the pictures is not important, but we do need you to see the pictures clearly, so that we can get good recordings of your brain activity. Try to relax and keep your mind quiet, while simply observing the flashed pictures. (M) Please try to enter into a meditative state in which there is no conceptual proliferation about the pictures, where you simply see the pictures with raw sense perception.

Additionally, please try to limit blinking and other movements as much as possible. If you have any questions please ask the experimenter now."

Appendix III

Questions 1-4 were received by both participant groups. Question 5 in questionnaire 1 was only for control subjects. The equivalent question for meditators was question 5 in questionnaire 2. Questions 6-8 were for meditators only.

Questionnaire 1

1.) What was the experience in general like?

2.) Did you feel like you clearly perceived the stimuli flashed on the screen during the experiment, regardless of whether you could remember them when tested afterward?

3.) Please estimate how often your perception of the stimuli was clear vs. degraded (or suppressed/disrupted).

4.) Did you catch yourself thinking about any of the stimuli that were flashed on the screen? If so, which particular stimuli and how often did this occur?

5.) Were you able to consistently keep your mind relatively quiet?

Questionnaire 2

5.) Were you able to consistently enter into the state that was requested? Can you describe the consistency?

6.) What did you do or try to do in order to enter the state that was requested?

7.) Can you describe the state? What would you call this state or practice?

8.) Did any other odd phenomena occur while you were in this state?

Appendix IV

These are the instructions for the task condition. The sentence that is marked with (M) is the only sentence that differed between the meditator and control group instructions, in that it was only present for the meditators.

"During this practice and subsequent portion of the experiment, everything on the screen will be the same. The only change is that now you will be pressing buttons in response to what type of pictures appear. For example, you will press the green button for faces and the white button for striped patches. You will not, however, be pressing a button for blank squares. Please try to press the appropriate buttons before the next image appears. If the next image appears before you were able to press the button, don't worry, just move on to the next image. Also, do not worry if you accidentally press a button in response to the blank squares. Please keep your eyes on the red dot at the center of the screen, and focus on the task at hand. Remember to relax, keep your mind fairly quiet, and try not to blink too much.

(M) Please do not enter into any special states like you were asked to in the previous trial period. If you have any questions please ask the experimenter now."

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