Brain Lateralization of Attentional Control Following Brief Meditation Training

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Abstract

When individuals view a rapid series of visual stimuli and are asked to report two targets (T1 and T2) among distractors, an attentional blink (AB) occurs that is, reduced performance in reporting the second target when it follows the first target within 500 ms. AB magnitude as well as left visual field advantage, which is often reported when processing rapid stimuli, are subject to bottom-up and top-down control. Meditation types, in particular ‘open monitoring meditation’ (OMM) and ‘focused attention meditation’ (FAM), can further modulate these effects. We used both behavioral and electroencephalography (EEG) data to determine how a brief OMM versus FAM session impacts attention allocation in the AB task. A total of 32 participants without prior meditation experience engaged in a 20-minute FAM or OMM session before completing the AB task. To investigate lateralization effects, T2 appeared either center, left, or right of fixation in equal proportions. For the behavioral data, repeated-measures ANOVA on T2 recognition accuracy revealed significant differences between groups, with higher accuracy (i.e., reduced AB magnitude) in the OMM versus the FAM group. For the EEG data, we found greater attention allocation to T2 (higher amplitude of the P300 component) for the OMM versus the FAM group and differences in delta, theta, and gamma frequency bands.

Keywords: Attentional blink, Meditation, Lateralization, EEG, ERSP

Sammendrag

Når individer ser en serie med hyppig visuelle stimuli og blir bedt om å rapportere to mål (T1 og T2) blant distraherende stimuli, oppstår et oppmerksomhetsblink (AB), en redusert evne i rapportering av det andre målet når det følger det første målet innen 500ms. AB størrelse og venstre synsfeltfordel, som ofte rapporteres ved behandling av hyppige stimuli, er underlagt både bottom-up og top-down kontroll. Meditasjonsteknikker, spesielt ‘open monitoring meditation’ (OMM) og ‘focused attention meditation’ (FAM), kan ytterligere modulere disse effektene. Vi brukte atferdsdata og elektroencefalografi (EEG) data for å undersøke effekten av en kort OMM- versus FAM-økt og deres påvirkning på oppmerksomhetsallokering i en AB-oppgave. Totalt 21 deltakere uten forutgående meditasjonserfaring deltok i en 20-minutters FAM- eller OMM-økt før de gjennomførte AB-oppgaven. For å undersøke lateraliseringseffekter ble T2 presentert enten på samme plass som, eller til venstre eller høyre i lik avstand fra, fikseringspunkt i midten. Repeterte målinger ANOVA for atferdsdata viste signifikante forskjeller når det gjelder annerkjennelsesnøyaktighet mellom gruppene, med høyere presisjon (redusert AB-størrelse) i OMM versus FAM gruppen. EEG-dataene viste større oppmerksomhetsallokering til T2 (høyere amplitude av P300-komponenten) for OMM versus FAM gruppen og forskjeller i delta-, theta- og gammafrekvensbånd.

Nøkkelord: Attentional blink, Meditasjon, Lateralisering, EEG, ERSP

Preface

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1. Attention

Attention is an expression of cognitive experiences that are self-evident, processes that facilitate cognitive and behavioral achievements, regulation of information processing, and behavioral guidance. There are many manifestations and varieties of attention, including focused attention, divided attention, selective attention, effortful attention, sustained attention and intentional and directed attention, where each of these manifestations occur under different behavioral contexts (Cohen, 2014). In the study we present here, we investigate a phenomenon pertaining to selective attention, namely the *attentional blink* (AB), where an individual fails to report two target stimuli, T1 and T2, when they are presented within 500ms of each other (Raymond, Shapiro, & Arnell, 1992).

1.1 Selective attention. One of the first theoretical accounts of selective attention was proposed as early as 1958, maintaining that an individual would only be able to attend to a single flow of information from their senses, which must be filtered before it can be recognized (Broadbent, 1958). In contrast, the attenuation theory states that information which is important enough will be assigned to conscious processing, even if the information is not consciously acquired (Treisman, 1964). Many theories of selective attention belong to the so-called 'late selection models', with consensus on how early processing is carried out, but with differences regarding how a secondary selective process occurs before information is transferred to *short-term memory* (Deutsch & Deutsch, 1963; Friedenberg, 2013; Norman, 1968), which many consider as being part of *working memory* (WM) (Baddeley, Eysenck, & Anderson, 2015).

1.2 AB and the RSVP paradigm. One of the more familiar methods used to investigate selective attention is through the *Rapid Serial Visual Presentation* (RSVP) procedure, which has proven quite useful, particularly when it comes to studying the effects of the AB, where the participant is asked to identify two targets, a dual task RSVP. In the example above, digit 7 would be known as the primary target (T1) and another digit, 4, could be a secondary target (T2), such that 4 is following 7 at random among other symbols in the stream. The AB effect appears when two masked targets, T1 and T2, are presented with an interstimulus interval of less than 500ms (K. Shapiro, Raymond, & Arnell, 2009; van Leeuwen, Müller, & Melloni, 2009), leading to a failure of reporting T2. The AB has been studied extensively over the last decades, especially following the study by Raymond, Shapiro, and Arnell in 1992, and is considered to be one of the earliest observations within the field of selective attention (Cohen, 2014). Initially, it was presumed that the AB effect could be uniquely observed when studying visual processing, but further studies reported the effect for other modalities, even being cross modal (Arnell & Jolicœur, 1999).

A typical effect mentioned in the AB literature is ‘lag 1 sparing’, where T1 and T2 presented within 200ms are believed to be processed together (Potter, Chun, Banks, & Muckenhoupt, 1998). Lag 1 sparing occurs in cases where T1 and T2 are presented in the same location and is less pronounced or even absent when the two targets appear in different locations possibly because directing attention towards a new location becomes impossible while processing a stimulus at the original location (Visser, Zuvic, Bischof, & Di Lollo, 1999). Indeed, individual differences in WM or attentional span were found to impact AB magnitude. Specifically, high scoring individuals are less likely to ‘blink’ than individuals with scores at the lower end of the scale (Willems & Martens, 2015). There are also studies showing a reduced AB in players of action videogames who are better at spatial attention allocation (Green & Bavelier, 2003).

2. Formal and Informal AB Accounts

Several AB accounts have been developed following the first mention of the effect by its current name (Broadbent & Broadbent, 1987). Thus, in their review article, Dux and Marois

(2009) classify AB accounts as either formal or informal. The latter include the inhibition model, the interference model, bottleneck models, hybrid models, as well as the ‘temporary loss of control’ hypothesis and the ‘delayed attentional reengagement’ account. Formal accounts include the ‘gated auto associator model’, the ‘corollary discharge of attention movement’ model, the ‘locus coeruleus norepinephrine model’, the ‘boost and bounce’ theory, the ‘episodic simultaneous type/serial token’ model, the ‘attention cascade’ model and the ‘threaded cognition’ model.

2.1 Informal AB accounts. According to the interference model, which is based upon the similarity theory of visual search (J. Duncan & Humphreys, 1989; Dux & Marois, 2009; Isaak, Shapiro, & Martin, 1999), incorrect T2 reporting in the AB is a reflection of multiple RSVP items competing for retrieval (K. L. Shapiro & Raymond, 1994). First, representations of items in a visual field are created in parallel at different spatial scales. Next, a comparison between these representations and an internal template is performed, based on specific features related to the target. Finally, the item selected as a potential template match is assigned limited processing resources during the subsequent ‘attentional dwell time’ of 500ms (Isaak et al., 1999; Ward, Duncan, & Shapiro, 1996). Within the dwell time, multiple targets in the RSVP stream compete for resources already assigned to previously presented items, ultimately resulting in an AB. Alternatively, in a dual-task RSVP, the T1 and T2 masks compete with the masked item, T1 and T2, for the same cognitive and perceptual resources (Isaak et al., 1999).

Another ‘informal’ explanation of the AB effect was offered by Chun and Potter (1995), who proposed a two-stage model of the AB based on delayed consolidation and identification of T1 when followed by T2 within 200-400ms. At the first stage of the model, a stimulus will rapidly activate stored conceptual representations, leaving the information volatile and susceptible to being overwritten or decay due to subsequent stimuli (Dux & Marois, 2009).

Several studies have investigated this volatility, showing how AB only occurs in the presence of a backward masked T2. Giesbrecht and Lollo (1998) performed a revision of the two-stage model by introducing an intermediate buffer as a temporary storage of the output from the first stage of the model. Thus, the representation encoded at the first stage overwrites the previously stored representation. The new representation may either be transferred to the second stage or be overwritten by the next input. This revised version of the two-stage model enables trailing masks to overwrite representations of target stimuli without interfering with processing at the first stage. As for the AB effect, the revised model claims that, when T1 and T2 are presented within close temporal proximity, T2 is less likely to be encoded into WM, as T1 is still being processed. Thus, Giesbrecht and Lollo (1998) claim that a stimulus-substitution theory in terms of an object-substitution hypothesis is central for revising the two-stage model, where a representation of a leading target may be erased in the holding buffer, due to output of a trailing mask. This claim was further supported by reports by Dell'Acqua, Pascali, Jolicoeur, and Sessa (2003), who showed that a four-dot backward mask generates an AB effect at shorter lags. However, Giesbrecht, Bischof, and Kingstone (2003) argued against a T2 substitution mechanism as a possible explanation for why information in the intermediate holding buffer was interfered with. Thus, they found no link between the object-substitution hypothesis predicting late-stage visual processes and four-dot masking interfering with the AB. Instead, Giesbrecht et al. (2003) proposed an early-stage visual process being responsible for the effect.

There are several studies supporting the two-stage model based on neuroimaging methods. Gross et al. (2004) used magnetoencephalography (MEG) to identify which subsystems of the attentional network interact, thus generating attentional limitations. Kranczioch, Debener, Schwarzbach, Goebel, and Engel (2005) used fMRI to show an increase in activation in frontal and parietal cortices when T2 is detected, compared to a missed T2, and opposite patterns of activation in occipitotemporal regions. There was also increased activation in frontal and parietal areas when T2 was missed compared to trials where no T2 were presented, and a selective reduction in activity when T2 was presented with the same latencies as the AB in areas linked with predominantly automatic and emotional processing. Importantly, missed targets generally did not evoke a clear P3 component. These findings support the two-stage model as there are specific visual areas responding to T2 regardless of detection or blink, while parietal-frontal regions are selectively activated when T2 is reported.

Potter, Staub, and O'Connor (2002) performed a study showing that the original two-stage model could not explain their results. They proposed an extension of the model, coined the 'two-stage competition model', which explains how T2 presented 13-53ms after T1 benefits from an attentional window already made available at T1 presentation, thus allowing T2 to pass T1 in the processing queue. The theory was further extended by Dux and Harris (2007), who showed that inhibition of distractors during a task, in which selection of temporally distributed stimuli is necessary, is vital to avoid an AB effect, as well as how failure to inhibit distractors contributes to the AB effect.

A similar bottleneck model is the attentional dwell time hypothesis proposed by Ward et al. (1996). The authors argued that a capacity-limited visual processing resource is stretched thin due to competition between two target objects. A direct consequence of this competition is processing one target in depth at the expense of other targets, which may not even be detected. Overall, this would support a view of attention being dependent on a sustained mental state for guiding behavior.

Another bottleneck model built on the original two-stage model by Chun and Potter (1995) is the central interference theory. During critical stages of processing, such as when adding the task of identifying T2, short-term consolidation of T1 would be affected, impairing its encoding in WM (Jolicoeur, 1998). Furthermore, WM consolidation and response selection depend on capacity-limited central processing, which in turn is what separates it from the original two-stage model (Dux & Marois, 2009).

The inhibition model is based on a shut-and-lock model, where an attentional gate is locked and closed for about 400ms after a stimulus is presented (Raymond et al., 1992), thus leading to the AB effect. Raymond et al. (1992) suggest that the attentional gate functions as an attentional filter when a subject is presented with an RSVP stream, where they need to attend to each item in the stream and link them in a meaningful manner. This enables the individual to effectively lock out stimuli that are visually similar to previously presented items. Alternatively, when there is no need to relate information between items, and the only task is to attend a target stimulus, the gate is less permeable, thus reducing detectability of all stimuli (Raymond et al., 1992). Furthermore, this indicates that the AB occurs due to confusion between features related to, and during identification of, T1.

The inhibition model was further investigated by Di Lollo, Kawahara, Shahab Ghorashi, and Enns (2005), who considered that lack of resources due to the presentation of T1 could not explain AB. Instead, they formulated the hypothesis of temporary loss of control (TLC), according to which AB is the result of a temporary loss of endogenous control over selective attention subsequent to information filtering. The input filter would affect the initial processing of bottom-up signals and is maintained by a central processor in the prefrontal cortex, unable to multitask. In the AB paradigm, the central processor monitors the stream of information to identify those stimuli that match the target characteristics (Di Lollo et al., 2005). Rather than TLC, Nieuwenstein (2006) suggested a delayed selection process and thereby delayed attention allocation during the AB task. Attention selection would be affected by delayed attentional engagement (Nieuwenstein, Chun, van der Lubbe, & Hooge, 2005), whereby depleted attentional resources for T2 processing delay T2 detection and selection.

Hybrid models have also been used to explain AB mechanisms. Vogel, Luck, and Shapiro (1998) proposed a model integrating the two-stage model and the interference model. In this model, all items in the RSVP are stored in a conceptual short-term memory (CSTM) buffer after identification, where they are prone to decay and replacement and therefore become unavailable for reporting. Attention is necessary for consolidating information in the buffer into visual working memory (VWM) (Allen, Baddeley, & Hitch, 2014; Baddeley, 1986). Thus, in order to transfer information about specific targets from CSTM to VWM, certain characteristics must match between the representation and target template. When T1 processing is engaged, resources necessary for T2 processing and transfer is unavailable, hence the increase in errors and higher AB magnitude (Vogel et al., 1998). This leaves us with both a bottleneck in WM and an interference between target representations, giving rise to the AB effect.

2.2 Formal AB accounts. Chartier, Cousineau, and Charbonneau (2004) offered an explanation of the AB by developing a two-stage framework composed of an identification stage and a memorization stage, further comprising two layers, one competitive and one recurrent. The framework is based on Chun and Potter (1995) and Jolicoeur (1998) models, where a competitive layer's function is to identify a visual stimulus based on two competing networks, where each network identifies specific characteristics, such as symbols or colors (Kohonen, 1982). The second stage, an auto-associative layer, attempts to consolidate information in short-term memory (STM), based on information from the first stage (Hopfield, 1982). Further, the layers are influenced by a dual mechanism including a comparison process and a neural fatigue diminishing learning strength. During the comparison process, if the attributes of the stimulus match those of the target, this stimulates an opening of a mental gate to STM to enable encoding, and an inhibitive process hindering further comparison. During encoding, neural fatigue develops, which diminishes learning strength. Using simulation, the authors generated data replicating results from actual participants. The inhibition process and the subsequent slow recovery rate represent the primary cause behind AB. Lag 1 sparing would be due to the mental gate being open for longer than the duration of T1 presentation (Dux & Marois, 2009).

According to the corollary discharge of attention movement (CODAM) model, an inverse model controller (IMC) must first boost the processing of certain items in a sequence for them to be admitted into WM (Fragopanagos, Kockelkoren, & Taylor, 2005). In order to avoid T2 interference during T1 encoding, this boost is withheld from T2 at shorter lags by a monitor module inhibiting the IMC, thus leading to AB. The module compares target representations with the predictor for the current stimulus via a corollary discharge from the IMC. Corollary discharge refers in general to any signals which influence sensorimotor processing, related to motoric timing, allowing reafferent, self-generated sensory input, and exafferent, change-driven environmental sensory input, stimuli to be distinguished in the central nervous system (Fukutomi & Carlson, 2020). Once T1 processing is done, the IMC no longer emits a discharge, and the monitoring module therefore no longer inhibits the IMC. In other words, at short lags, IMC is unable to boost T2 due to inhibition. For lag 1 sparing to occur, T1 and T2 are attentionally enhanced, resulting in both of them entering WM.

Nieuwenhuis, Gilzenrat, Holmes, and Cohen (2005) proposed a neurobiological mechanism underlying the AB effect, by further developing a computational model of the LC norepinephrine system and its influence on information processing. Locus coeruleus (LC) is an area of the brain stem which contains up to half of all the neurons generating norepinephrine in the central nervous system (Berridge & Waterhouse, 2003). The authors showed that the LC norepinephrine system, which plays a vital role in goal-directed behavior and attention, may generate an AB during the refractory period of LC subsequent to T1 presentation. In other words, LC is unresponsive for T2 within 500ms. Furthermore, Nieuwenhuis et al. (2005)

suggest that lag1 sparing is the result of the temporal dynamics of the presented stimuli and the allocation of enhanced attention.

The formal boost and bounce theory (Olivers & Meeter, 2008) extended the TLC study replicated by Olivers, van der Stigchel, and Hulleman (2007). According to this theory, there are two major stages involved during an attention task. The first stage is sensory processing, which involves an activation of perceptual features representations and high-level information related to categorical and semantic information. Representations are then strongly and rapidly activated at stimulus onset, followed by a return to resting state. This process allows for multiple representations to be activated at once, but also leaves activation of individual items vulnerable to neighboring items in the RSVP, if they are similar and presented at the same location. The second stage involves monitoring and maintaining information in WM as well as pairing an input with a suitable response. Olivers and Meeter (2008) acknowledge that, despite of unknown details about the connection between stimulus presentation and response, a crucial link is established through feedback from neurons in the central working memory to relevant sensory representations and suitable response, as previously suggested by Dehaene, Kerszberg, and Changeux (1998). Furthermore, WM utilizes an input filter to enhance the processing of certain stimuli matching the target, and to inhibit distractors. In the boost and bounce theory, there are two capacity limitations: there can be only one attentional set active at any given time, and WM limitations for how much information that can be stored. However, although neither of these limitations explain why AB occurs, the theory provides an explanation for lag 1 sparing when it specifies that the input filter in WM allows processing of T1 and T1+1 distractor to be enhanced. Attentional enhancement of a distractor stimulus then induces a suppression or a bounce of subsequently presented stimuli, leading to the AB effect.

The episodic simultaneous type/serial token (eSTST) model was developed by Wyble, Bowman, and Nieuwenstein (2009) and is an extension of the simultaneous type/serial token model by Bowman and Wyble (2007). The eSTST model suggests that there is a self-imposed limitation on encoding of visual information, which is exemplified by the AB effect. Allocation of attention and engagement of WM are considered opposite processes. Thus, during an RSVP-task, all items are identified at a conceptual stage, activating their type representations. In order to be successfully reported, this information must be bound to a token in WM, providing episodic information related to the stimulus. This binding process only occurs if a particular node mediates deployment of attention. After T1 stimulus onset, the binding process is occupied with attaching T1 to a suitable token, leaving the node suppressed and unable to include other information. Hence T2 suppression at this time triggers the AB. Importantly, the node is maintained in an enhanced mode as long as target items appear in an uninterrupted sequence, allowing subsequent targets to be identified, thereby accounting for lag 1 sparing.

The attention cascade model developed by Shih (2008) employs computational details from several attention gating theories. It is built upon the two-stage model of Chun and Potter (1995), but also has certain similarities with the interference theory (K. L. Shapiro & Raymond, 1994). According to this model, stimuli are processed using either a bottom-up salience pathway or a mandatory pathway. Stimuli using the bottom-up salience pathway trigger an attentional window and enter the central decision processor in WM. Stimuli using the mandatory pathway first activate long-term memory representations before being transferred to a peripheral sensory buffer. If the representation matches the target template, an attentional window is triggered and enhanced, to further consolidate the representation into the decision processor, assuming sufficient encoding resources are still available. In the attention cascade model, the encoding processor has a capacity limit for processing T1 and T2, which generates the AB due to T2 being left vulnerable to decay and interference. Attentional enhancement could last longer than T1 presentation time, allowing for subsequent targets to be processed, which explains lag 1 sparing. The duration of attentional enhancement is, however, dependent on task demand and therefore varies accordingly.

The threaded cognition model (Taatgen, Juvina, Schipper, Borst, & Martens, 2009) explains AB as being the product of an overexertion of control during memory consolidation. AB results from inhibiting target detection while another target is being encoded into WM. For lag 1 sparing, the attention system recognizes T1 and subsequent stimuli in close temporal vicinity, and the need to report these signals has a higher priority than maintaining control over the production rule, thus protecting consolidation.

3. Neural Attention Networks

Corbetta and Shulman (2002) proposed two interacting neural networks underlying attentional control, based on accumulating evidence and previously-described models. One of these networks prepares and applies goal-directed selection of stimuli and responses in top-down fashion and includes brain areas such as intraparietal and superior frontal cortex, but also the intraparietal sulci (IPs) and the frontal eye fields (FEFs). This system is known as the ‘dorsal system’, or the IPs-FEF network. The other network is specialized for detecting behaviorally relevant stimuli, particularly when the presented stimuli are unattended and salient. It is lateralized to the right hemisphere and includes the temporoparietal and inferior frontal cortex, as well the temporoparietal junction (TPJ) and the ventral frontal cortex (VFC). This system makes up what is called the ‘ventral frontoparietal system’ or the TPJ-VFC network. The authors explain how the two systems interact as follows. First, the TPJ-VFC network serves as an alerting system, detecting behaviorally relevant stimuli in the environment. If a relevant stimulus is detected, the dorsal system is able to precisely locate it despite a lack of high-resolution spatial sensors. Alternatively, when an unexpected event is detected, the TPJ-VFC system functions as a circuit breaker of ongoing cognitive activity, such that subjects break the attentional set and form a new one based on incoming stimuli (Shulman et al., 2002).

4. Attention and Meditation

Attention can be greatly affected by meditation, which is a technique used to achieve a state of relaxation and well-being. Among meditation types, two practices show distinct effects on attention: *focused attention meditation* (FAM) and *monitoring meditation* (OMM) (Lippelt, Hommel, & Colzato, 2014; Lutz, Slagter, Dunne, & Davidson, 2008). During FAM, where the meditator guides their attention towards an event or object, such as ones breath, constantly monitoring their concentration to avoid mind-wandering (Tops, Boksem, Quirin, Ijzerman, & Koole, 2014). In contrast, during OMM, the meditator concentrates on their own consciousness, independent of internal or external objects or events (Lutz et al., 2008; Vago & Silbersweig, 2012). As exemplified by Colzato, Sellaro, Samara, Baas, and Hommel (2015), one may induce different types of mental states through meditation, which in turn affects AB magnitude. Individuals without prior experience with meditation engaged in a brief session of either OMM or FAM, followed by an AB task. The FAM technique would increase top-down control by inducing single channel processing and by increasing local competition between relevant and irrelevant information. The OMM technique would weaken top-down control and reduce cognitive competition by utilizing parallel processing. The authors reported a smaller AB for participants in the OMM group compared to participants in the FAM group.

Other studies have shown that, during an attention demanding task over a longer period of time and involving unexpected stimuli, the OMM technique improves cognitive performance more than the FAM technique does (Valentine & Sweet, 1999), possibly because OMM is associated with a broader attentional span. Valentine and Sweet (1999) studied how performance on a sustained attention test, Wilkins’ counting test, was affected by either concentrative meditation (similar to FAM) or by mindfulness meditation (similar to OMM). Compared to the controls, meditation groups performed better in general, and experienced meditators outperformed inexperienced meditators. Furthermore, mindfulness meditators performed better than concentrative meditators if the presented stimulus was unexpected. No difference was found when the presented stimulus was expected.

In order to clarify the underlying neurobiological mechanisms of how OMM and FAM influences the mind to such a degree that performance on certain tasks becomes strengthened, Vago and Silbersweig (2012) developed a framework known as self-awareness, self-regulation and self-transcendence (S-ART). The authors outline an integrative frontoparietal neural networks dedicated to self-specifying and narrative self (NS) processing, supported by six neurocognitive processes. These networks have different functionalities, where the self-specifying network is a task positive control network, whereas the NS is task negative. By developing S-ART through meditation, one might modulate the positive self-specifying network and negative NS networks.

Tops and colleagues (Tops, Luu, Boksem, & Tucker, 2013) integrated several competing theories targeting the neural substrates of awareness in their predictive and reactive control systems (PARCS) theory. Thus, the default mode network (DMN) and the anterior insula (AI) define two homeostatic and behavioral control systems. AI becomes activated when task-related attention is applied in conjunction with awareness. DMN, on the other hand, becomes active when an individual is passive, not stimulated by external input, or not performing a particular task. Through PARCS, mental states may be linked to brain states and functions. The theory suggests that through a shift from reactive control to an internal model-guided control, mindfulness meditation should increase mental resilience.

Lippelt et al. (2014) published a review where they investigated how different meditation techniques (FAM, OMM, and loving kindness meditation LKM) affect cognitive processes such as attention, conflict monitoring, and creativity. They highlight the ways that different meditational techniques have different effects on cognitive processes, as follows. FAM narrows the attentional focus due to the concentration aspect of the method. OMM, on the other hand, induces broader attentional focus, as practitioners do not focus on anything specific. As for LKM, it was difficult to determine a clear effect on specific cognitive processes across various experimental designs, sample characteristics, and tasks described in the studies investigated. Overall, LKM incorporates too many elements from the other two methods (Lippelt et al., 2014; Vago & Silbersweig, 2012).

Meditation, whether it is done intensively during a few hours or just during a brief single session by young or older adults (van Leeuwen et al., 2009) was found to have a positive impact on attention and/or other cognitive abilities (Colzato et al., 2015; Slagter et al., 2007). For example, Braboszcz and colleagues (Braboszcz et al., 2013) investigated the plasticity of visual attention in active practitioners of Isha yoga, which is a variant of FAM, by asking them to perform an AB task before and after 3 months of intense meditation training. Isha yoga training was found to be negatively correlated with earlier experience with meditation and performance on the AB task. In another study, Delgado and colleagues (Delgado-Pastor, Perakakis, Subramanya, Telles, & Vila, 2013) looked at the performance in an oddball task (identify a target tone among a series of standard tones) by Vipassana meditation practitioners, which is a variant of OMM (Cahn & Polich, 2009). The authors found increased attentional abilities in meditators compared to controls.

Thus, meditation has been found to influence the processing of sensory information and attention control. There has been a lot of progress during the past decades on meditation effects. (Colzato et al., 2015; Rolke, Heil, Streb, & Hennighausen, 2001; Yordanova et al., 2020), but the consequences of meditation and how it influences brain lateralized attentional control are among the questions researchers are yet to agree upon. In particular, it is unclear if a short meditation session activates the same neurological pathways, compared to longer meditation sessions exercised by meditation practitioners.

5. EEG Research on Meditation

Electroencephalography (EEG) is a suitable method and non-resource demanding (Light et al., 2010) for investigating the effects of meditation on cognition and, more specifically, on the brain activity associated to selective attention of visual stimuli (Purves & Brannon, 2013), due to its non-invasive functionality. EEG simply involves placing electrodes on the skull that measure the activity of neurons conveyed across synapses either chemically or electrically, resulting in post-synaptic potentials and action potentials. The method mainly measure the postsynaptic currents of pyramidal cells located in the infragranular and supragranular cortical layers, thus creating a summation of these currents, which creates a measurable signal (van Putten & Hofmeijer, 2016). Skull, scalp, and brain tissue, all conduct electricity passively due to synaptic activity, in which the signal strength is determined by the tissue's conductivity (Buzsaki, Anastassiou, & Koch, 2012; Gazzaniga, Ivry, & Mangun, 2019). EEG electrodes pick up on these signals, and neuronal activity can be measured based on voltage change (St. Louis, Frey, & Britton, 2016). Importantly, one does not measure the action potential of a single neuron, but rather the sum of the *local field potential* (LFP) creating a volume of leading LFP fluctuations.

Yordanova et al. (2020) exposed highly experienced meditators to either OMM, FAM or loving kindness meditation (LKM), while monitoring brain activity using EEG. Compared to controls, meditators exhibited connectivity patterns of broadly distributed delta and theta wave networks lateralized to the left hemisphere with a local integrating focus in the left posterior hemisphere, and alpha wave networks lateralized to the right hemisphere with local integrating focus in the right posterior hemisphere. Moreover, the authors reported delta coherent oscillations across all three forms of meditation as well as an increase in the theta band in the left hemisphere and coherent patterns in the fast alpha range in the right hemisphere. Synchronization patterns between left- and right-hemispheric beta networks were different, depending on the meditation technique applied: lateralized coherence in the beta band, with enhanced beta coherence in the left hemisphere in the OMM group, enhanced beta coherence in the right hemisphere in the FAM group, and no inter-hemispheric asymmetry in the LKM group. Yordanova et al. (2020) further speculate that the increased beta connectivity in the left hemisphere corresponds to a wider attentional focus on visual stimuli, as seems to be the case with OMM, while the similar connectivity in the right hemisphere represents highly focused attention guided towards a more specific item or event, similar to the expected effects of FAM.

EEG was also used to measure brain activity during an AB task in the form of *event related potentials* (ERP), which capture electrical activity down to the millisecond related to the onset of a specific stimulus, thereby ensuring high temporal precision (Light et al., 2010). Several ERP components have been used to describe cognitive functions related to visual, auditory, somatosensory, and higher-order processing. By measuring the amplitude of ERP components from different electrodes, one can determine the allocation of attentional resources to a particular cognitive process. One may also look at a component’s latency and sequence to pinpoint the exact time of that particular activity (C. C. Duncan et al., 2009).

Mismatch negativity MMN, P300 and N400 are well-documented ERP components. In particular, P300 is a component that has been studied a fair amount and has been linked to numerous functions and disorders (Cui et al., 2017; Howe, Pinto, & De Luca, 2014; Jeon & Polich, 2003; Polich, 1996). One of the earliest studies reporting on the P300 describes it as a major waveform alteration where the amplitude of the EEG signal reaches a peak around 300 ms after stimulus onset (Sutton, Braren, Zubin, & John, 1965). Later studies revealed subcomponents of the P300, recognized as the P3a (Snyder & Hillyard, 1976) and the P3b

(Squires, Squires, & Hillyard, 1975). The P3a marks early attention processes and has a frontal scalp distribution, suggesting changes in working-memory representations. The P3b relates to transmitting attention-driven signals to parietal and temporal structures (Polich, 2007). The P300 has repeatedly been linked with WM and is one of the most thoroughly researched ERPs identified (Darque, Del Zotto, Khateb, & Pegna, 2012; C. C. Duncan et al., 2009). However, P300 has not always been observed. For instance, if a cross-categorical discovery is required, such as recognition of a face, an early selection process allows attention to be focused toward other more senseful stimuli at a faster rate (Darque et al., 2012). A multi-channel model has been proposed to explain why the AB is sometimes absent when target stimuli are faces (Awh et al., 2004; Landau & Bentin, 2008).

Several studies have used EEG and especially ERPs to study the AB. For instance, the method was used to investigate whether the effect was a mere result of suppression of post-perceptual processing or of sensory processing itself (Vogel et al., 1998). The AB in both cases coincided with the latency of the P300, starting at around 300ms after T2 onset, peaking at around 300-400ms, and returning to baseline at the 500-600ms mark, which was taken as evidence that participants noticed both T1 and T2 though failed to report T2 in some cases, thus indicating suppressed post-perceptual processing. A possible explanation would be that AB is a bi-product of a transient, broader inhibition of cortical networks in order to process a localized target stimulus (McArthur, Budd, & Michie, 1999). Slagter et al. (2007) performed a longitudinal study, in which participants underwent a three-month meditation program using the Vipassana technique. Before and after meditation training, participants completed an AB task. The EEG data revealed a smaller P3b component elicited by T1, indicating reduced allocation of mental resources to processing subsequent stimuli. Furthermore, participants with the largest decrease in P3b also had the least number of trials showing an AB effect. Overall, their study indicates that mental training through meditation may increase control of the attention allocation process of limited resources in a demanding task. Another study examining the ERP correlates of the AB revealed no clear P300 component for missed targets within or outside the AB interval, but well-defined P300 components for targets detected within the AB interval, thus suggesting that this information reaches WM (Kranczioch, Debener, & Engel, 2003).

An additional method of studying EEG signals locked to specific timepoints is the measurement of event related spectral perturbation (ERSP) (Scott Makeig, 1993), which captures the average dynamic change in amplitude within various frequency bands (delta, theta, alpha, beta, gamma). When looking at changes in the different frequency bands, one examines event related synchronization (ERS) and event related de-synchronization (ERD), in which ERS are seen as positive changes and ERD as negative changes, all measured in decibel (dB) (Grandchamp & Delorme, 2011; Zhang, Zhang, & Liu, 2017). However, there are some limitations using ERSPs and/or ERPs, two of which are the issues of spatial mixing and phase resetting (Scott Makeig, Debener, Onton, & Delorme, 2004). By spatial mixing Scott Makeig et al. (2004) states that ERP and ERSP data are comprised of signals from multiple neurons and non-brain sources, indiscriminately being recorded by scalp electrodes, leading to a cancellation, rather than a sum, of recorded signals. As for phase resetting, the authors claims that the phase of EEG activity at several frequencies can partially collapse and affects ERPs, without increasing EEG power. In order to nullify these limitations, one performs independent component analysis (ICA) (Anemüller, Sejnowski, & Makeig, 2003; S. Makeig et al., 2002). The different frequencies have been linked with different cognitive processes, illustrated in Travis and Shear (2010). Delta frequencies are usually associated with slow wave sleep, theta frequencies are in meditation expressed during monitoring of ongoing experience lacking high levels manipulation or control, while alpha frequencies are split into alpha1 (8-10Hz) and alpha2 (10-12Hz) frequencies. Alpha1 are expected when performing meditation which transcends own activity, while alpha2 occurs during cortical idling, sitting with one’s eyes closed. Beta bands has been suggested to function as a uniting frequency of meditation experiences and during focused executive processing, thus being observable during several meditation techniques. Finally, gamma frequencies are related to object recognition and the construction of experience content.

Studies utilizing EEG data such as ERSP, often report differences in delta frequencies during meditation practice, as seen in Cahn, Delorme, and Polich (2010) and Tei et al. (2009).

6. Goals of the Current Study

In this study, we combine meditation and attention. Meditation involves a series of complex and different training methods impacting one’s regulation of emotions and attention, to the extent of where one lays the foundation of emotional balance and well-being. The term ‘meditation’ refers to techniques through which one aspires to achieve relaxation, but also other more long term goals (Lutz et al., 2008). In term of results, increased efficiency, precision and flexibility of visual attention processing across different tasks, are some of the immediate effects associated with meditation, though longer lasting effects have also been identified (Hodgins & Adair, 2010). With this knowledge in mind, we conducted an experiment in which we had a closer look at meditation effects on selective attention.

The current study is the first to report the effects of brief meditation on brain lateralization patterns in an AB task that is, differences in performance when T2 is presented in the center, to the left, and to the right of the visual field (Bergerbest, Shilkrot, Joseph, & Salti, 2017). We asked participants to listen to pre-recorded FAM or OMM guided meditation, which would change their state of mind and thereby affect their task performance. Brain lateralization patterns when processing targets in the AB task have previously been reported in individuals trained via long meditation sessions using EEG. A reduced AB effect was found, which was strongly linked with a left visual-field advantage (Bergerbest et al., 2017; Holländer, Corballis, & Hamm, 2005; Yordanova et al., 2020). However, in a recent behavioral study, Bergerbest and colleagues have found a slight but significant right visual-field advantage over the left (Bergerbest et al., 2017). Importantly, the authors used three streams of RSVP stimuli instead of two, such that performance for identifying targets at the central location could be clearly contrasted with performance for identifying targets to the left and to the right of the central location. More importantly, they also did not mind what order the targets were reported, for example a T1 represented by an 8, followed by a T2 represented by a 2, reporting 8,2 or 2,8 would be considered a correct answer. In the current study, this is not the case.

The null hypothesis (H_0) of this study is that a single brief FAM or OMM session has no effect on attention control in terms of AB magnitude, lateralization patterns, and P300 distribution. The alternative hypothesis (H_1) is that a single brief FAM or OMM session has distinct effects on attention control in terms of AB magnitude, lateralization patterns, and P300 distribution.

Methods

7. Participants

Thirty-eight individuals participated in the study, recruited using fliers, word of mouth and social media. Participants were between 20-38 years old (*M* = 24.70, *SD* = 2.64). Participants reported no former long-term experience with meditation, they were free of any neuropsychological conditions and were not under the influence of any medication. A condition for participating in the study was right handedness. A total of 6 participants were excluded for being tested on pilot versions of the test, for being left-handed, for delivering incomplete data, or due to technical problems. We report complete data from a total of 32 participants (16 male, 16 female, M = 24.39, SD = 3.61).

8. Ethics

The study received ethics approval from the regional committee for medical and health research ethics Vest (REK-Case 60748/2020) and the University of Bergen; all participants signed an informed consent form for volunteering in the study in accordance with the declaration of Helsinki. They were compensated with a 200NOK gift card for participation and travel expenses.

9. Apparatus

Stimuli were presented by an Intel® Core™2 CPU 6400 @ 2.13GHz computer on a 24inch ThinkVision monitor model T24-D10, with a refresh rate of 60 HZ. The screen resolution was set to 1080p, 1920 x 1080, with a color depth of 32-bits. The experiment ran on a Microsoft Windows XP 2002 system, with 3GB RAM. The participants sat down at a fixed spot, about sixty cm from the screen. The experiment was run and programmed with E-Prime Professional 2.0. The participants were outfitted with an EEG-cap with fifty-nine electrodes. In addition, data was also collected from 4 eye-electrodes, 2 reference-electrodes and 1 ground-electrode. An amplifier, Brainamp DC BrainProducts and Powerpack BrainProducts, were used to convert, amplify and accommodate the electrical signals from the scalp. Electrodes were linked to a 64 Channel BrainProducts electrode input box. An Intel® Core™2 CPU 6400 @ 2.13GHz computer running Brainvision Recorder was used to record and monitor the signals. An abrasive gel, Abralyt, was applied at each electrode site to ensure stable signals, as well as to lower impedance.

10. Stimuli

Target items were digits (2-9) and distractors were letters from A-Z excluding I, O, Q and S, due to potential confounds with similar digits. The letters and digits were presented in white on a black background and the font was Arial, 24 points. A third of the target items were presented in the center of the screen, another third about 1.5 degrees to the left, and yet another third was presented 1.5 degrees to the right. At a 60 cm viewing distance, participants could view all stimuli without saccading left or right. There were 18 practice trials, followed by 288 experimental trials consisting of 32 trials for each T2 location (Left, Right or Center) and for each T1-T2 lag (1, 3, 8). This amounted to 96 trials where T2 appeared in the center, 96 trials where T2 appeared to the left, and 96 trials where T2 appeared to the right. All stimuli were presented in individually randomized order. The RSVP stream consisted of 4 or 6 distractors, T1, 0, 2 or 7 distractors, T2, and 3-12 distractors. The experimental design was 2 (Group: OMM vs. FAM) x 3 (Lag: 1 v 3 vs. 8) x 3 (Location: Center vs. Left vs. Right).

11. Procedure

The study was conducted in an EEG-laboratory at the Institute for biological and medical psychology at the University of Bergen. Prior to testing, participants received and fille out consent forms, containing details about experiment goals, rights as volunteers and privacy policy. The testing area consisted of a faraday caged room, fitted with all the EEG equipment, a camera used to monitor the participant during trials due to health and safety, a monitor and keyboard. The camera provided a live feed but did not record any footage.

For each participant an EEG cap had to be prepared, requiring 40-70 minutes per participant. We used a standard 64-electrodes cap, of which 59 electrodes were applied on the scalp, and four monitored eye movements (two horizontal, two vertical). Further, we fitted one reference electrode on each mastoid and a ground electrode at the neck. In order to reduce impedance levels, cotton swabs dipped in alcohol were used to scrub away dead cell matter, followed by application of Abralyte gel on electrode sites. Electrode impedance levels were kept below 10 μΩ (micro-ohm).

Following EEG preparations, participants were moved to a pre-marked spot 60cm away from the monitor. Participants were given both on-screen and verbal instructions, and an explanation of the task. They were also asked to keep their head still and refrain from blinking during trials. Participants could start each trial by pressing a button, so they could take short breaks as needed during the experiment.

The experiment involved four separate sessions: rest, meditation, rest, AB task. First, a resting state of one minute was performed, where the participants rest with their eyes closed. The sound of a bell would indicate the end of the resting session. This session was followed by a meditation session, where the participants would listen to a pre-recorded script of either FAM or OMM instructions, lasting approximately 17 minutes. The scripts were translated from Dutch to Norwegian (Colzato et al., 2015) and recorded by a Norwegian male native speaker. The meditation session was then followed by the AB task after a short break.

Each AB trial began with a centered fixation cross for 516ms, followed by a *Rapid Serial Visual Presentation* (RSVP) stream at the center of the screen, except for the right and left T2 stimuli (see Figure 1). Each item was presented for 66ms, with a 33ms interstimulus interval. T1 was presented at either the 5th or the 7th slide, whereas T2 was presented either at Lag 1 (0 distractors between T1 and T2 presentation), Lag 3 (2 distractors between T1 and T2 presentation) or Lag 8 (7 distractors between T1 and T2 presentation). Thus, T2 was presented on the 6th or 8th slide for lag 1, 8th or 13th slide for lag 3 and 13th or 15th slide for lag 8. A total of 18 slides were shown during a trial. Each stimulus was randomly selected for every trial and there were no repeats for T1 and T2. At the end of each trial, participants were instructed to type in the first and the second target. When missing a target or making a mistake, participants would type in the 0-key instead. After completing the task, a debrief followed. On average, the complete AB task lasted for 30 minutes.

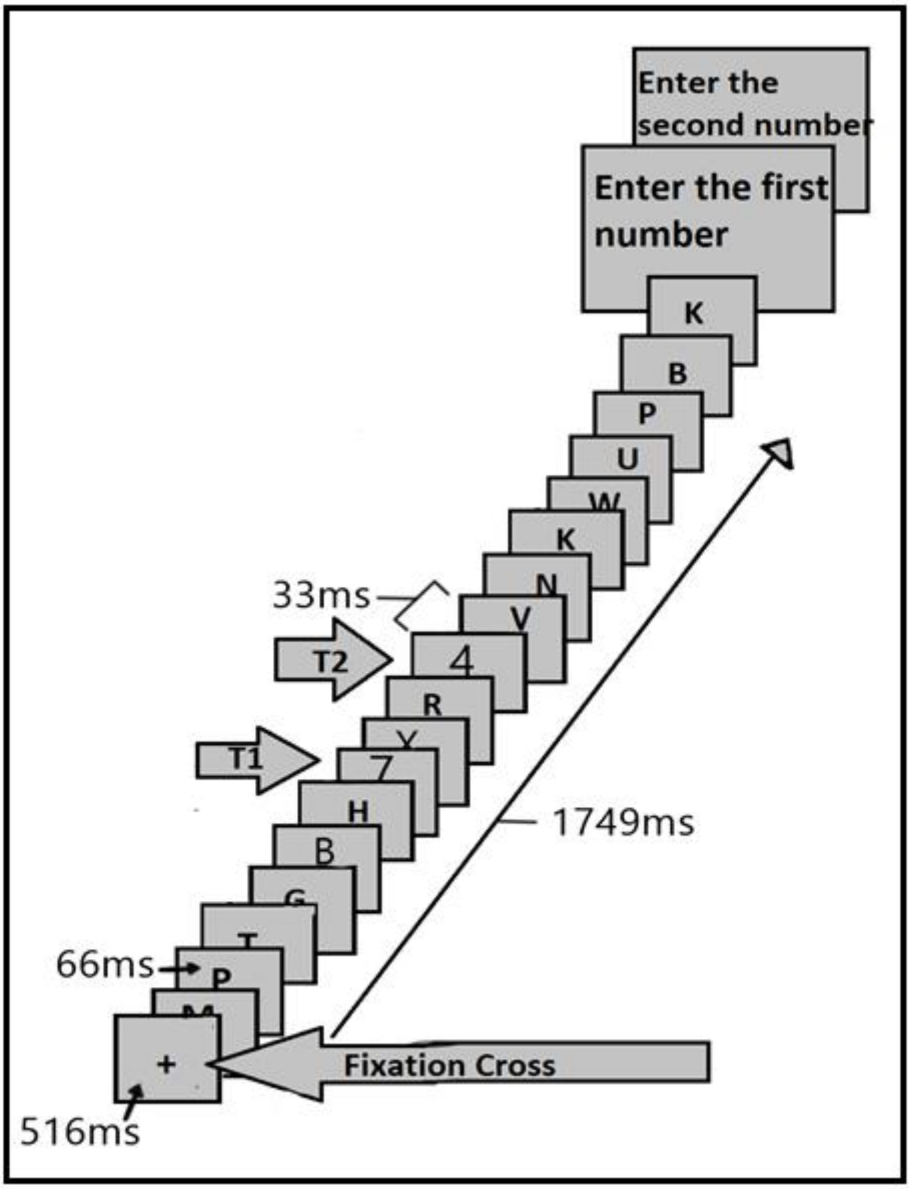


Figure 1. *Example of a typical trial. T2 (digit 7) follows T1 (digit 4) three slides apart (lag 3). In other trials, T2 appeared immediately after T1 (lag 1) or 8 slides apart (lag 8). Here, T2 appears in the center position, but in other trials it was presented 1.5° to the left or to the right of fixation.*

Results

12. Behavioral Data

The behavioral data were analyzed using Microsoft Excel and SPSS. Reporting T1 or T2 in the wrong order were considered as incorrect.

12.1 Accuracy.

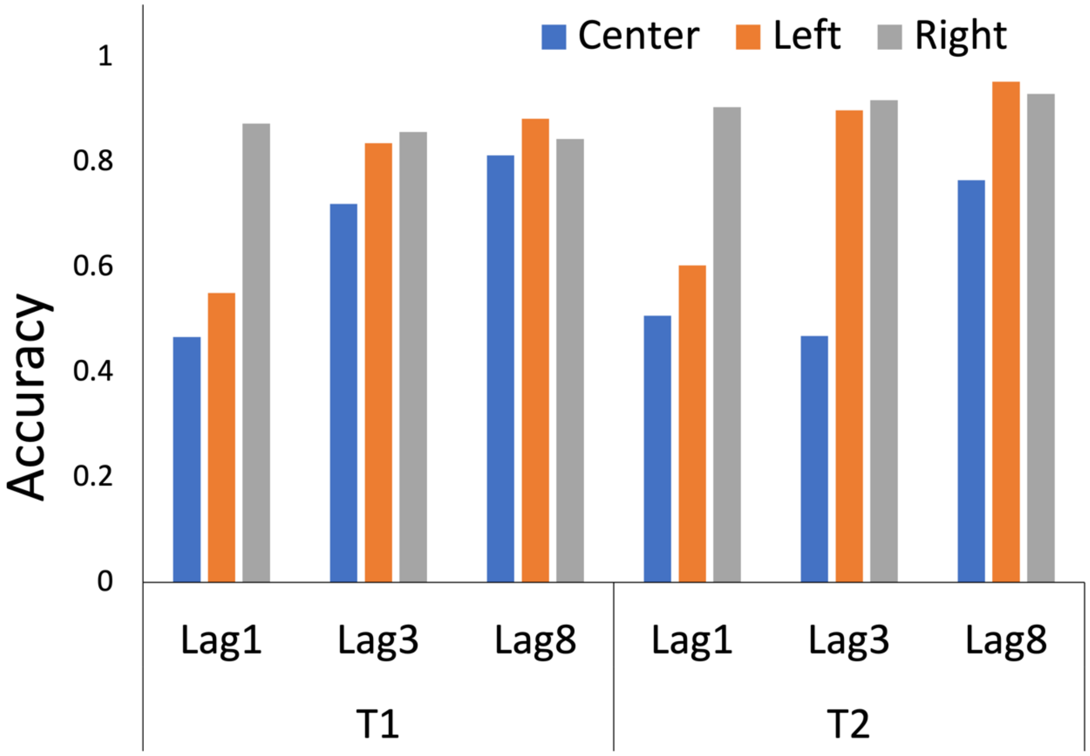
12.1 Accuracy. We compared the accuracy scores across T1 and T2 in a 2 (Target: T1 vs. T2) x 3 (Lag: 1 vs. 3 vs. 8) x 2 (Group: FAM vs. OMM) ANOVA for each of the three locations, with the first two factors within subjects and the last factor between subjects.

At the central location, the analysis yielded an interaction between target and lag, F (2, 60) = 59.28, $p < 0.001$, $\eta_P^2 = 0.664$. Bonferroni-corrected pairwise analyses revealed higher scores for T1 than for T2 at lag 3 (M = 0.756 vs. 0.525), F (1, 30) = 90.29, $p < 0.001$, $\eta_P^2 =$ 0.751 and at lag 8 (M = 0.838 vs. 0.794), F (1, 30) = 90.29, $p = 0.009$, $\eta_P^2 = 0.751$. In addition, we found that accuracy scores were higher for participants in the OMM group compared to participants in the FAM group, F (1, 30) = 5.00, $p = 0.033$, $\eta_P^2 = 0.143$.

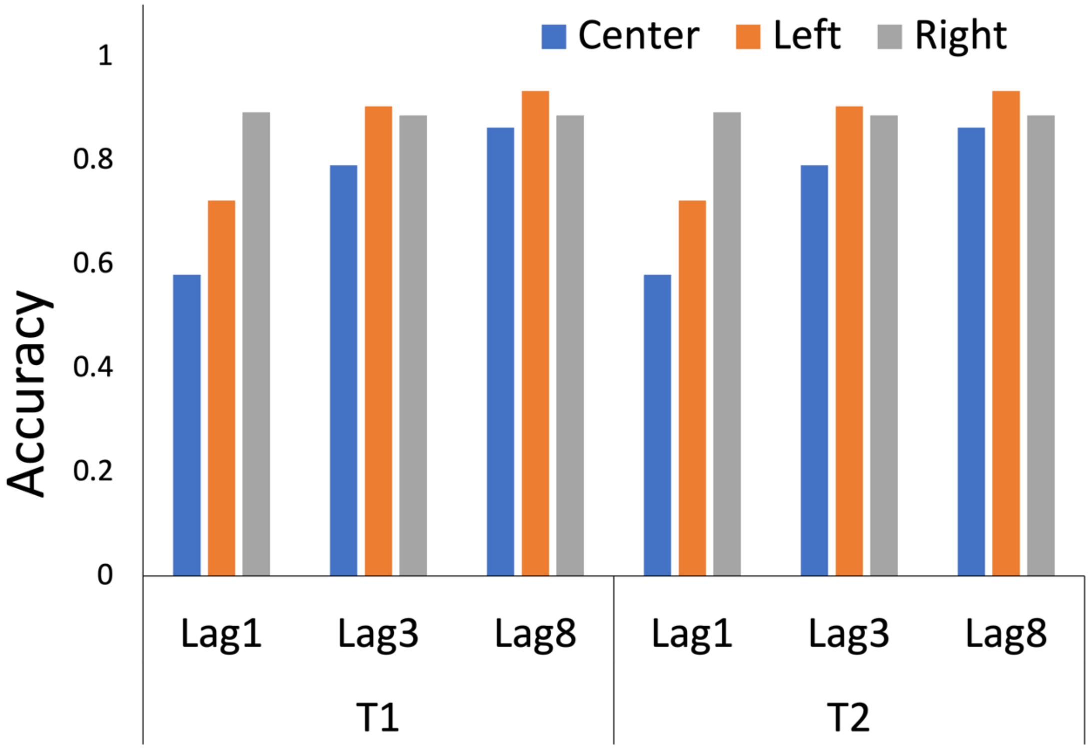
At the left location, the analysis yielded a main effect of target, with higher scores for T2 than for T1 across the board (M = 0.857 vs. 0.805), F (1, 30) = 52.55, $p < 0.001$, $\eta_P^2 = 0.637$, and a main effect of lag, with higher scores for lag 8 (M = 0.938) compared to both lag 1 (M = 0.659) and lag 3 (M = 0.896), , and also with higher scores for lag 3 compared to lag 1, F (2, 60) = 58.11, $p < 0.001$, $\eta_P^2 = 0.660$. There was no interaction between target and lag. In addition, we found that accuracy scores were higher for participants in the OMM group compared to participants in the FAM group, F (1, 30) = 6.78, $p < 0.001$, $\eta_P^2 = 0.184$.

At the right location, the analysis yielded an interaction between target and lag, F (2, 60) = 9.00, $p < 0.001$, $\eta_P^2 = 0.231$. Bonferroni-corrected pairwise analyses revealed higher scores for T2 than for T1 at lag 3 (M = 0.929 vs. 0.872), F (1, 30) = 23.12, $p < 0.001$, $\eta_P^2 =$

0.435 and at lag 8 (*M* = 0.949 vs. 0.865), *F* (1, 30) = 38.36, $p < 0.001$, $\eta_P^2 = 0.561$. There was no significant effect of meditation group, $p = 0.220$.



FAM Group



OMM Group

Figure 2. Average accuracy values (m) across conditions.

12.2 Reaction time. We next compared reaction time scores across T1 and T2 in a 2 (Target: T1 vs. T2) x 3 (Lag: 1 vs. 3 vs. 8) x 2 (Group: FAM vs. OMM) ANOVA for each of the three locations, with the first two factors within subjects and the last factor between subjects.

At the central location, we found an interaction between target and lag, F (2, 60) = 4.36, $p = 0.017$, $\eta_P{}^2 = 0.127$. Bonferroni-corrected pairwise analyses revealed faster responses to T1 at lag 8 (M = 1607 ms) compared to both lag 1 (1740 ms) and lag 3 (M = 1787 ms), F (1, 30) = 5.61, $p = 0.006$, $\eta_P{}^2 = 0.279$. T2 was responded to significantly faster than T1 at all lags, F (1, 30) = 5.61/72.17/125.86, $p < 0.001$, $\eta_P{}^2$ = 0.771/0.706/0.808. Further, we found no effects of meditation type on response times, $p = 0.665$.

At the left location, the analysis yielded a main effect of target, with faster responses to T2 compared to T1 across the board (M = 0.810 ms vs. 0.1469 ms), F (1, 30) = 158.70, $p <$ 0.001, $\eta_P{}^2 = 0.841$. Meditation type had no effect on response times, $p = 0.801$.

At the right location, the analysis yielded a main effect of target, with faster processing of T2 compared to T1 across the board (M = 811 ms vs. 1449 ms), F (1, 30) = 216.94, $p < 0.001$, $\eta_P{}^2 = 0.879$. Also, we found a main effect of lag, F (1, 30) = 216.94, $p = 0.031$, $\eta_P{}^2 = 0.109$, with faster responses to targets at lag 1 compared to lag 8 (M = 1106 ms vs. 1151 ms). There were no further significant response differences between lag 1 and lag 3, or between lag 3 and lag 8. As before, there were no effects of meditation type on reaction times, $p = 0.606$.

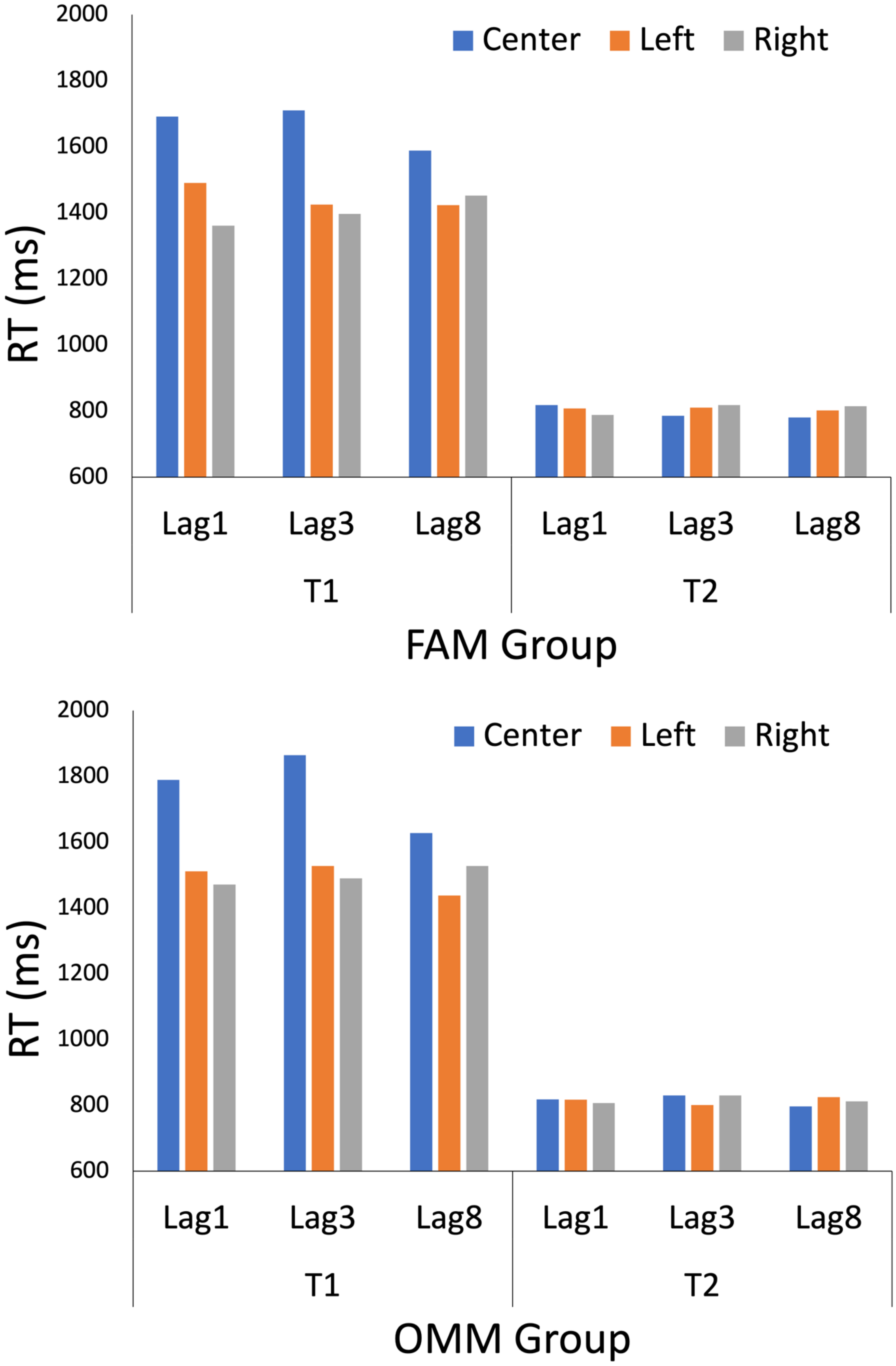


Figure 3. *Average reaction time values (ms) across conditions.*

13. EEG-Data

EEG data from -200ms prior to and until 1000ms post T2 onset were analyzed using the EEGLAB toolbox (Delorme & Makeig, 2004) v2021.0 in Matlab. Data were first filtered manually, followed by ICA decomposition for denoising. Permutations-based statistical analysis was applied with False Discovery Rate (FDR) correction at a p = .05 threshold.

13.1 T2 ERP amplitude and latency

We plotted and visualized grand average potentials associated to the OMM and FAM groups across lags and locations, recorded at all scalp channels relative to T2 onset. Figure 4 tracks the potential evoked by T2 when presented at the center of the screen. At lag 8, a P300 component was elicited at 420ms after SO, reaching 10.86 μV in the OMM group. A lower amplitude of the P300 was elicited in the FAM group at 426ms after SO, reaching 6.86□V. At lag 1, the magnitude of the P300 component in the OMM group was smaller, visible at 318ms after SO and reaching 5.46□V. In the FAM group, P300 latency is slightly longer, c at 434ms after SO, peaking at 4.46□V. At lag 3, neither FAM or OMM generate a clear cut P300 component, though a tendency is visible in the OMM group at 484ms, reaching 4.81□V. Topographic maps activation will also be investigated further below, which may offer more information on whether this activation is significant. Alternatively, ERP waves could be examined at several key electrode placements on the scalp (frontal, parietal, and occipital areas across hemispheres) to determine whether the amplitude and the distribution of the P300 component is similar. It may be the case that we are able to observe the component over some but not all scalp locations, which yield no clear result if averaged. Otherwise, this much-reduced activation of the P300 component within the AB is expected based on earlier studies showing no P300 component detectable within the blink, where T2 onset is likely to go undetected by conscious processes.

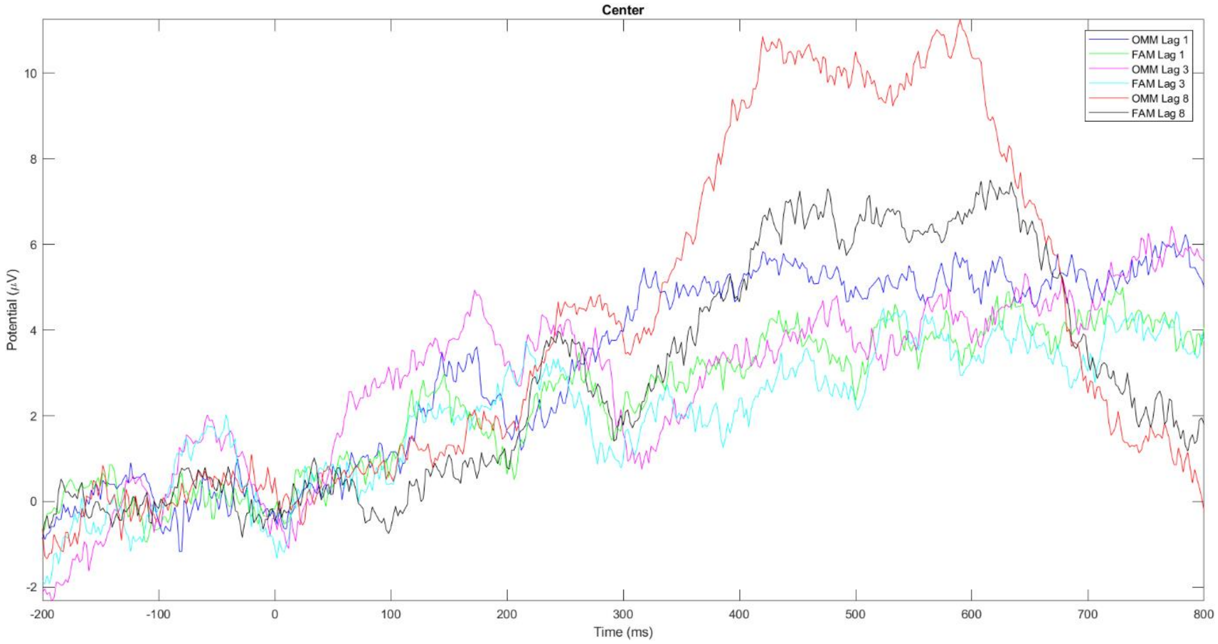


Figure 4. Average potential of all scalp electrode channels relative to T2 onset. Data are presented for OMM and FAM groups at lag 1, 2, and 3, when T2 is presented in the centre of the screen (time in ms on the x-axis, and amplitude in μV on the y-axis).

Figure 5 tracks the average potential evoked by T2 when presented to the left of the screen. At lag 8, T2 elicits a P300 component in the OMM group at 418ms after SO, peaking at 14μV. For the FAM group, a similar activation is elicited at 440ms, reaching 10.69μV. At lag 1, T2 elicits a P300 386ms after SO, reaching 8.4μV in the OMM group, and a peak P300 426ms after SO, reaching 6.99μV in the FAM group. Importantly, when T2 is presented at lag 3, a P300 is elicited 394ms after SO, reaching 8.15μV in the OMM group, and a P300 reaching 7.8μV 436ms after SO in the FAM group, which suggest that, targets presented off-center are consciously being detected despite their distribution within the AB.

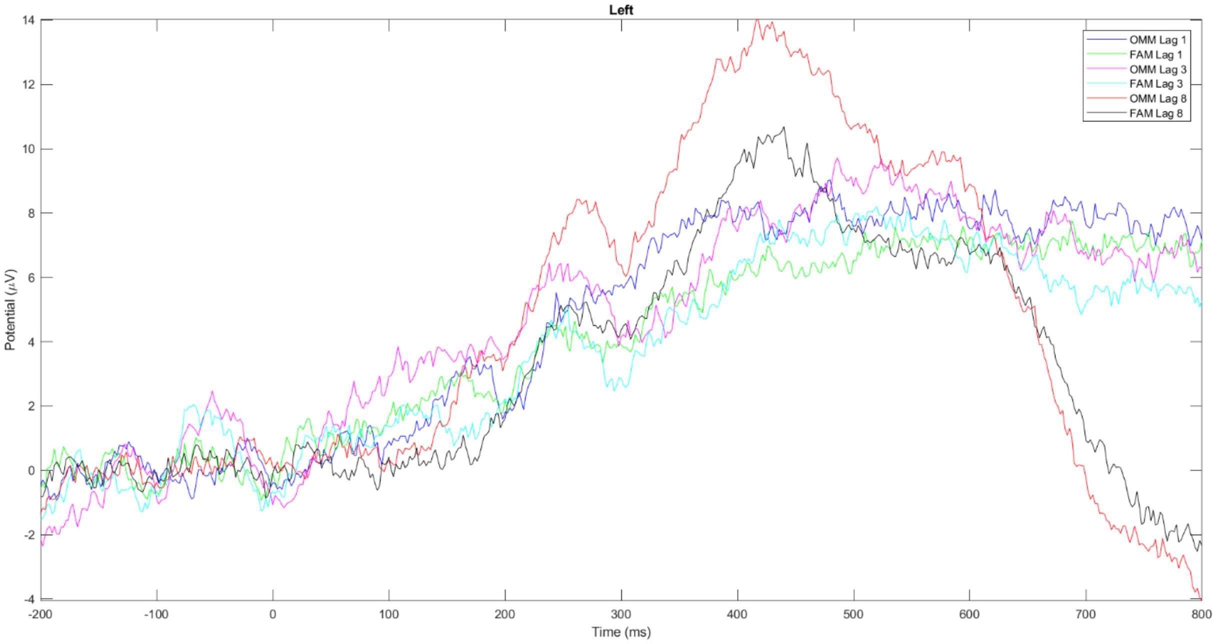


Figure 5. Average potential of all scalp electrode channels relative to T2 onset. Data are presented for OMM and FAM groups at lag 1, 2, and 3, when T2 is presented to the left (time in ms on the x-axis, and amplitude in μV on the y-axis).

A P300 component was elicited at lag 8 for T2 presented to the right onscreen, at 13.72μV, 420ms after SO, for the OMM group, as seen in Figure 6. For the FAM group, a P300 was elicited with the same timestamp, reaching 9.68μV. At lag 1, a peak latency of 8.82μV associated with the P300 component was elicited in the OMM group 346ms after SO, whereas in the FAM group the P300 is visible 416ms after SO, reaching a peak amplitude of 6.42μV. Again, at lag 3 we can observe a P300 component reaching 8.64μV 474ms after T2 onset in the OMM group, and 6.65μV 442ms after T2 onset in the FAM group.

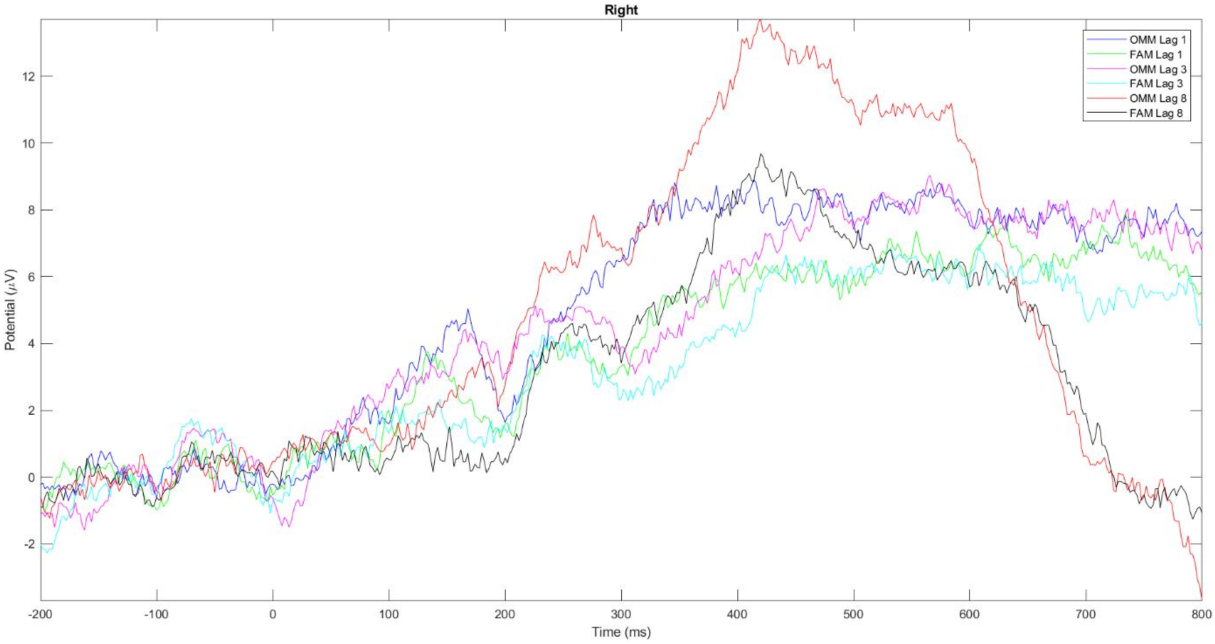


Figure 6. Average potential of all scalp electrode channels relative to T2 onset. Data are presented for OMM and FAM groups at lag 1, 2, and 3, when T2 is presented to the right (time in ms on the x-axis, and amplitude in μV on the y-axis).

13.2 Statistical analysis results from topographic maps. We plotted all scalp channels in in the form of EEGLAB topographic maps for two statistical designs. First, we briefly present the results of a 3 (lag: 1 vs. 3 vs. 8) x 2 (Group: 0 = OMM and 1 = FAM) ANOVA. Next, we detail the results for the main topic of the thesis relating to lateralization effects, by calculating of a 3 (location: Center vs. Left vs. Right) x 2 (Group: 0 = OMM and 1 = FAM) ANOVA across two time windows. In both analyses, the first factor was calculated within-subjects and the second between subjects. For the lag by group analysis, we investigated average activation for a time-window between 300-500 ms post T2 onset. For the location by group analysis, we investigated two time-windows pertaining to the P300 component, namely 300 to 400 ms and 400 to 500 ms after T2 onset. We calculated permutations with FDR correction at the $p < .05$ level to highlight the electrodes contributing to main effects and interactions.

13.3 T2-elicited P300 across lags at each location. In Figure 7, we can observe a main effect of group, with significantly more activation in the OMM than in the FAM group. There was no effect of lag and no interaction between factors. These results suggest that within- and outside-AB trials, and particularly for lag 3 vs. lag 8, had no differential effects for any of the two groups.

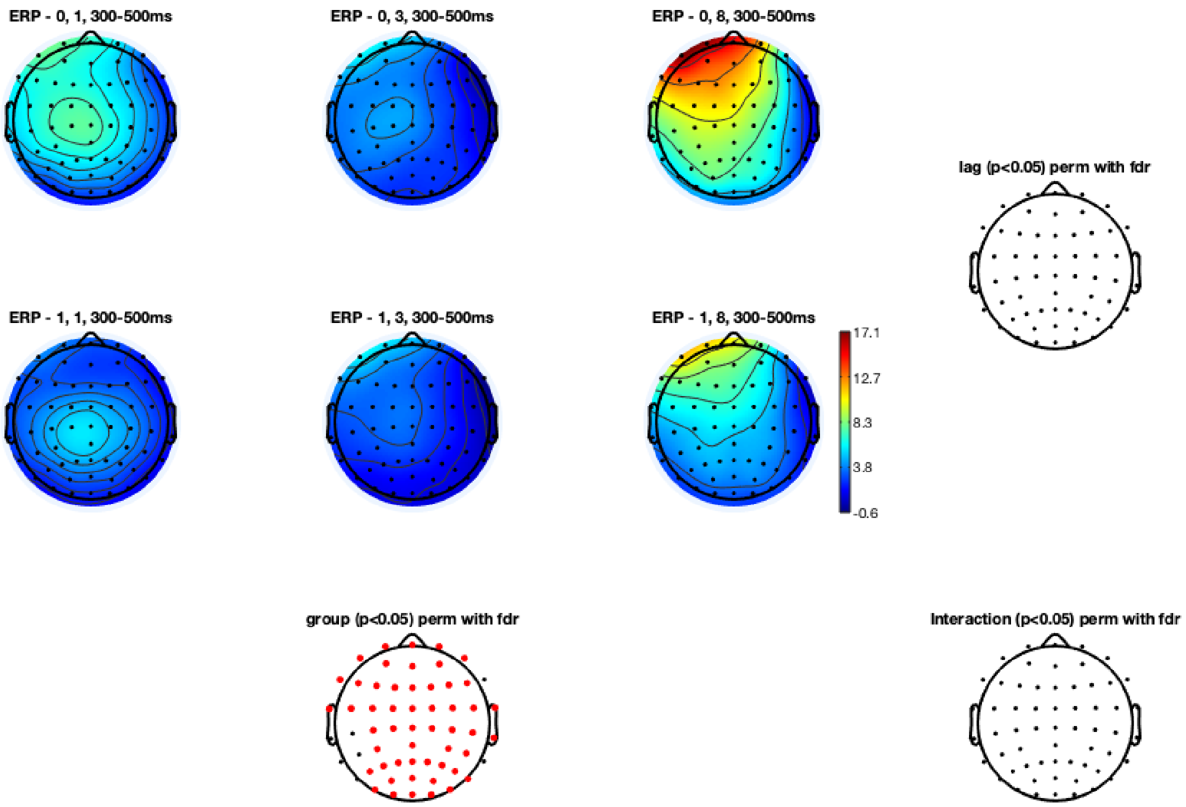


Figure 7. Average topographical maps of activity over 300-500 ms elicited by T2 presented at the centre for lag1, lag3, and lag8 and the two meditation groups (0 = OMM, 1 = FAM).

Figure 8 shows no main effects of either group or lag in trials where T2 appears to the left of the screen. This time, results suggest not only a lack of difference in activation for within- and outside-AB trials, and particularly for lag 3 vs. lag 8, but also a lack of difference between groups when processing peripheral stimuli.

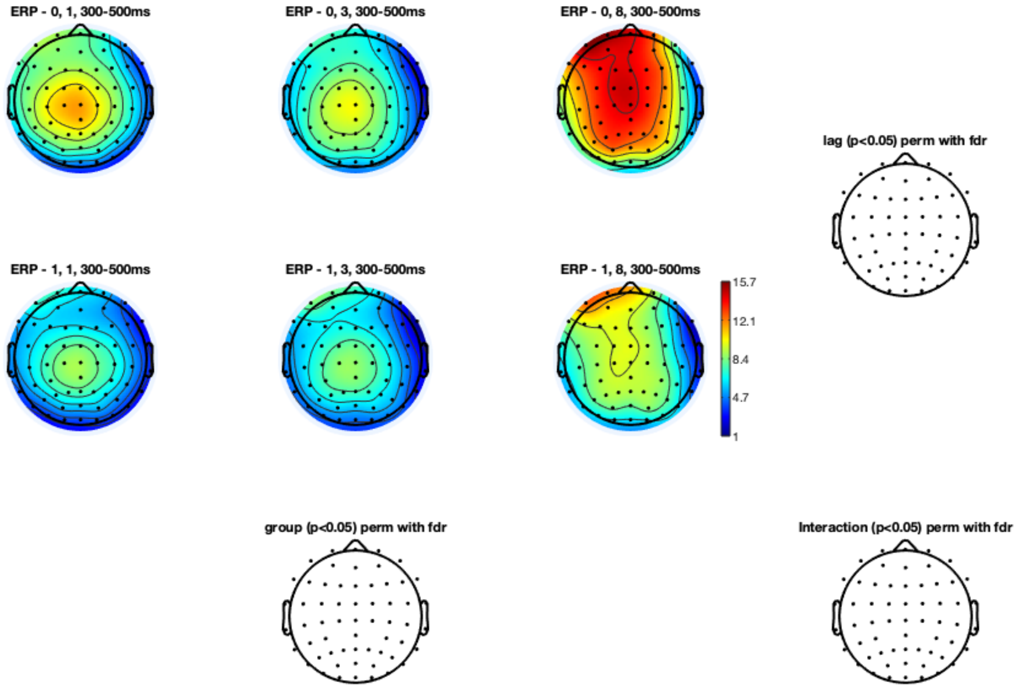


Figure 8. Average topographical maps of activity over 300-500 ms elicited by T2 presented at to the left for lag1, lag3, and lag8 and the two meditation groups (0 = OMM, 1 = FAM).

Save for a single electrode in the right occipital region across lags, Figure 9 shows no main effects for the P300 component elicited by T2 presented to the right of the screen. As before, the results suggest a lack of difference in activation for within- and outside-AB trials, and particularly for lag 3 vs. lag 8, as well as a lack of difference between groups when processing peripheral stimuli.

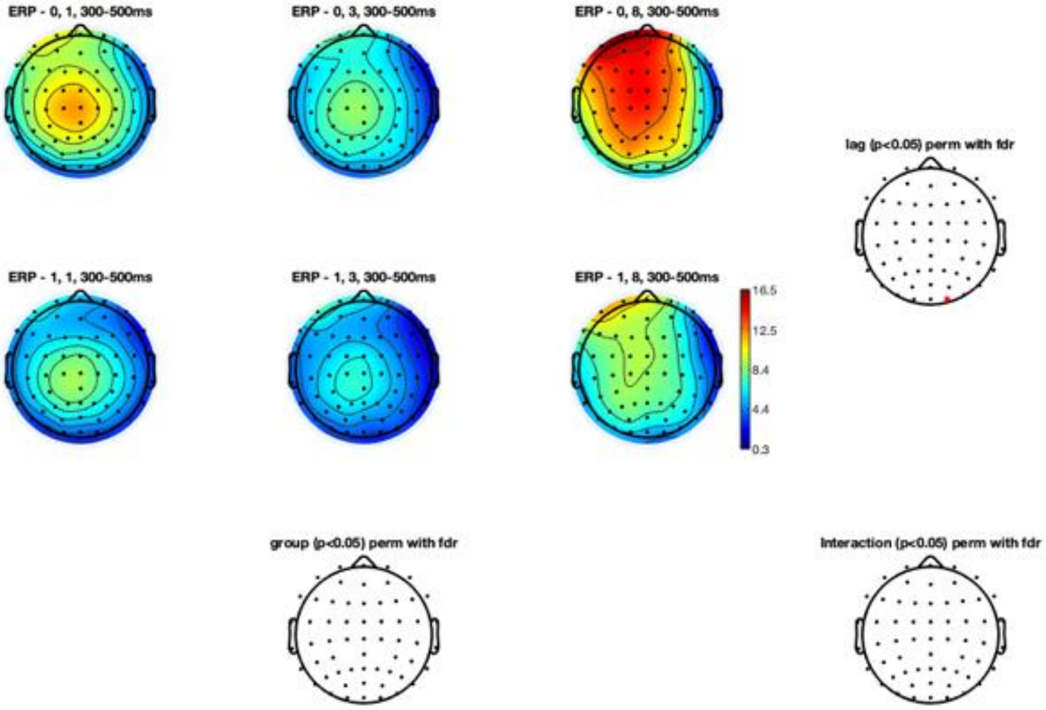


Figure 9. Average topographical maps of activity over 300-500 ms elicited by T2 presented at to the right for lag1, lag3, and lag8 and the two meditation groups (0 = OMM, 1 = FAM).

13.4 T2-elicited P300 at lag 1. Figure 10 shows average data elicited at lag 1 at 300-400ms after T2 onset. The topographical illustration highlights a difference between central and peripheral locations in both groups, as well as higher positive activity for the OMM group compared to the FAM group. Permutation analyses with FDR show a significant effect of location, at electrodes AFz and AF4 in the anterior-frontal area, the frontal area, excluding F7, F5, F6 and F8, frontocentral area, central area, centroparietal area, parietal area, excluding P7, parieto-occipital area, excluding PO7 and PO8, occipital area, excluding O1, and electrodes T7 and TP8. The analysis also shows a significant difference between the groups at electrodes in the right central area, the right centroparietal area, parietal area, excluding P7 and P5, parieto-occipital area, excluding PO7, and electrodes FC6, FT8, T8 and TP8.

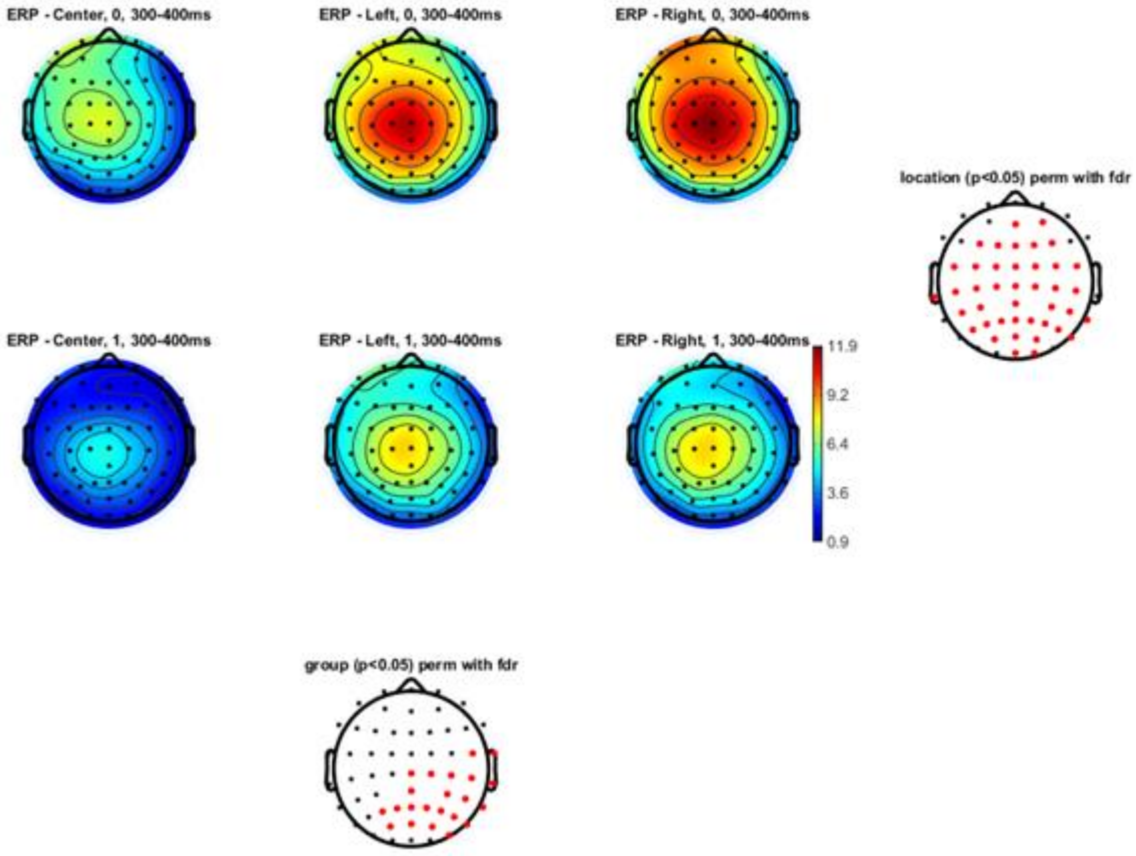


Figure 10. Average topographical maps of activity over 300-400 ms elicited by T2 at lag 1 for the center, left, and right location, across the two meditation groups (0 = OMM, 1 = FAM).

The permutation analysis over average data elicited at lag 1 at 400-500ms after T2 onset, presented in Figure 11, shows a significant effect of group at electrodes at occipital, parieto-occipital and parietal areas as well as at the right centroparietal and central area and electrodes CP3, C1, FC4, TP8 and T8. No significant effect of location was found at lag 1.

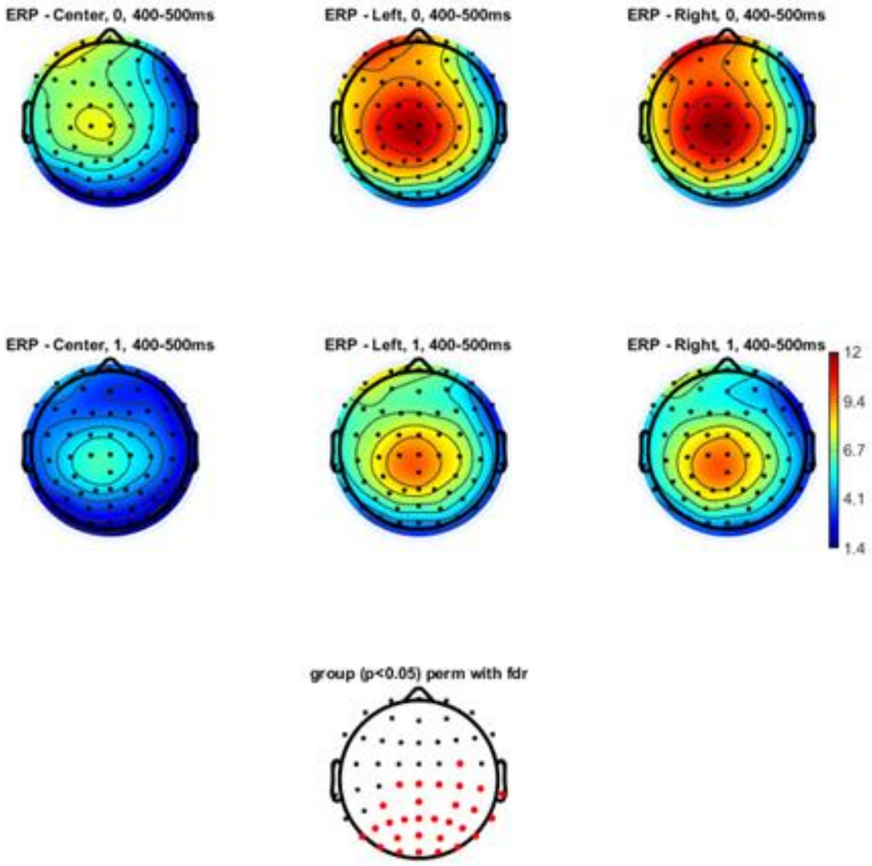


Figure 11. Average topographical maps of activity over 400-500 ms elicited by T2 at lag 1 for the center, left, and right location, across the two meditation groups (0 = OMM, 1 = FAM).

13.4 T2-elicited P300 at lag3. Visual inspection of the data elicited for lag 3 at 300-400ms after T2 onset, presented in Figure 12, shows increased activity for the left and right location compared to the central location, with overall higher values for the left. Permutation analyses, however, only reveal an effect of group, namely for electrodes in the occipital and parieto-occipital area, the parietal area excluding P7, the centroparietal area, the right central and frontocentral area, and TP8, T8, FT8, F6, F8 and C1.

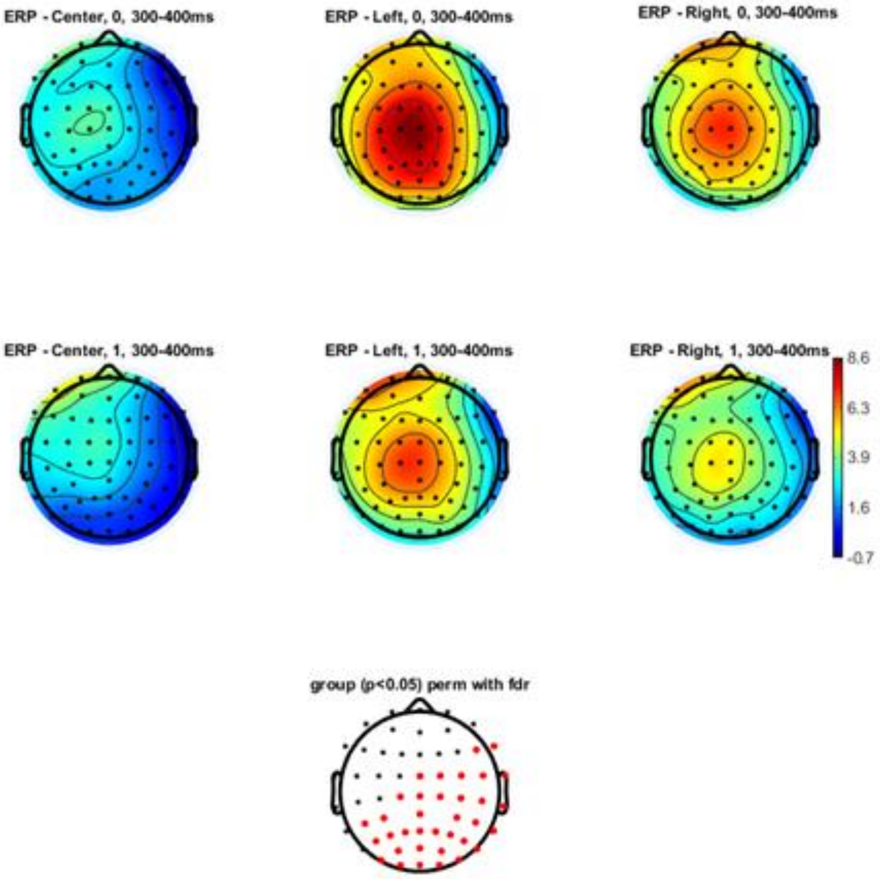


Figure 12. Average topographical maps of activity over 300-400 ms elicited by T2 at lag 3 for the center, left, and right location across the two meditation groups (0 = OMM, 1 = FAM).

As seen in Figure 13, ERP-data recorded at lag3 400-500ms after T2 onset shows significant activation for electrodes at the occipital, parieto-occipital, parietal, centroparietal area, and central area excluding C5, as well as at the right frontocentral area and at electrodes TP8, T8, FT8, F4, F6, F8 and FC1. Lag 3 is crucial for determining the effects of mediation type on AB magnitude, as it is the interval situated within the classical 200 to 500 ms time window after stimulus onset. We can therefore conclude without doubt that a brief OMM session significantly contributed to reducing AB magnitude.

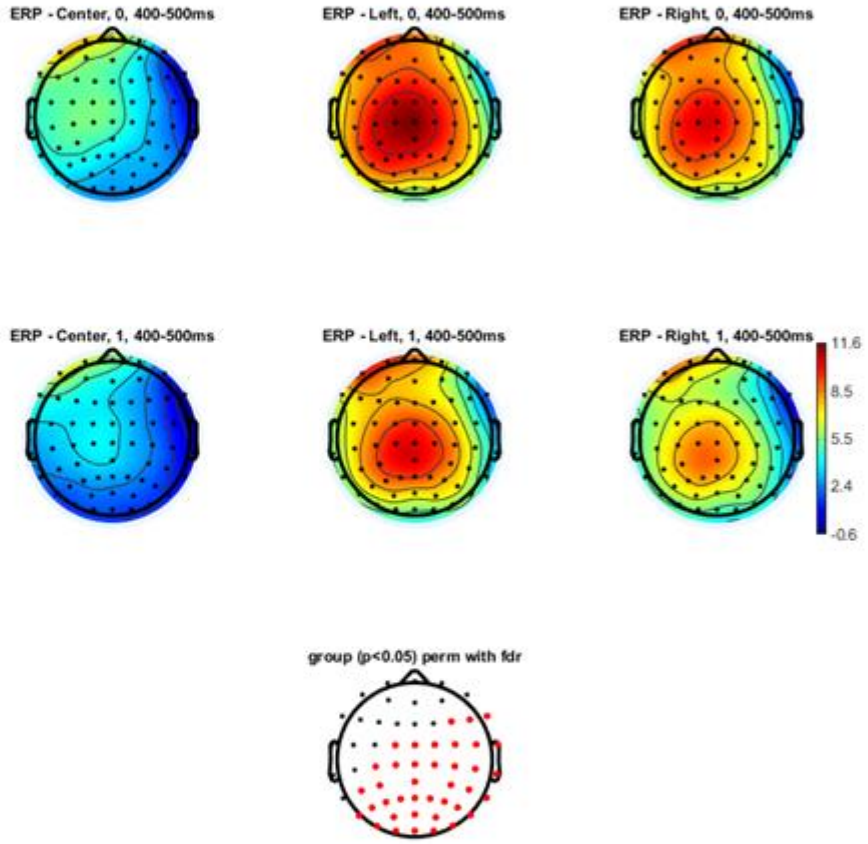


Figure 13. Average topographical maps of activity over 400-500 ms elicited by T2 at lag 3 for the center, left, and right location, across the two meditation groups (0 = OMM, 1 = FAM).

13.5 T2-elicited P300 at lag8. Overall, data for lag8 T2 recorded 300-400ms post T2 onset and presented in Figure 14 shows higher activity levels at peripheral locations compared to the central location. Permutation analyses revealed a main effect of group, with a significantly stronger signal elicited for the OMM group. The electrodes involved are situated at occipital, parieto-occipital and parietal areas, as well as at the right centroparietal area, in addition to TP8, C4 and C6.

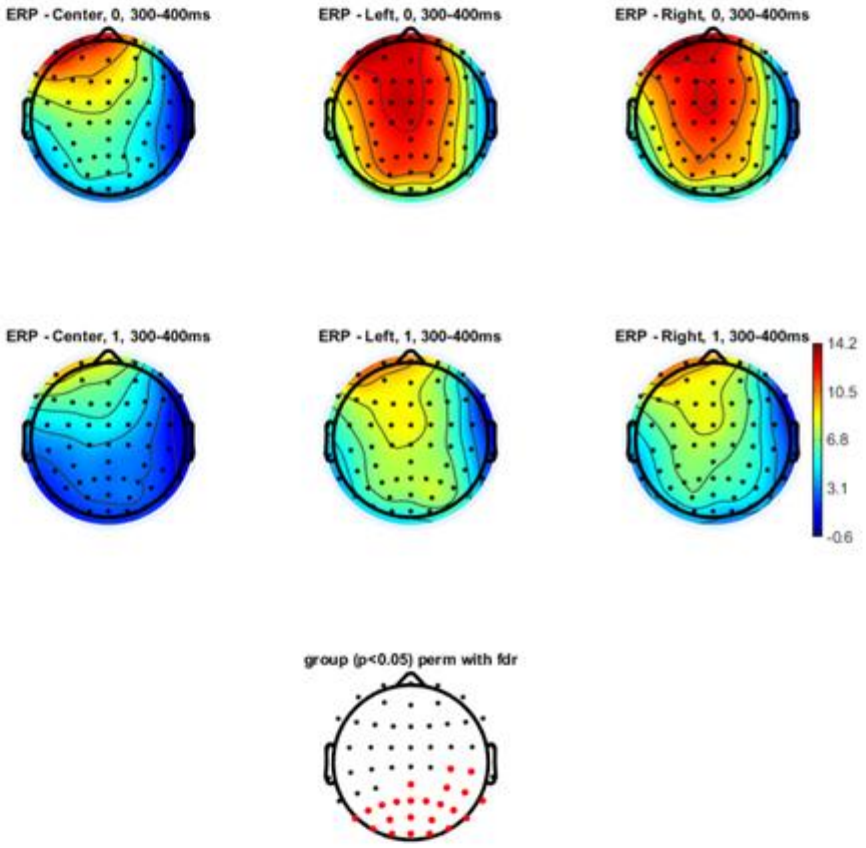


Figure 14. Average topographical maps of activity over 300-400 ms elicited by T2 at lag 8 for the center, left, and right location, across the two meditation groups (0 = OMM, 1 = FAM).

Visual inspection of the ERP-data for T2 presented at lag 8 and 400-500ms post stimulus onset, mainly shows differences between groups. However, permutation with FDR highlights a single electrode, P8, as being significant between groups, as seen in Figure 15.

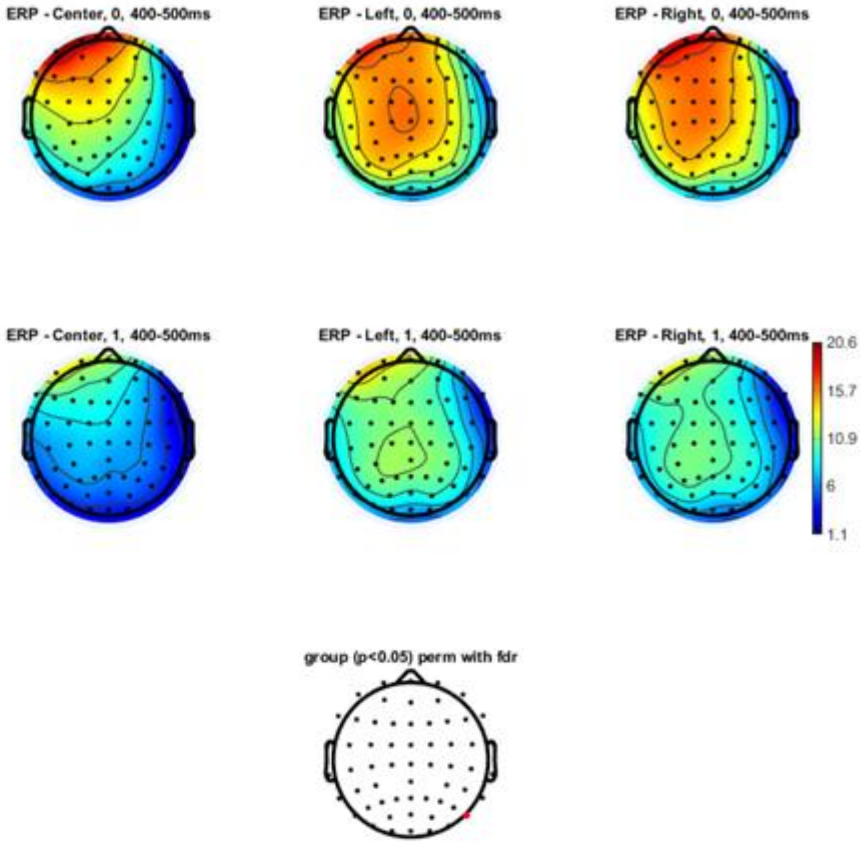


Figure 15. Average topographical maps of activity over 400-500 ms elicited by T2 at lag 8 for the center, left, and right location, across the two meditation groups (0 = OMM, 1 = FAM).

So far, we have discussed differences across groups and across central and peripheric locations for the P300 component, which is reported in the literature as an important marker of selective attention. However, it may be the case that the factors investigated in our analyses also have an influence on activity elicited before and after the 300-500 ms time window, thereby involving further ERP components, such as the P200, the P300 and tha N400 that would help us draw further conclusions about AB processing. We present in Figure 16 topographic data at lag 3 for all locations, calculated from 0 to 1000 ms after T2 onset, in bins of 100ms. We include this information simply as the start of an exploratory analysis, for understanding attentional resource allocation. The figure also illustrates how T1 processing is already engaged (0-300ms) before the T2 P300 component time window. Desynchronization is also observed at 500-1000ms.

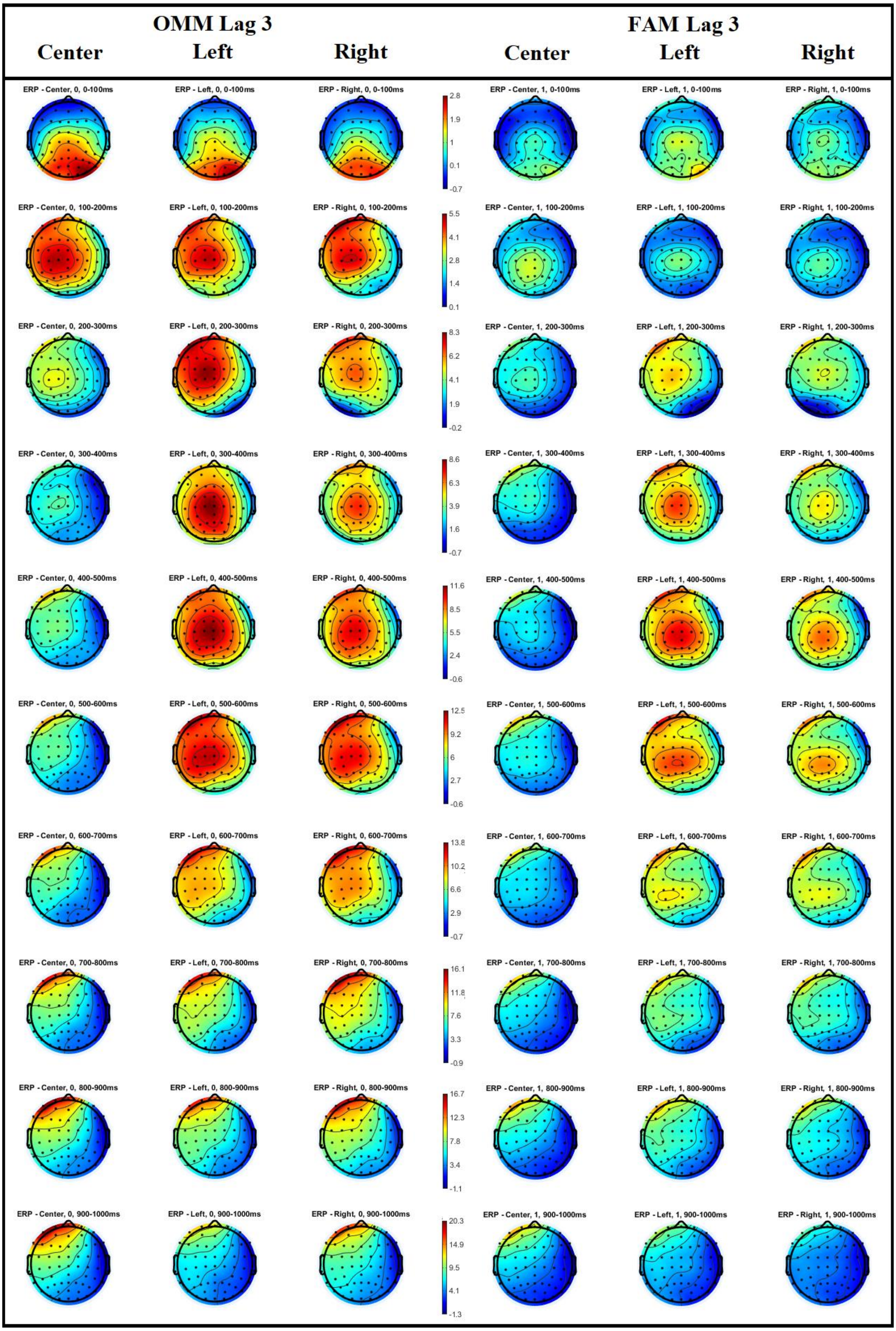


Figure 16. *Average activation of OMM and FAM groups at 0 – 1000ms after T2 onset at lag 3 for each one of the three locations (center, left, and right).*

14. ERSPs

After plotting channel measures, permutation statistics were calculated to detect main effects and marginal means using permutations at the $p < 0.05$ level with false discovery rate (FDR) corrections. ERSP plotting options were set to 250-600ms, yielding data from 355-443ms after SO. Frequency range were set to delta (0-4Hz), theta (4-8Hz), alpha (8-13Hz) and beta (13-30Hz). Gamma frequency bands from (30-100Hz) were also examined in intervals of 10Hz. We plotted average/RMS of all scalp electrodes and report only significant effects of group (OMM, FAM), lag, and interaction between them in the 300-500 interval after T2 onset.

14.1 Main effects. As seen in figure 17 below, there are significant group effects in the delta bands for all locations, possibly with stronger effects at peripheral locations. (Center *dB* = .46, Left *dB* = .6, Right *dB* = .49.). Investigation of theta main effects revealed differences between the groups when T2 was presented in the peripheral visual fields. We also found group effects, except for a brief moment at 395ms, in theta bands for both conditions. In trials where T2 are presented to the right, group effects span frequencies of 4-6Hz respectively. (Left *dB* = .57, Right *dB* = .5). Looking at beta frequencies, we found a main effect on the interaction between group and lag for central T2 at frequencies of 18.5-22Hz and 24.5-26Hz, occurring at 355-380ms and 400-440ms. (Center *dB* = .51). For gamma frequencies, we report a main effect between groups at frequencies of 32-40Hz, from 355-380ms and 400-443ms when T2 was presented at the central location. An even stronger effect was found at frequencies of 80-87Hz, from 360-390ms and 410-443ms for the right visual field. (Center *dB* = .59, Right *dB* = .73).

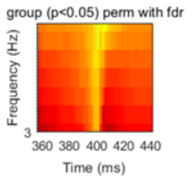
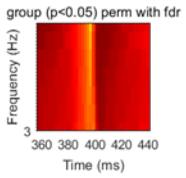
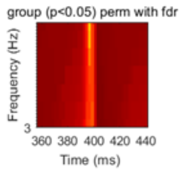
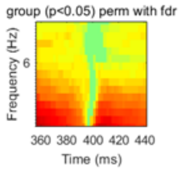
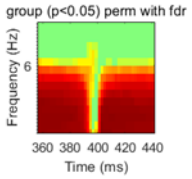
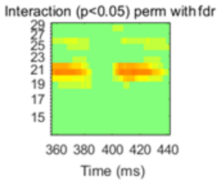
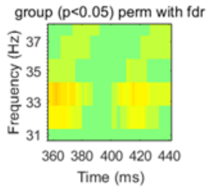
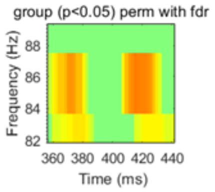
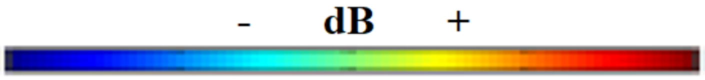
Main Effects	**Group for central T2**	**Group for left T2**	**Group for right T2**	**Interaction between group and lag for central T2**
Delta				
Theta				
Alpha				
Beta				
Gamma				
				

Figure 17. *Shows significant main effects in band frequencies delta (0-4Hz), theta (4-8Hz), alpha (8-13Hz), beta (13-30Hz) and gamma (30-100Hz) based on T2 location, based on statistically significant group differences, and interaction between group and lag. Empty cells stand for non-significant effects.*

14.2 Marginal means. Figure 18 highlights ERSP effects when marginal means statistics are applied. When T2 was presented at the center, we identified a within-group effect in the OMM group. When T2 was presented at the periphery, we identified a within-group effect for both OMM and FAM. (Center *dB* = .46, Left *dB* = .6, Right *dB* = .49). Examining theta marginal means revealed an effect in the OMM group in frequencies of 4-5.5Hz, stretching from 355-390ms and 400-443ms, due to the temporal presentation of T2, in trials where T2 was presented to the left. Marginal means highlight a lag effect in both OMM and FAM groups when T2 is presented to the right. The effect is stronger in the OMM group compared to the FAM group in frequencies of 4-6Hz at the timeframes 355-390ms and 400-443ms. The FAM group shows effects mainly in frequencies of 4-6Hz, at 355-380ms and 400-420ms. (Left *dB* = .57, Right *dB* = .5). Marginal means where T2 was presented at the central location, at gamma frequencies of 30-34Hz, 355-390ms and 400-443ms, revealed an effect in the FAM group due to differences of T2 lag. There was also a significant effect in frequencies of 80-83Hz occurring at 355-390ms and 410-443ms for the OMM group, also due to T2 lag differences. (Center *dB* = .59, Right *dB* = .73).

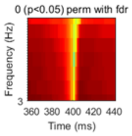
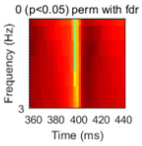
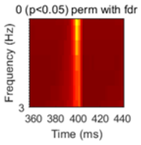
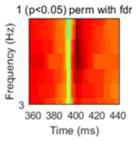
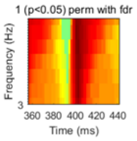
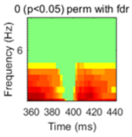
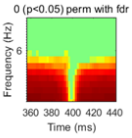
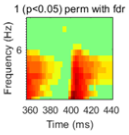
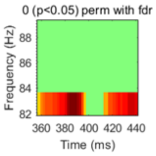
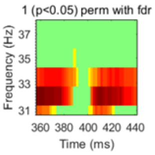
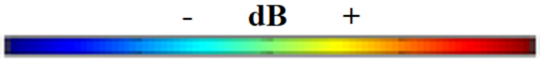
	OMM			**FAM**		
Marginal Means	**Lag for central T2**	**Lag for left T2**	**Lag for right T2**	**Lag for central T2**	**Lag for left T2**	**Lag for right T2**
Delta						
Theta						
Alpha						
Beta						
Gamma						
						

Figure 18. *Shows significant marginal means in band frequencies delta (0-4Hz), theta (4-8Hz), alpha (8-13Hz), beta (13-30Hz) and gamma (30-100Hz) based on T2 location, comparing OMM and FAM groups to identify within-group effects due to lag. Empty cells stand for non-significant effects.*

Discussion

15. General discussion

In this study, we report significant behavioral and neurophysiological effects for individuals without prior experience of meditation of a brief meditation session, either FAM or OMM in an AB task. The OMM group had a higher T1 and T2 recognition rate than the FAM group, indicating that OMM induces a different state of mind compared to FAM, as highlighted in previous studies (Lippelt et al., 2014; Lutz et al., 2008; Tops et al., 2014; Vago & Silbersweig, 2012; Valentine and Sweet, 1999). The results also feature the importance of T2 lag, and the interaction between factors when T2 is presented 1.5 degrees to the left or to the right of fixation. Overall, peripheral location was associated with higher T1 and T2 response accuracy, most likely because peripheral targets are easier to notice than central targets, as they afford abrupt onsets in an RSVP where the stream is presented in the center. Interestingly, although T1 was always presented in the center, T2 location affected T1 recognition rates.

When comparing accuracy for T1 and T2 at the central location, T1 scores are clearly higher than T2 scores. However, for peripheral trials, the reverse is true, with higher T2 recognition accuracy for T2 than for T1. Furthermore, both types of meditation affect target recognition both within and outside the AB, thus at lags 1, 3, and 8. Specifically, lag 3 and lag 8 data is similar across groups, with participants in the OMM group scoring significantly higher. on accuracy. These findings imply that OMM participants experience no AB at the central location. Indeed, at the left and right location we can even observe a reverse AB that is, lag 3 accuracy is higher than lag 1 accuracy, for example.

Furthermore, our results contribute to previous studies on AB by confirming a left visual-field advantage over central locations (Holländer et al., 2005). However, our behavioral results also suggest a right visual-field advantage over the left (Bergerbest et al., 2017). Indeed, pairwise comparisons between accuracy scores for T2 across locations highlight a significantly higher T2 recognition rate for the right location compared to both the central and the left location, which in turn indicates an attention-related lateralization pattern where information processed in the left hemisphere reduces AB magnitude. Unsurprisingly, T2 recognition scores outside the AB (lag 8) resulted in higher accuracy across locations. The results further show no lag 1 sparing (Potter et al., 1998) for peripheral trials, thus confirming previous reports that a change in location cancels the effect (Bergerbest et al., 2017; Visser, Bischof, & Di Lollo, 1999; Visser, Zuvic, et al., 1999). As for the interaction between location and meditation, T2 recognition rates show a tendency and a strong effect size, but no statistically significant effect. A possible interaction would indicate a difference between left and right location, with participants in the OMM group showing a different lateralization patterns compared to participants in the FAM group. Nevertheless, we obtained a significant interaction between T2 location and meditation when looking at T1 recognition rates, indicating that both meditation type and T2 location impact the ability to accurately report T1.

For T2, accuracy was higher at later lags, although participants in the FAM group performed worse at the central location at lag 3 than at lag 1, suggesting lag 1 sparing due to T1 and T2 being processed together (Potter et al., 1998). For T1, accuracy increased from lag 1 to lag 3 in both the OMM and the FAM group suggesting that, for lag 3, participants in the FAM group prioritized T1 over T2 processing. These findings fail to corroborate the original two stage model proposed for AB, where the first target as the first encoded information should be overwritten by the second target (Chun & Potter, 1995). Furthermore, according to the two-stage competition model by Potter et al. (2002), T2 should surpass T1 in the processing queue, which is not something our findings support, unlike reports by Giesbrecht and Lollo (1998), who found that trailing masks overwrite the representations of target stimuli without interfering with first stage in WM processing. Thus, T2 would escape detection because WM is busy processing T1. An alternative would be to look at the results in light of the inhibition model and explain the AB effect at lag 3 for the FAM group as being the result of the attentional gate being closed off (Raymond et al., 1992). Nevertheless, as both TLC hypothesis and delayed selection processes suggest, less attentional resources being available is unlikely to be the reason for the AB (Di Lollo et al., 2005; Nieuwenstein, 2006; Nieuwenstein et al., 2005). Hybrid models (Vogel et al., 1998) are more likely to fit our data , as our results indicate higher accuracy at later lags except for T1 when T2 is presented in the right visual field.

Two-stage formal accounts of AB such as the one by Chartier et al. (2004) would imply that the AB observed in the FAM group would be due to an ongoing inhibition process and slow recovery rate after T1 presentation. It is a suitable idea, which further explains why recognition rate for T2 is lower than for T1 for central locations at lag 3. Nevertheless, other models and theories are equally suitable. First, CODAM would explain these results as an inhibition of the T2 processing boost until the IMC no longer emits a discharge (Fragopanagos et al., 2005). Second, the AB findings in our study could be explained in the LC norepinephrine framework as a consequence of the refractory period occurring after T1, which leaves LC unresponsive to T2 (Nieuwenhuis et al., 2005). Third, the eSTST model would explain the AB as a consequence of an ongoing binding process of T1 to a suitable token, triggering T2 suppression and therefore the AB (Wyble et al., 2009). Finally, the cascade model could also be a viable alternative, where the encoding processors capacity only allows T1 to be fully processed at early lags, thus leaving T2 vulnerable to decay and interference (Shih, 2008).

As for lag 1 sparing, there is only one case where we observed this effect, namely in the FAM group when T2 is presented at the center. Reduced performance at lag 3 compared to lag 1 could be explained by the boost and bounce theory (Olivers & Meeter, 2008), where the input filter in WM allows processing of T1 and a T1 + 1 distractor. Alternatively, the threaded cognition model could explain the observed lag 1 sparing as protecting T1 consolidation (Taatgen, Juvina, Schipper, Borst, & Martens, 2009).

Based on the literature, several accounts offer plausible explanations for the AB as reported in our study, which may be due to them all tapping the same neural network. However, while these accounts explain trials where T2 is presented at the center, there is no explanation for why trials where T2 are presented at the periphery are less susceptible to the AB effect, nor for why there should be a left or a right visual advantage, let alone for why different types of meditation affect performance in different ways. We therefore need to look closer at the impact of neural networks and the effects of meditation on attention by examining the EEG data.

T2 -elicited P300 amplitude and latencies for the central location indicate a significant effect at lag 8 for both meditation groups. At first sight, neither of them is associated with a clear P300 component when T2 is presented at lag 3, where AB is most likely to occur, suggesting that the T2 was most likely missed (Kranczioch et al. 2003). However, topographic map analyses do not fully support this conclusion. Although slightly reduced, a P300 component is observed when T2 is presented at lag 1. Comparing the potential amplitude with the behavioral data, where we found the lowest T2 accuracy scores for the central location at lag 3, it seems that a lower potential or lack of a P300 component is associated with a higher chance of an AB, with the reverse indicating better processing. This becomes even clearer when comparing lag 3 and lag 8 trials, where the difference in amplitude is the highest within groups. These results are compatible with Kranczioch et al. (2003), who reported a connection between unreported T2 and the lack of an P300 component. Earlier studies would attribute higher potential levels in lag 1 compared to lag 3 to lag 1 sparing (Potter et al., 1998). Interestingly, behavioral data for the OMM group shows the same mean accuracy in lag 1 and lag 3.

The subcomponents of P300, the P3a (Snyder & Hillyard, 1976) and P3b (Squires et al., 1975) have been linked to early attention processing in frontal working-memory representational change and to transmission of attention-driven stimulus respectively (Polich, 2007). Our data suggests that the initial peak of activity in frontal areas later shifts towards parietal and temporal areas, which agrees with the suggested patterns of the P3a and P3b components mentioned in Polich (2007). Topographical data matching the AB frame indicated that there were significant group effects in all trials from 300-500ms after SO, and a location effect for trials where T2 appear at lag 1. This also corresponds with the behavioral data. To boot, it seems that for all trials, the potential levels are higher in the OMM group in general. Interestingly, the topographical data from lag 3 trials seems to indicate higher potential levels when T2 is presented to the left, which would indicate a left visual field advantage, not reflected in the behavioral data. Therefore, we may infer that the topographical data alone does at the level of the P300 component does not explain away the behavioral results.

In trials where T2 was presented to the left, amplitude was higher for lag 8 compared to lag 1 and lag 3. The highest peak of the P300 is seen at lag 8in the OMM group followed by the FAM group. Compared to behavioral data, lag 8 trials were the ones with the highest T2 recognition rate, which in turn is reflected in figure 2.2. As for Lag 1 there is also a P300 component for both OMM and FAM, with the first being at a higher amplitude than the latter, thus supporting the hypothesis of OMM having a greater impact on mental processing compared to FAM. As for trials where T2 is presented in the right visual field, again lag 8 yields the highest potential amplitude, with a higher peak elicited in the OMM group than in the FAM group. Behavioral data further supports these findings, with lag 8 exhibiting higher T2 recognition rates. As seen in trials presenting T2 to the left, the lag 1 and lag 3 also elicit a P3a component, with a higher peak in the OMM group compared to the FAM group. For lag 3, a change in amplitude patterns is clear compared to trials where T2 was presented at the central location. The P3a component is observable in both OMM and FAM in lag 3 trials. This change in amplitude patterns is likely due to the change in T2 location and is supported by behavioral data indicating that when a target is presented in the peripheral view, the AB is less likely to occur.

The interacting neural networks underlying attentional control proposed by Corbetta and Shulman (2002) consist of the IPs-FEF network and the TPJ-VFC network, functioning in a top-down fashion. As the participants in this study attends expected stimuli, the IPs-FEF network should be activated, yielding activity in corresponding brain areas. The TPJ-VFC, lateralized to the right hemisphere, should not be activated as much, as stimuli are not considered unexpected per se. Based on Colzato et al. (2015), where FAM strengthens top-down control and OMM weakens it, one would expect to see higher potential levels in FAM trials. In this study however, OMM participants exhibited stronger ERPs in general and performed better on the AB task. Furthermore, studies on meditation and attention consistently report different effects related to OMM compared to FAM, where OMM clearly induces a stronger effect on attentional control and increases cognitive performance on AB tasks due to the nature of the technique (Lippelt et al., 2014; Lutz et al., 2008; Tops et al., 2014; Vago & Silbersweig, 2012; Valentine & Sweet, 1999). Therefore, other mechanisms might come into play. Both S-ART and PARCS offer possible explanations. The frontoparietal neural networks in S-ART could account for early activity in frontal regions, and the differences observed between OMM and FAM could be explained by modulation of the self-specifying and NS network (Vago & Silbersweig, 2012). According to PARCS, one would expect to see increased activity in AI, due to the nature of the AB task, where OMM would contribute to increases mental resilience - in this case increased T1 and T2 recognition. Alternatively, FAM would likely increase reactive control to stimuli, inhibiting performance. Looking at the topographic images of T2 presented at lag 1, lag 3 and lag 8, 300-400ms and 400-500ms after SO, there were significant group effects across trials, supporting all former claims related to different effects achieved through FAM or OMM. Furthermore, a significant location effect was also present for T2 presented at lag 1, 300-400ms. This effect is further corroborated with the significant behavioral results for T2 location.

Behavioral data alone lack a clear indication for why a right visual field advantage was present. Therefore, in this study, we performed ERSP analysis which revealed significant main effects in delta, theta, beta and gamma bands for T2 location and for marginal means of T2 lag. The main group effects in delta frequencies across all locations were expected based on previous studies (Cahn et al., 2010; Tei et al., 2009; Yordanova et al., 2020). The differences in marginal means are also expected, though surprisingly enough, there were no significant effects in the FAM group when T2 was presented at the center. Furthermore, the effects in the FAM compared to the OMM group are smaller, which would indicate that the FAM technique did not alter the mindset of the participants as efficiently as OMM did. As for the main effects in theta frequencies indicating significant differences when T2 is presented to the right as opposed to the left, no such differences were observed for targets at the central location. Significant effects in theta frequency bands have been previously reported, specifically in the left hemisphere (Yordanova et al., 2020), which corresponds to the right visual field and the advantage revealed in this study.

Marginal means compared between the OMM and the FAM group across locations were only significant effects when T2 was presented to the left visual in the OMM group. This could imply, according to bottleneck models, that the amount of attentional resources allocated to the task at hand were higher for T2 presented to the right, than to the left or at the central location. Furthermore, the significant effects on gamma bands for T2 presented at the central and right location could be linked to target recognition. However, frequencies differed quite substantially, with significant effects at the central location occurring at 30-40Hz, while for the right location occuring at 80-90Hz. Nevertheless, it is not unreasonable to assume that these effects in gamma bands could impact recognition rates. Furthermore, marginal means effects in gamma frequencies were present in trials where T2 was presented to the right in the OMM group at 80-83 Hz, and at the center location in the FAM group at 30-34Hz, which suggests that effects in higher gamma band frequencies signal a change in attention allocation. As for the interaction between group and lag for central T2 in beta bands, it could be the same effect observed in Yordanova et al. (2020), who reported enhanced beta coherence in the left hemisphere for OMM group and in the right hemisphere for FAM. However, when looking at marginal means, no significant effect was found in beta band frequencies.

16. Conclusion

Behavioral and EEG evidence reveals, for the first time, that a single brief meditation session administered to novices has distinct effects not only on behavioral correlates of AB magnitude, but also on EEG attention markers, including higher P300 amplitude for the OMM versus the FAM type and location specific ERSP effects across several frequency bands. By combining the behavioral and EEG data, this study adds to current knowledge in the field of attention control including brain lateralization and could be taken as a reference point for studies of attention disorders.

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