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Using meditation to improve measures of attention in older adults

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Abstract

Age-related cognitive decline greatly impacts quality of life for older adults. Previous research has indicated that meditation may act as a neuroprotective factor to prevent age-related cognitive decline. This thesis sought to replicate previous findings and investigate if a four-week meditation intervention would improve sustained attention. Participants 60 years and older (n=27, 17 female) were recruited and assigned to a focused-attention (FA) meditation or relaxation group which met for four weeks, three times a week. Resting-state EEG was used to collect individual alpha peak frequency (iAPF) and frontal alpha asymmetry (FAA). The Sustained Attention to Response Task (SART) was also used to measure attention. After the intervention, we found no change in iAPF, FAA or SART performance. This thesis found that a four-week FA meditation practice does not influence sustained attention in older adults, however suggestions as to why no relationship was found are discussed and future research is warranted.

Keywords

Focused attention meditation, EEG, attention, sustained attention, SART, frontal alpha asymmetry, individual alpha peak frequency

Summary for Lay Audience

Age-related cognitive decline greatly impacts quality of life for older adults. Previous research has indicated that meditation may act as a neuroprotective factor to prevent age-related cognitive decline. This thesis sought to replicate previous findings and investigate if a four-week meditation intervention would improve sustained attention in older adults. Participants 60 years and older were recruited and assigned to a focused-attention (FA) meditation or relaxation group which met for four weeks, three times a week. Brain activity was measured by resting-state electroencephalography (EEG) to measure alpha brain waves in both power and Hertz. Previous researchers have identified alpha as a neural marker showing which areas of the brain are inactive, how efficiently active areas of the brain are being used, and therefore can be used to investigate attention. The Sustained Attention to Response Task (SART) was also used to measure attention through performance in reaction time and accuracy. After the intervention, we found no change in our EEG measures of alpha or SART performance. This thesis found that a four-week FA meditation practice does not influence sustained attention in older adults, indicating that it may not be suitable as a tool to help maintain sustained attention. Furthermore, suggestions as to why no relationship was found are discussed and future research is warranted.

Co-Authorship

This thesis was written in collaboration with Dr. Lindsay Nagamatsu who provided feedback and guidance throughout the research and manuscript preparation.

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List of Abbreviations, Symbols, Nomenclature

ACC = Anterior Cingulate Cortex

DASS-21 = Depression Anxiety and Stress Scale

DLPFC = Dorsolateral Prefrontal Cortex

EEG = Electroencephalography

EOG = Electro-oculographic

ERP = Event-Related Potential

FA = Focused Attention

FAA = Frontal Alpha Asymmetry

FCI = Functional Comorbidity Index

FFT = Fast Fourier Transform

fMRI = Functional Magnetic Resonance Imaging

GDS = Geriatric Depression Scale

IADL = Instrumental Activities of Daily Living

iAPF = Individual Alpha Peak Frequency

LPFC = Lateral Prefrontal Cortex

MBSR = Mindfulness-Based Stress Reduction

MEG = Magnetoencephalography

MMSE = Mini-Mental State Examination

MoCA = Montreal Cognitive Assessment

pMFC = Posterior Medial Frontal Cortex

PTSD = Post Traumatic Stress Disorder

SART = Sustained Attention to Response Task

SF-12 = SF-12 Patient Questionnaire

TAU = Treatment as Usual

TMT = Trail Making Test

Chapter 1 - Introduction

1.1 Cognitive decline in older adults

Adults aged 65 and older are the fastest growing age group in Canada (Statistics Canada, 2012). In a 2011 survey, there were five million older adults in Canada, and it is estimated that by the year 2036 there will be 10.47 million adults aged 65 and older in Canada (Public Health Agency, 2014). This increase is partly due to the Baby Boomer generation becoming older, as well as recent advances in technology and healthcare which have increased the average life expectancy for Canadians. Importantly, as adults age they commonly experience some form of age-related cognitive decline (Salthouse, 2009). Cognitive decline is a term which encompasses any kind of decrease in information processing or language. Age-related cognitive decline refers to cognitive decline due only to age, rather than the effects of disease (Karr, Graham, Hofer, & Muniz-Terrera, 2018). These changes bring about a reduction in quality of life and can challenge ones' ability to successfully perform activities of daily living (Hartman-Stein & La Rue, 2011).

1.2 Reduction in attention in older adults

One area of cognitive decline is a reduction in attention, and more specifically sustained attention. Sustained attention can be defined as one's ability to appropriately hold their focus on changes in their environment in order to respond to unexpected or random events for varying lengths of time (Staub, Doignon-Camus, Bacon, & Bonnefond, 2014b). Sustained attention is important for many basic functions, such as being aware of one's environment so that they may properly respond to it. For example, when driving a car, it is important to sustain attention on the road and surrounding areas, as to avoid getting into an accident.

Researchers have found detectable age-related changes in areas of the brain associated with sustained attention. There is a notable decrease in gray matter in the frontal lobes associated with aging (Zimmerman et al., 2006). Additionally, gray matter volume reductions occur in the frontal lobe earlier in life than age-related reductions seen in other areas of the brain (Giorgio et al., 2010). Previous researchers have identified the frontal lobes as areas of the brain vitally important for executive functions such as sustained attention (Alvarez & Emory, 2006). This decrease in gray matter, or neuronal cell bodies, has been linked to a decrease in sustained attention a well as other executive functions (Zimmerman et al., 2006). Therefore, as humans age the area of the brain vitally important for sustained attention significantly decreases in size and does so before many other age-related neurophysiological changes. Unfortunately, sustained attention has not been extensively investigated in the literature in comparison to other executive functions, such as memory, in regards to aging (Staub, Doignon-Camus, Bacon, & Bonnefond, 2014a).

Researchers are beginning to investigate sustained attention and aging more actively, and several techniques and tools to measure sustained attention have been proposed. One increasingly popular tool is the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). This task presents single-digit numbers individually, temporally separated by a fixation cross. The participant is asked to press a button as quickly and accurately as possible when presented with all possible numbers, labelled as non-targets, except for one number of the experimenters choosing, labelled as the target. When presented with this target number, the participant is asked to withhold the button press. Reaction time to non-target numbers and accuracy for target numbers are collected. This task measures sustained attention as it reflects the participant's ability to hold their attention on a task that is repetitive and uninteresting while having to respond everyone to two seconds. This task has been used in older adult populations as well as younger populations, and remains a reliable behavioural measure of sustained attention (Staub et al., 2014a).

The SART has been used in previous research trying to investigate how age influences sustained attention. Overall, there is evidence to suggest that sustained attention, as typically measured by the SART, decreases with age. For example, Fortenbaugh, Degutis, and Esterman (2017) reviewed the current literature and found that older adults typically show increased reaction time and decreased accuracy during sustained attention tasks, when compared to younger adults and adolescents. In another study, Fortenbaugh and colleagues (2015) assessed a sample of 10,000 participants across the lifespan and found an inverted U-shaped distribution in sustained attention. These findings suggest that as humans age they show stronger sustained attention, plateau in middle age, and then begin to decline in older age. Similar results have been found across other studies which used variations of the SART to investigate sustained attention (Carriere, Cheyne, Solman, & Smilek, 2010; McAvinue et al., 2012).

Alternative behavioural tools also exist to measure both sustained attention and other types of attention. Previous cognitive neuroscience research has used them reliably, such as the oddball task which uses reaction time and accuracy rates to indicate sustained attention performance, as well as other executive functions such as processing speed. These tasks require the participant to respond to stimuli which occur infrequently and randomly, and are typically auditory, visual, or both. When examining responses to an oddball task, neuroscience researchers often utilize event-related potential (ERP) in conjunction. This includes looking at activity in the brain collected through electroencephalography (EEG) that is time-locked to stimuli. For example, researchers typically look at P300 and N200 components with oddball tasks, and determine the positivity and negativity, respectively, 200-300 ms after a stimulus is presented (Patel & Azzam, 2005). From this, researchers can determine neural markers of processing speed and attentional capacity.

An issue with this kind of experiment with older adults is that it does not take into consideration the decline in sensorimotor abilities that happen with age. For example, Lindenberger and Baltes (1994) conducted a study looking at older adult's intelligence scores and sensorimotor abilities such as visual and auditory acuity. The authors found that sensorimotor abilities accounted for much of the intelligence scores in older adults. This study suggests that looking at how adults respond to tasks involving motor and movement components may be confounded by their slowing sensorimotor functioning. Falkenstein, Yordanova, and Kolev (2006) also found that between a group of older and younger adults, there were no differences in ERP responses to both visual and auditory stimuli, but there was a difference in the motor response to the stimuli. Falkenstein, Yordanova, and Kolev discuss the possibility that this difference in performance in an oddball task could be confounded by age-related sensorimotor decline. Furthermore, a literature review was conducted by Li and Lindenberger (2002) who found that there are many studies which report differences in behavioural measures in cognition which are mediated by sensorimotor declines related to aging.

Behavioural measures of cognition can come with other unavoidable confounds such as the effects of energy of the participant, where participants may have high levels of attention but may be too tired to remain focused on a task (Lieberman, 2007). Practice effects can also influence results, whereby participants perform better on tasks simply because they have done the task before (Bartels, Wegrzyn, Wiedl, Ackermann, & Ehrenreich, 2010). Another behavioural confound can occur if participants feel different levels of motivation to do well on the task. For example, participants who may not be motivated to do well on the task may do worse than those who are more motivated, therefore their performance would not accurately reflect ability (Padmala & Pessoa, 2010). Consequently, there is a need for some way to determine attention in older adults which will not be confounded by decline in sensorimotor abilities, practice effects, motivation, or other common confounds.

1.3 Attention and EEG

One such way to try and avoid these confounds is the use of biomarkers or physiological recordings which measure processes in the brain that are interpreted to be related to cognition. The field of cognitive neuroscience uses different tools to indirectly measure cognition in this way. Researchers use technologies such as functional magnetic resonance imaging (fMRI), EEG, and magnetoencephalography (MEG) to record physiological processes and make inferences about cognition. These measures can look at the structure or function of different areas of the brain responsible for aspects of cognition, and their relationship with observable behaviours, such as response to some of the tasks mentioned previously (i.e., SART performance). For the current thesis, the focus will be on EEG.

EEGs can be used in various settings and configurations to record electrical brain activity while participants are either resting or completing specific tasks. Recording EEG involves placing a cloth cap which holds a number of electrodes on a participant's head. The electrodes record the electrical activity on the scalp resulting from neuronal activity in the cortex around the area where the electrode has been placed. This electrical activity can then be used to determine the precise timing of activity across the cortex. This data can be analyzed in various ways, including looking at brain frequency oscillations such as alpha and beta waves, which infer states of consciousness in the participant. EEG is a useful tool in the field of neuroscience as it can record cortical activity with high temporal accuracy.

Although there are likely confounds when using methods such as EEG, these confounds are consistent. For example, neurological responses to a task being measured by EEG should remain consistent in a participant unless there are structural or functional changes in the brain. These changes do not occur unless there is a notable intervention, therefore there is less of a concern for fluctuating performance based on everyday occurrences (i.e., mood and motivation), as there are for behavioural measures.

1.4 Neurophysiology of sustained attention

1.4a Peterson & Posner model of attention

While the focus of this thesis is on sustained attention, reviewing models of general attention will help with outlining the background behind the rationale for this study. More specific models of sustained attention will be discussed later in this thesis. One of the most influential models of attention was first reported by Posner and Petersen in 1990, which divided the attention system into three parts. The first network was identified as the alerting network. This describes the process of being alerted of a stimulus being present or becoming present. The second network is the orienting network, which describes a person's ability to choose which stimuli and modality (e.g., visual or auditory), to maintain attention towards. The last network is the executive network. This describes a person's ability to focus attention on a stimulus and to inhibit processing of other distractor targets simultaneously. These networks work together during normal activities of daily living but have distinct neural connections and behavioural connotations.

The alerting system is used when a person first notices the presence of a stimuli. This is separate from when the person actually senses the target or stimuli at all. The alerting system typically begins with what's called a 'warning cue', and this often initiates activity in the locus coeruleus which releases the neurotransmitter norepinephrine (Aston-Jones & Cohen, 2005). This activity prepares the brain for incoming stimuli, and inhibits unnecessary activity as to focus solely on incoming stimuli, as indicated by some ERP studies (Petersen & Posner, 2012). The alerting network uses both anterior and parietal areas of the brain.

The orienting network encompasses the moment after the initial alerting when the brain identifies where the target is coming from and from which modality, for example, visual or auditory. Corbetta and Shulman (2002) expanded on this network, indicating that there are two different networks used when orienting attention. One network is used when the presented visual cue actually indicates where a target is found, and activates a dorsal network including both the frontal eye fields and the interparietal sulcus. The second network is activated when a cue is believed to indicate where the target will be shown, but in fact is false. In this instance, the ventral frontal cortex is used and is believed to indicate that a switch in orienting is needed. This leads to the activation of the temporoparietal junction when the participant is actively switching their orientation. The ventral network is also lateralized to the right hemisphere with strong functional links to dorsal areas of the brain and the frontal cortex.

As with the alerting network, there is an important neurotransmitter used in the orienting process. For the orienting network, researchers have shown that acetylcholine is vitally important (Petersen & Posner, 2012). In previous studies researchers have found that areas such as the basal forebrain, and more generally the superior parietal lobe, greatly affect the participant's ability to orient attention (Petersen & Posner, 2012). If an anti-cholinergic drug is injected into a monkeys brain where the human superior parietal lobe would be, their ability to alert attention is maintained but the ability to orient attention is impaired (Davidson & Marrocco, 2000; Voytko et al., 1994). Interestingly, regardless of the sensory modality of the stimuli being used, the areas of the brain that are activated (as studied by fMRI) are very similar, suggesting that the networks within the orienting system for different modalities work closely (Driver, Eimer, Macaluso, & van Velzen 2004). Even more interesting is that researchers have found that once a person has oriented their attention to one stimuli and modality, this increases the ability to detect other stimuli of that modality and decreases the ability to detect stimuli of other modalities (Desimone & Duncan, 1995; Womelsdorf et al., 2007).

The third network describes executive control, which focuses on the moment where a stimulus is detected and the processes that accompany it. Whereas the alerting and orienting networks begin with bottom-up processes from sensory areas of the brain, executive control mainly utilizes top-down control by both monitoring and resolving conflicts. For example, at the beginning of an experiment a participant is given instructions on how to do a task, and at this time there is top-down processes that focus on the task at hand and ignoring other stimuli that are unrelated. This process continues when participants are asked to switch between tasks. Second, there are processes that are active during the length of the task, where the participant must use top-down control to maintain their focus and appropriately respond to the task, while also adjusting for any feedback given from the task regarding their performance. Researchers have identified two anatomically and functionally separate networks which control both of these processes, and together constitute the executive control network. This has been labelled as the dual network view (Dosenbach, Fair, Cohen, Schlaggar, & Petersen, 2008).

During the cue portion of a task, the participant uses top-down processes to focus on the stimuli and respond appropriately. Researchers have looked at fMRI studies to see which areas of the brain are active at the beginning of a cue. The lateral frontal and parietal areas of the brain, or frontoparietal system, are used at the beginning of trials (Petersen & Posner, 2012), and are linked functionally during resting-state fMRI (Dosenbach et al., 2007). As the trials continue, participants are required to use top-down processes to maintain focus on the task and to respond appropriately when given performance feedback. During this maintenance of focus, the bilateral anterior insula and the medial frontal and cingulate cortex, or the cingulo-opercular system, are active. As with the frontoparietal system, the cingulo-opercular system is functionally linked during rest-state fMRI, indicating that the two networks are not functionally working together, but are working separately (Dosenbach et al., 2006; Dosenbach et al., 2007). Additionally, there is research to suggest that these networks work in order of one another, with the frontoparietal system being active before the cingulo-opercular system, which reflects the order of attentional processing in this model, i.e., with the cue occurring before maintaining performance in the task (Ito, Stuphorn, Brown, & Schall, 2003; Ploran et al., 2007).

The processes of focusing and maintaining attention on the task at hand is the network in this model that most closely fits with sustained attention. It is for this reason that the remainder of this thesis will focus on the networks within the executive control system described by Petersen and Posner (2012). It is also acknowledged that there are many models of attention in the literature that are not discussed in this thesis. However, the model discussed by Petersen and Posner (2012) will be used because it best fits the work being described here.

1.4b Clayton, Yeung & Kadosh model of oscillations in sustained attention

Cells in the brain, or neurons, communicate by sending electrical signals. When anatomically distinct areas of the brain are active, or are communicating with other areas of the brain, distinct cortical oscillations occur within this electrical activity. These oscillations can be defined as typical patterns of characteristics such as the speed of the oscillation. Multiple oscillations have been associated with sustained attention, however there is still much research which needs to be done to fully understand the relationship between cortical oscillations and sustained attention (Clayton, Yeung, & Cohen Kadosh, 2015). However, Clayton and colleagues (2015) have reported findings from other researchers regarding cortical oscillations and related them to models of attention, including the model discussed above by Petersen and Posner (2012). Clayton and colleagues focus mainly on the executive control aspect of attention, as it is closely linked to the processes of sustained attention, as indicated above.

The first important oscillation regarding sustained attention is the theta frequency band. The theta oscillation is typically reported in the four to eight Hertz range, and is associated with the monitoring or prolonged focus aspect of sustained attention (Clayton et al., 2015). Regarding the executive control model, theta oscillations have been reported in the medial frontoparietal and cingulo-opercular cortices, indicating that theta is related to both networks (Ishii et al., 2014; Oehrn et al., 2014). Interestingly, theta has been associated with these processes both when there is increasing cognitive fatigue and an improvement in reaction time and accuracy. This indicates theta’s relationship with both an increase and a decrease in attentional focus. It is hypothesized that an increase in power in the theta range indicates the detection of an inconsistency between an incorrect behaviour (i.e., an incorrect response to a task) and the correct behaviour (i.e., the correct response to a task), and is independent of the correction of the response or the increase in attentional focus (Clayton et al., 2015). Research has also indicated theta oscillations as a way for brain areas associated with sustained attention to communicate. For example, the lateral prefrontal cortex (LPFC) and posterior medial frontal cortex (pMFC) are indicated in sustained attention and are important for performance monitoring. Furthermore, theta oscillations have been seen to synchronize activity between the LPFC and pMFC (van de Vijver, Ridderinkhof, & Cohen, 2011).

Another interesting relationship between sustained attention and cortical oscillations focuses on the alpha frequency band. Alpha oscillations range between seven to 14 Hertz, and is the most prominent oscillation during resting wakefulness (Klimesch, Sauseng, & Hanslmayr, 2007). Researchers have seen that alpha oscillations typically increase with improved performance on sustained attention tasks (Kirschner, Kam, Handy, & Ward, 2012), and decrease with decreased task performance, specifically when there is cognitive fatigue (Liu, Zhang, & Zheng, 2010; Sun, Lim, Kwok, & Bezerianos, 2014). There has also been work to show an alpha frontoparietal synchronization with relation to the executive control network in sustained attention (Sadaghiani et al., 2012).

Interestingly, there is a relationship between sustained attention and both global, and local alpha oscillations. Researchers have identified a strong relationship between alpha power and inhibition of activity in the brain (Clayton et al., 2015). Alpha power represents the average power in the alpha band across areas of the brain and is typically calculated using a method called Fast Fourier Transform (FFT). More specifically, as different modalities of sustained attention are activated, alpha power increases in task-irrelevant areas (Anderson & Ding, 2011; Bollimunta, Chen, Schroeder, & Ding, 2008; Makeig & Inlow, 1993; Mazaheri et al., 2014). Furthermore, an increase in alpha in one area of the brain has been found to correlate with increases in cortical activity in other areas of the brain. For example, as alpha power decreases in posterior lobes, there is an increase in sustained attention-related activation in the pMFC and LPFC (Mathewson et al., 2014). This further implicates alphas relationship with executive control in sustained attention.

The inhibition and alpha model have more support in the literature that is not discussed here. As this is an area that has had extensive research conducted on it, it warrants its own section within this thesis for discussion. Klimesch, Sauseng and Hanslmayr (2007) have reported a thorough and detailed exploration into the literature on alpha and its role in attention, and more specifically sustained attention.

1.4c Klimesch inhibition timing hypothesis with alpha

Klimesch, Sauseng and Hanslmayr (2007) describe the hypothesis that alpha works as an inhibitory oscillation which aids in the top-down processing of executive control during sustained attention. The authors argue this theory with three main pieces of evidence; first, alpha activity increases during memory retention as a way of inhibiting other distractor memories or neural processes. Second, alpha increases in motor brain areas during motor tasks where the participant is asked to withhold a motor response to inhibit muscle memory movements and other stored memory movements. Third, alpha increases in task-irrelevant areas of the brain as compared to resting-state.

The inhibition timing hypothesis of alpha stems from researchers' assumptions that alpha activity is mainly driven by inhibitory neurons (Klimesch, Sauseng, & Hanslmayr, 2007). There have also been fMRI studies, as discussed in previous sections, which have shown an inverse relationship in alpha power and metabolic activity in the brain, meaning as alpha activity increases, there is less neuronal activity. Despite this research there is actually not much known about the specific neurophysiology of alpha oscillations (Klimesch, Sauseng, & Hanslmayr, 2007). However, based on the available research regarding alpha and cognition, there is strong evidence to suggest alpha's inhibitory role in sustained attention.

The first point of this model proposed by Klimesch, Sauseng and Hanslmayr (2007) discusses alpha as a tool to reduce distractor memories when trying to retain a new memory. In previous work, it has been seen that when participants are instructed to retain memories, for example a string of numbers, there is an increase in alpha in memory-related areas (Busch & Herrmann, 2003; Cooper, Croft, Dominey, Burgess, & Gruzelier, 2003; Herrmann, Senkowski, & Röttger, 2004; Jensen, Gelfand, Kounios, & Lisman, 2002; Klimesch, Doppelmayr, Schwaiger, Auinger, & Winkler, 1999; Sauseng et al., 2005; Schack & Klimesch, 2002). This has been hypothesized as showing that higher alpha oscillations are actually inhibiting other memories from interfering with the task at hand. This was further supported by researchers who found that as the number of items the participant was responsible for memorizing increased, so did alpha power (Jensen et al., 2002; Klimesch et al., 1999; Schack & Klimesch, 2002). This indicates that as we are expected to focus more on an increasing number of stimuli to memorize, our brains need to further focus on the task at hand and inhibit any distractor memories or processes. These findings further implicate alpha as a tool for top-down processing, in that alpha is related to the ability for the brain to focus on one task at a time and inhibit distractions.

The second line of evidence for the inhibition timing hypothesis is similar to the first, in that areas of the brain that are needed to perform top-down processing see an increase in alpha. For example, it is reported that when participants are asked to perform a motor task that is different from those that they have become accustomed, i.e., those that are muscle memory, researchers see an increase in alpha in the related areas of the brain (Hummel, Andres, Altenmüller, Dichgans, & Gerloff, 2002; Neuper, Schlögl, & Pfurtscheller, 1999). This research suggests alpha as a mechanism to inhibit muscle activity that is automatic, and to perform a different muscle activity. Therefore, the use of alpha improves top-down processing when performing motor tasks.

The third line of evidence regarding the inhibition timing hypothesis of alpha refers to the consistent finding of increased alpha power in areas of the brain that are task-irrelevant. There has also been evidence to show that global alpha power during a task aids in performance by inhibiting unrelated processes across the brain (Klimesch, Sauseng, & Hanslmayr, 2007). Therefore, not only can alpha specify which processes are active in local areas of the brain, it can do so on a global scale. Resting-state studies have shown global alpha before a task also improves performance on said task. It was hypothesized that this is the case because the brain is inhibiting irrelevant areas and is preparing for incoming stimuli (Klimesch, Sauseng, & Hanslmayr, 2007). This evidence also supports the hypothesis that alpha power is directly linked to top-down processes, and therefore the ability of a person to sustain attention on a task and perform well. Researchers have identified this relationship in real time, by showing alpha power shift from high to low depending on the area of the brain needed for the task at hand in animal models (von Stein, Chiang, & Konig, 2000).

Taking the literature regarding alpha into consideration, there seems to be a strong link between sustained attention and alpha. However, most of the studies cited above are ERP studies or invasive animal research. Therefore, in this thesis I sought to explore the relationship between resting-state alpha and sustained attention in humans. This was done using two different measures discussed below.

1.4d Individual Alpha Peak Frequency

One feature of EEG that is being more frequently used to measure cognition, specifically attention, is individual alpha peak frequency (iAPF). iAPF is defined as the frequency within the alpha band associated with the highest power peak (Grandy et al., 2013) and is typically collected during resting-state EEG (i.e., during the absence of an external task). iAPF, and other alpha measures, are typically calculated through FFT which takes the amplitude recorded by EEG and from this calculates the power spectrum. As stated above, higher alpha power has been associated with inhibition of task-irrelevant processes, however the research on alpha frequency is sparse in terms of sustained attention. That being said, there has been a relationship reported between higher occipital alpha peak frequency during memory retention tasks versus higher frontal alpha frequency during manipulation memory tasks (Sauseng et al., 2005). Researchers have also linked higher alpha peak frequencies with better general cognition (i.e., vocabulary use and inhibition and response control), and more preparedness for focusing attention on a stimulus (Angelakis, Lubar, & Stathopoulou, 2004; Grandy et al., 2013; Min & Herrmann, 2007).

Furthermore, abnormal levels of attention have been found to be related to iAPF. A study by Wahbeh and Oken (2013) found a relationship between iAPF and the hyper alertness and increased attention which is typical in patients with Post-Traumatic Stress Disorder (PTSD). Wahbeh and Oken (2013) found that those with a diagnosis of PTSD had a significantly higher iAPF than healthy controls. This is indicated as a possible biomarker for PTSD and can also be interpreted as a biomarker for increased attention and alertness (American Psychiatric Association, 2013). iAPF is traditionally viewed as a stable, trait-like neurophysiological measure (Salinsky & Morehead, 1991). However, it has been seen to have age related changes. Specifically, as adults age their iAPF has been observed to become slower (Scally, Burke, Bunce, & Delvenne, 2018). Therefore, since older adults typically show this decrease iAPF and there is literature to suggest this may be related to decreases in sustained attention, it is important to further investigate this relationship and identify interventions which may improve iAPF.

1.4e Alpha power asymmetry

The second measure of EEG in this thesis is alpha power asymmetry. Alpha power asymmetry is a measure which identifies which side of the brain (e.g., left/right, frontal/parietal) has higher relative alpha power. Existing research typically looks at left frontal versus right frontal alpha asymmetry (FAA). As mentioned above, alpha power is inversely related to cortical activity, meaning that higher alpha power indicates lower cortical and inferred brain activity (Laufs et al., 2003; Klimesch, Sauseng, & Hanslmayr, 2007).

Alpha asymmetry can be influenced by interventions and neurofeedback. One study by Quaedflieg and colleagues (2016) found a neurofeedback intervention using iAPF was effective in training a relative rightward shift in alpha power. Quaedflieg and colleagues used EEG to give participants real-time feedback as to what their iAPF was throughout the intervention by showing them their iAPF value on a screen. They then asked participants to attempt to increase that number. Additionally, Moscovitch and colleagues (2011) found they were successful in shifting frontal alpha power from left to right in a population with society anxiety disorder.

The relationship between FAA and cognition is an unclear area of the literature. Gotlib, Ranganath, and Rosenfeld (1998) investigated the relationship between FAA during resting-state and attentional processing and found no relationship. However, research by Ambrosini and Vallesi (2016) investigated whether FAA correlated with performance on phasic and sustained cognitive tasks in a population of healthy adults. Phasic tasks involved better performance when quickly switching between different tasks, and sustained cognitive tasks included maintaining attention on which task and stimuli are being presented. In the scope of this thesis, phasic tasks encompass the cue initiation of executive control, and sustained cognitive tasks encompass the maintenance of attention in executive control. Ambrosini and Vallesi found that there was not one asymmetry pattern which yielded more efficient cognition. They found that participants who showed a more rightward FAA performed better during the phasic cognitive control tasks. Furthermore, the participants with a more leftward FAA performed better in the tasks targeting sustained cognitive control. This research may indicate that, in terms of cognition, there may not be a favorable asymmetry in alpha power, but that there are different types of cognitive function related to either relative left or rightward FAA.

Past research has identified that those with mental illnesses such as depression show a particular alpha asymmetry pattern different from those of healthy controls. For example, it has been seen that those with depression have higher relative FAA in the left frontal cortex compared to the right, indicating less cortical activity in the left frontal cortex (Eidelman-Rothman, Levy, & Feldman, 2016). This is hypothesized to be the neurophysiological marker defining the behavioural withdrawal and sadness that accompanies depression. Conversely, higher relative right FAA with accompanying less cortical activity in the right frontal cortex, indicates healthier emotional functioning, or more approach-oriented behaviour. The relationship between FAA and stress-related disorders (e.g., PTSD and anxiety) is not currently clear in the literature, however it is hypothesized that the relationship is similar to that of alpha asymmetry and depression.

However, the literature has been inconsistent regarding this expected rightward shift in FAA being associated with reduced depression and healthy cognition. Fachner, Gold, and Erkkilä (2013) found that after a music therapy and standard care treatment, patients experienced a reduction in depression and anxiety symptoms but an increase in leftward FAA compared to a control group and baseline. These authors expected to find a rightward FAA as is found in the literature; they reported that these results may be due to some other kind of emotion processing change related to music therapy. These studies suggest that a relative rightward FAA indicates positive affect and healthy emotion processing; however, this relationship must be further investigated.

As mentioned above, there has been some success in shifting alpha power in those experiencing social anxiety (Moscovitch et al., 2011) and depression (Eidelman-Rothman et al., 2016). These results led to a reduction in symptom severity in the participants. There are various other interventions, aside from neurofeedback, that have successfully increased iAPF and initiated a rightward shift in FAA as well as an improvement in cognition. This will be discussed further below.

1.5 Meditation

One intervention which has been seen to improve cognition and influence both measures of iAPF and FAA is meditation (Barnhofer et al., 2007; van den Hurk, Giommi, Gielen, Speckens, & Barendregt, 2010). There are many different forms of meditation and they may be described differently depending on the style of the practice. However, a formal meditation will typically include the practitioner bringing awareness to the present moment while attending to either their breath or a thought. Loving-kindness meditation is an increasingly popular meditation style, which focuses on thinking about sending out thoughts which are kind or loving in nature to yourself, those around you and other beings. Loving-kindness meditation shares some aspects with gratitude-based meditations, which focus on feeling gratitude about different aspects of one's life. Body scan meditations are a practice which are commonly used in programs such as the Mindfulness-Based Stress Reduction program (MBSR; Kabat-Zinn, 2005), and they ask the participants to bring attention to each part of the body in sequence and to nonjudgmentally observe what is there. Mindfulness-Based Cognitive Therapy is another structured program which has yielded various benefits for its participants (Hazlett-Stevens, Singer, & Chong, 2018). Meditations which focus on mindfulness specifically aim to observe nonjudgmentally your experiences, thoughts and emotions. Lastly, focused attention (FA) meditation mainly asks the practitioner to focus on the sensation of breathing while letting any thoughts or emotions drift through their awareness while not attending to them. Among these meditation forms are others that are more specific in their practice or include a combination of various styles.

Many forms of meditation have been seen to improve areas of mental health, cognition, and other areas of wellbeing as mentioned previously (Ainsworth, Eddershaw, Meron, Baldwin, & Garner, 2013; Tsai & Chou, 2016). However, the focus of this thesis is FA meditation because it is recommended for beginners since it is relatively easy to learn and can form the basic skills for practicing other forms of meditation (Wallace, 2006).

1.6 Meditation, attention, iAPF and alpha power

As mentioned above, meditation can influence measures of attention, iAPF and alpha power. As there are many different forms and doses of meditation, previous studies can be difficult to compare. However, meditation researchers are starting to parse out what is the minimum amount of meditation that can improve a person's cognition and which types of meditation work best. For example, previous research has found that meditation interventions as short as four days can improve attention, as well as some other measures of cognition in younger adults (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Also, multiple types of meditation have been seen to improve attention. For example, Tsai and Chou (2016) found that a three month meditation intervention looking at open monitoring meditation significantly improved participants' overall executive function as well as their attention. Their study also found that FA meditation significantly improved overall executive function.

More importantly, researchers have begun to investigate the neural relationship between improved attention and what happens during and after a meditation practice. Increased sustained attention is ingrained in the basis of any meditation practice (Malinowski, 2013). The Liverpool Mindfulness Model consists of mind training, core processes, mental stance and outcomes. The core processes of mindfulness are skills such as attentional focus and cognitive flexibility that are intertwined and important for, and are practiced by, meditating.

Petersen and Posner’s (2012) model of attention includes three subsections, including alerting, orienting and executive control. Researchers have broken down the many parts of the core meditation practice and can match many aspects of attentional focus in meditation to these different subsections of attention. For example, it is important for meditators to have the ability to monitor what’s going on in their mind to determine whether they are focusing on the correct stimuli, i.e., typically the breath. However, just this small part of meditating includes the alerting that the meditator has let their mind wander, and the reorienting of attention back to the breath. There are also many components related to the executive function network of attention in meditation. For example, this network has been suggested to perform the cognitive effort of meditation where the meditator has to maintain focus on the breath while letting any other thought, emotion, or sensation be noticed but not paid attention to (Malinowski, 2013).

Furthermore, Hasenkamp, Wilson-Mendenhall, and Barsalou (2012) conducted an fMRI study to identify what happens in the brain during each of these steps. They broke down focused attention meditation into four parts: mind-wandering, awareness of mind-wandering, shifting attention back to meditation, and sustained focus. As they used the sustained focus phase as the baseline, there are significant relationships reported for the other three stages of meditation. The awareness of mind-wandering stage was associated with dorsal anterior cingulate cortex (ACC) and bilateral anterior insula activity. The shifting phase showed significant activity in the dorsolateral prefrontal cortex (DLPFC). These areas of the brain are consistent with activity related to the attention model suggested by Petersen and Posner (2012). More specifically, the monitoring aspect of executive control and the cuing aspect of executive control, respectively.

In terms of alpha asymmetry and meditation, the literature is not quite clear of the strength or direction of the relationship. For instance, researchers such as Davidson and colleagues (2003) conducted a randomized control trial in a population of healthy adults, and found that those who completed a six-week MBSR program had an increase in a rightward FAA indicating more cortical activity in the left frontal cortex compared to the right during a resting-state and several task-based EEGs. Davidson and colleagues state that this finding fits with the past literature that healthy approach-related behaviour, or an increase in positive affect, is related to more activity in the left frontal cortex. Additionally, more activity in the right frontal cortex is related to more withdrawal-related behaviours, indicating more negative affect.

More recently, a group of researchers investigated the effect of MBSR on FAA in healthy, older adults. Moynihan and colleagues (2013) reported that an MBSR group maintained a frontal leftward shift in cortical activity (or a frontal rightward shift in alpha) after their intervention with a resting-state EEG. The wait list group of older adults showed a more leftward shift in alpha, indicating their cortical activity was initially leftward as with the MBSR group but were slowly shifting to the right. Moynihan and colleagues (2013) report that these results are consistent with past meditation literature which suggests a frontal leftward shift in brain activation, and a corresponding frontal rightward shift in alpha, indicating better, or more positive, affective style.

Other researchers have investigated the effects of meditation on FAA in those with major depressive disorder. More specifically, Barnhofer and colleagues (2007) found no changes in a sample of participants with a history of suicidal depression after an eight week Mindfulness-Based Cognitive Therapy treatment during a resting-state EEG. However, they found those in the treatment as usual (TAU) group had a deterioration of a frontal leftward shift in alpha, meaning their alpha asymmetry was becoming increasingly higher on their right side of the frontal lobe. Barnhofer and colleagues (2007) reported these findings as fitting with Davidson and colleagues (2003) research in that those who were in the TAU group were experiencing a reduction in the positive affect that is associated with more activity in the left frontal cortex. Barnhofer and colleagues also stated that these findings indicated that the TAU group were at a higher risk for relapse.

Most of the previous research on meditation has focused on younger adults, taking advantage of the undergraduate pool of students, or those who have been meditating for their entire life. With the exception of some of the studies mentioned above, this focus on young adults in the meditation literature consistently leaves out older adult participants.

This is rather unfortunate for several reasons. First, older adults are at risk of age-related cognitive decline, and could benefit from an intervention, such as meditation, which has been found to possibly serve as a neuroprotective agent against age-related cognitive decline (Malinowski, Moore, Mead, & Gruber, 2017; Marciniak et al., 2014). Older adults are also at risk of developing late-life depression (McFarland, 2005), of which meditation has been indicated as a possible addition to treatment in other populations (Barnhofer et al., 2007). However, not much research has addressed meditation as a possibly life-changing intervention and its efficacy for improving attention in older adults.

Additionally, there has been important recent research that suggests neurofeedback training can help improve measures such as iAPF in older adults. Angelakis and colleagues (2007) conducted a pilot study where they successfully used EEG neurofeedback to increase iAPF in a sample of older adults. Not only were they successful in increasing iAPF, but they also observed an increase in some cognition functions such as processing speed. This study suggests that older adults could participate in mental training activities, such as meditation, and as a result improve their iAPF and behavioural measures of cognition.

1.7 Gap in literature

In this thesis, I aimed to address this gap in the literature regarding whether meditation can improve neurophysiological and behavioural measures of sustained attention in healthy, older adults. Behavioural measures such as the SART were used alongside neurophysiological measures such as iAPF and FAA during rest. Older adults were randomized into a four-week FA meditation group or a four-week music relaxation control group and assessed pre- and post-intervention.

In this thesis I sought to address the following research questions in a community-dwelling sample of healthy older adults: 1) Can a four-week FA meditation intervention increase iAPF and rightward shift in FAA compared to a relaxation control group, 2) Can a four-week FA meditation intervention improve performance on a SART and other behavioural measures of attention, and 3) will any improvements in behavioural and neurophysiological measures of attention be related? I hypothesized that the FA meditation group would: 1) exhibit an increase in iAPF and right FAA compared to left, when compared to the controls and baseline, 2) exhibit an improvement in accuracy and/or response time in the SART and other behavioural measures of attention compared to a control group and baseline, and 3) have behavioural improvements in attention be related to improvements in neurophysiological measures of attention.

Chapter 2 - Methods

2.1 Participants

Twenty-one community-dwelling older adults, aged 60 years and older (17 females, mean age 66.90 ± 5.24 (SD)) were recruited for the study. G*Power was used to calculate a priori sample size. Sample size was calculated using two groups, power at 0.8 alpha at .05 and an effect size of 0.4 which have been used in previous meditation and attention studies (Elliot, Wallace, & Giesbrecht, 2014; Fortenbaugh et al., 2015). The total sample size calculated was 52 and was rounded to 60 to account for possible drop outs. Participants were recruited from senior community centres, previous participation in studies in our lab, and through newspaper advertisements. Participants were included if they met the following criteria: 1) living in a retirement home or independently in her/his own home, 2) minimum completed high school, 3) comfortable reading and writing English, 4) able to walk independently, 5) right-handed, 6) score ≥ 6/8 on the Instrumental Activities of Daily Living scale, and 7) score ≥ 24/30 on the Mini-Mental Status examination. Participants were excluded if they met any of the following criteria: 1) have a diagnosis of neurodegenerative disease, 2) have a diagnosis of cognitive impairment, 3) have a diagnosis of a psychiatric condition, 4) have had a concussion in the last 12 months, 5) have had a stroke, 6) have musculoskeletal or joint disease, 7) experience dizziness or loss of balance, 8) have visual, auditory, or somatosensory impairment, or 9) a recent history (past two years) of meditation practice or include a meditation component in their religious practice. All participants provided written informed consent.

2.2 Study design

All measures were completed once before and once after the interventions were given. Cognitive and mobility assessments were completed in the same session and took about 1.5 hours to complete. The EEG protocol was completed on a second day, which was on average 10 days after the cognitive session (with an outlier of 42 days) and took a total of 1.5 hours to complete. The outlier participant who completed the cognitive and EEG baseline sessions 42 days apart was unexpectedly unable to come in for the EEG and was therefore rescheduled when they were available.

2.3 Measures

2.3a Descriptive measures

We used a General Questionnaire to collect demographic information from participants including age, yearly income and education (Appendix A). The Depression Anxiety and Stress Scale (DASS-21; Gomez, Summers, Summers, Wolf, & Summers, 2014) was used to measure different aspects of mood. It asked participants to rate how much each of the 21-items apply to them on a four-point Likert scale. The 21-items were divided into three subscales which measure depression, anxiety and stress with a higher total score indicating higher levels of anxiety, depression or stress. The Geriatric Depression Scale (GDS; Yesavage et al., 1983) is a 15-item questionnaire which was verbally administered with the participant. The participants were asked to respond with a 'Yes' or 'No' to each of the questions to indicate whether that statement applied to them. Their final score was tallied by adding up the scores from all 15 questions, with a higher score indicating higher levels of depression symptoms. A Weekly Questionnaire (Appendix B) was used to collect information during the interventions about how relaxed, stressed and focused participants felt over the past week and during the current day. Participants in both groups filled out the questionnaire at the end of each week during the intervention (every third session). The questionnaire consisted of six items on a five-point Likert scale. At the end of the questionnaire, participants were asked if they had practiced their intervention (meditation or listening to relaxing music) outside of the regular sessions over the past week. If so, they were asked to indicate how many times and to describe each time (i.e., length of time).

The SF-12 Patient Questionnaire is a 12-item questionnaire which asked the participants to rate (on varying scales) how much each item pertains to them (Ware, Kosinski, & Keller, 1996). The 12 items can be broken down into 8 subscales, each with one to two items included in the subscale score, with higher scores indicating lower functioning. The 8 subscales are physical functioning, role-physical functioning, bodily pain, general health, energy/fatigue, social functioning, role-emotional functioning, and mental health. The final scores of the subscales are added for one mental functioning score and one physical functioning score. The Functional Comorbidity Index (FCI) asked participants to check 'Yes' or 'No' as to whether they have been diagnosed by a physician with 18 different groups of illnesses (i.e., asthma or osteoporosis). This questionnaire was used to measure participant's health. The Instrumental Activities of Daily Living (IADL; Lawton & Brody, 1969) questionnaire asked participants to indicate their ability to carry out various everyday tasks such as using the telephone or preparing food. Participants rated each of the eight activities on varying scales indicating the highest level of function with higher scores indicating higher levels of daily functioning.

2.3b Cognitive measures

The Cognitive Failures Questionnaire was used to measure the frequency that participants experienced cognitive failures. This self-report 25-item questionnaire asked participants to rate on a five-point Likert scale how much each item pertains to them (Broadbent, Cooper, FitzGerald, & Parkes, 1982). Items asked things like "Do you find you forget people's names?" which are related to cognitive failures. A higher total score indicates more cognitive failures.

The Mini-Mental State Examination (MMSE) was used to screen for participants who were experiencing any cognitive decline. The MMSE contains several activities and questions which measure different cognitive functions, for example working memory and spatial memory (Folstein, Folstein, & McHugh, 1975). This measure is used to determine if a participant is experiencing cognitive decline that might confound their performance on other measures. We excluded participants who score lower than 24/30. The Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) was used as a measure of global cognition. It is commonly used as a screening tool to indicate if a person has mild cognitive impairment. It is scored out of 30 points with a higher total score indicating better cognitive function.

Executive functions were assessed using three separate pen and paper tests. First, the Number Span Test is used to assess working memory. The Forward version begins with the experimenter verbally listing out three numbers and asking the participant to repeat them back in the same order (Grégoire & Van der Linden, 1997). The test continues in this fashion, with lists of numbers of the same length repeating twice and continuing until there are two lists of nine numbers. The test stops once the participant cannot correctly repeat back two series of numbers in a row that are the same length. Their final score is the number of individual lists of numbers that the participant correctly repeated back. The Backward version is administered in a similar way, except that the participant is asked to repeat back the numbers in the reverse order, beginning with a list of two numbers and continuing up to eight numbers. This test is scored the same as the Forward span. The score from the Forward span is subtracted from the Backward span with a lower final score indicating better working memory.

Second, the Stroop was used to measure response inhibition. It is a timed measure where participants are given a sheet of paper with different colours printed with conflicting ink colours (Stroop, 1935). For example, the word “red” printed in blue ink. This test requires participants to verbally state the colour of ink that each word is printed in as quickly and as accurately as possible. Their total time to complete the task was recorded, as well as any corrected or uncorrected mistakes. Before this test, participants reported font colour from a sheet of paper which had groups of X’s printed in various colours. The time to complete this task was subtracted from the time it took to complete the main task, and this is the final score of the Stroop. The Stroop measured the participants response inhibition and sustained attention.

Third, the Trail Making Test (TMT) assessed set-shifting. Part A consisted of 25 circles randomly assorted on a sheet of paper with numbers 1-25 written inside the circles (Lezak, Howieson, & Loring, 2004). The participants were given a pen and told to begin with the pen touching the circle containing the number one, and to connect all the circles with the numbers increasing in order until they reach the circle with 25 written in it, without taking their pen off the paper. The TMT Part B is similar to that of Part A, however the circles are now filled with numbers 1-13 and letters A-L. The participants are to connect the circles beginning with the number 1, connecting to the circle with A, the circle with 2, and so forth until they’ve connected all the alternating numbers and letters. Both Parts A and B are timed, and the final score used is calculated by taking the time on Part B from Part A to indicate executive function by means of subtracting lower level functions used for Part A from Part B. A smaller final score indicates higher executive function.

The SART consisted of the participant sitting 34-inches from a 25-inch monitor mounted 43-inches from the ground. On the monitor, randomly generated numbers from 0-9 appeared in the centre of the screen for 500 ms with a 900-1100 ms interstimulus interval (Figure 1). The participant was instructed to respond by pressing a button with their right index finger on a gamepad controller each time they saw a number between zero to two, and four to nine (non-targets), and to withhold their response when they saw a three (target). Participants had until the next stimuli was presented to respond to the current stimuli, therefore between 1400-1600 ms. If the participant did not respond, as a result of a correct response to a target or an incorrect response to a non-target, the next stimuli would appear after the interstimulus interval was complete. The interstimulus interval consisted of a fixation cross. Participants were instructed to respond as quickly but as accurately as possible. Each of the 14 blocks was randomly assigned to present either 5 or 7 targets. Each participant completed 14 blocks with 60 stimuli in each, which took about 35 minutes in total, including a mandatory halfway break. This ensured that participants were presented with 84 targets, which is the standard for the SART (Nagamatsu, Kam, Liu-Ambrose, Chan, & Handy, 2013). Participants were given the opportunity for a break after each block.

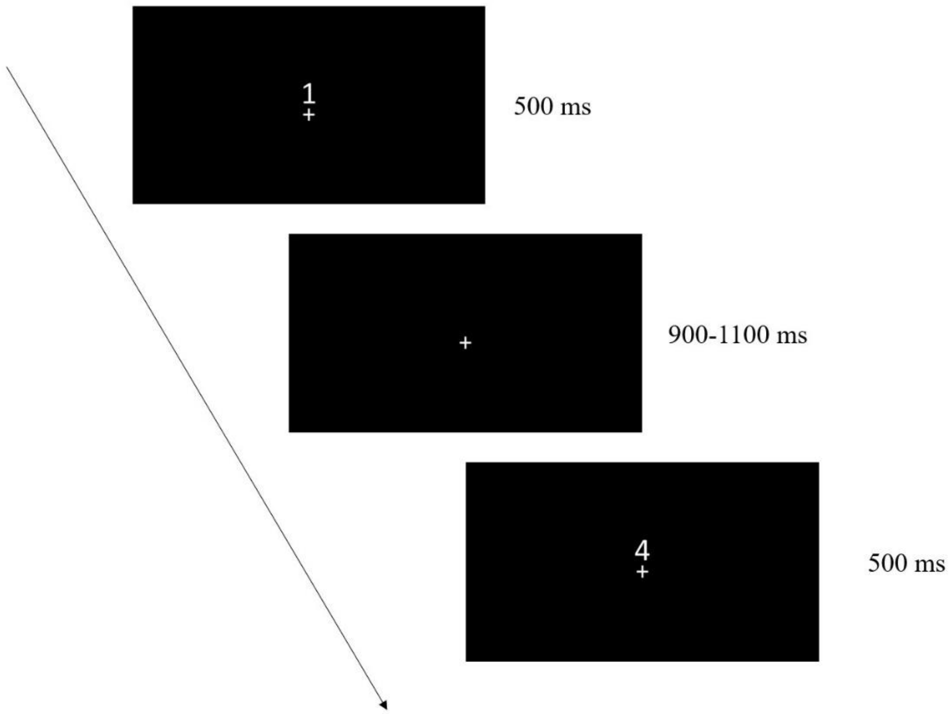

Figure 1: SART stimuli and timing.

2.3c EEG recording

EEGs were recorded with a 64-channel active electrode actiCHamp system from BrainVision Brain Products GmbH (Herrsching, Germany). Data was recorded off-line with BrainVision Pycorder. The electrodes were placed according to the 10-20 system, with the ground electrode placed at Fpz and referenced to channel AFz. Recording did not begin until all electrodes reached an impedance of under 20 kΩ. There were two mastoid reference channels and four electro-oculographic (EOG) channels, with two placed at the temples and two placed under the eyes, to collect any artefacts due to blinking.

Participants were asked to sit still with their eyes closed and let their minds wander for the five minutes of resting-state recording. The lights in the room were turned off but a desk lamp remained on. They sat in silence until the five minutes were over, at which time the experimenter stopped the recording and told the participant that s/he could open her/his eyes. Upon completion of the resting-state protocol, participants completed a cognitive task during EEG recording to assess event-related potentials (ERPs); however, the methods and results for the ERPs are not reported here as they are outside the scope of the present thesis.

2.3d EEG data preprocessing

Preprocessing was done with custom scripts in EEGLAB (Delorme & Makeig, 2004) within MATLAB (R2017B) and Fieldtrip toolbox (Oostenveld et al., 2011). A low-pass filter of 60 Hz was used with a high-pass filter of 0.5 Hz. The data was manually inspected to reject bad channels or areas with a high amount of noise. If bad channels were identified, the channel was taken out and interpolated from the channels surrounding it. Data were then epoched into two second intervals, and visually inspected again for bad channels and noisy artefacts. The data were then subjected to FFT using a Hanning-window with zero-padding and 0% overlap.

2.3e iAPF analysis

Individual Alpha Peak (iAPF) was then reported within 7.5 to 13.5 Hz and averaged across each group. iAPF was averaged across 17 posterior electrodes, which included P7, P5, P3, P1, Pz, P2, P4, P6, P8, PO7, PO3, POz, PO4, PO8, O1, Oz, and O2. These electrodes were used as previous studies have identified them as the areas which show the most prominent alpha frequency (Grandy et al., 2013). Peaks were defined as the frequency where the highest power was identified within the alpha range.

2.3f Frontal alpha power and asymmetry

Alpha asymmetry was calculated for both left and right anterior electrode sites. Right frontal alpha power was calculated by averaging power across Fp2, AF8, AF4, F8, F6, F4, F2, FT10, FT8, FC6, FC4, and FC2. Left frontal alpha power was calculated by averaging power across Fp1, AF7, AF3, F7, F5, F3, F1, FT9, FT7, FC5, FC3, and FC1. FAA was calculated by subtracting the right frontal alpha power value from the left, with a positive value indicating a leftward shift in alpha and a negative value indicating a rightward shift in alpha. This was calculated for each individual person and then averaged across groups. The alpha range used was between 7.5 and 13.5 Hz, as was used to calculate iAPF.

2.4 Intervention

Participants were randomly assigned to their groups using a random sequence generator (randomization.com) with random block sizes of 2, 4, and 6. The block sizes allowed for an equal number of participants to be assigned to each group. The sequence was held remotely by the Principal Investigator and group allocation was only revealed after baseline assessments were complete.

Both groups were led by the first author who has one year of experience leading meditations across different populations, and four years of meditation experience. The cognitive sessions (pre- and post-intervention) were administered by an experimenter blinded to group allocation. Both groups consisted of two to five people and met in a quiet room on Western University campus. Each group met three times a week for 20 minutes, for four consecutive weeks (12 sessions total). Participants were given the option to either sit on a chair or lay on a yoga mat on the floor and use blankets. Participants in both groups were encouraged to practice outside the scheduled group sessions, however this was not mandatory. Those in the meditation group were encouraged to practice meditations similar to the one in the group sessions, and those in the music group were given a copy of the music track in their preferred method (i.e., CD, USB, MP3, etc.). Attendance was recorded at each session.

2.4a Focused attention meditation group

Each meditation session was scripted to ensure each group experienced the same meditations in order (Appendix C). Meditations began with an introduction which brought the participants attention to their breath and the remainder of the practice was spent trying to keep their attention on the breath. Throughout the 12 sessions, the amount of silence in each meditation increased as the participants became more practised. Three techniques were introduced to participants to help them focus their attention on the breath, however using the techniques was optional. Participants were periodically reminded throughout the meditations to return their attention to their breathing when their minds wandered.

2.4b Music listening group

The music group spent their sessions listening to a relaxing, instrumental jazz music track. Participants were not given any specific instruction on what to do in the 20 minutes other than to relax and let their mind wander.

2.5 Statistical analysis

For all analyses, SPSS (Version 25) was used and alpha was set at .05 to determine the significance of each test. To investigate the first hypothesis regarding differences in iAPF and FAA between the music and meditation group we conducted an independent *t*-test to first determine if there were differences between the groups at baseline and endpoint separately. We then used stepwise regressions to investigate if these differences, if any were detected, were due to group while correcting for baseline scores (Vickers, 2005; Vickers & Altman, 2001). Using a regression in this type of study is recommended in papers by Vickers (2005) and Vickers and Altman (2001), who discuss the limitations of using an ANOVA for randomized controlled trials and the more appropriate robustness of the regression to detect differences in continuous variables between groups while also controlling for differences at baseline. Specifically, for the FAA regression, endpoint FAA was used as the dependent variable and group with FAA baseline was used as the independent variables. iAPF endpoint values were used as dependent variables with group and iAPF baseline values as independent variables.

To investigate any changes in behavioural performance of attention, independent *t*-tests were performed to see if there were any differences between groups both at baseline and endpoint. Stepwise regressions were also done for behavioural measures of attention with endpoint values as dependent variables and group with baseline values as dependent variables. These measures included reaction time and accuracy on the SART, the Number Span F-B, Stroop C-B and TMT B-A. The Cognitive Failures Questionnaire was also examined.

Lastly, to investigate the third hypothesis regarding the relationship between EEG and behavioural measures, a bivariate correlation was performed. This included all behavioural measures and all EEG measures listed above to further investigate any relationships within the data. Change values were calculated for each cognitive measure by subtracting each participant's baseline score from their endpoint score to investigate any significant changes over time.

To correct for multiple comparisons the Bonferroni method was used. The corrected alpha value for all *t*-tests was α=.002 to correct for 31 comparisons. The corrected alpha value for all correlations was α=.002 to correct for 24 comparisons. The corrected alpha for the regressions was not calculated until it was determined how many *t*-tests were significant, and therefore how many regressions would be performed.

Chapter 3 - Results

3.1 Descriptive measures

Groups were not significantly different in baseline demographics with all Bonferroni-corrected p-values > .002 (Table 1) demonstrating that our randomization worked. Both the meditation and music group had 100% attendance rate. Both groups also had a statistically similar mean number of extra sessions practiced outside the formal sessions, with the meditation group practicing a mean of 7.46 extra sessions and the music group practicing a mean of 8.00 extra sessions. There were 21 total participants included in the EEG analysis, and 24 in the cognitive analysis (Figure 2).

Group	Meditation	Music
N	14	13
Age	68 ± 3.91	67.31 ± 5.48
Gender	10 female (71.4%)	7 female (53.8%)
ABC	93.57 ± 6.90	95.4 ± 3.10
MoCA	24.57 ± 2.24	26.31 ± 2.39
IADL	8 ± 0	7.92 ± .28
GDS	1.36 ± 1.60	.92 ± 1.04
FCI	2.14 ± 1.70	1.38 ± .96
MMSE	27.86 ± 1.35	28.69 ± .751
High School (n)	0 (0%)	1 (7.70%)
College/trade (n)	7 (50%)	2 (15.38%)
Bachelors (n)	5 (45.45%)	9 (69.23%)
Graduate (n)	2 (14.29%)	1 (7.70%)
DASS-21 Depression	3.69 ± 3.89	2.87 ± 3.60
DASS-21 Stress	7.56 ± 3.63	6.60 ± 5.21
DASS-21 Anxiety	2.75 ± 2.30	3.33 ± 3.18
SF-12 Mental	54.02 ± 7.28	54.48 ± 4.96
SF-12 Physical	52.60 ± 4.92	51.82 ± 7.77

Table 1: Demographics for both groups with standard deviations. *ABC = the Activities-specific Balance Confidence Scale, MoCA = Montreal Cognitive Assessment, IADL = Instrumental Activities of Daily Living, GDS = Geriatric Depression Scale, FCI = the Functional Comorbidity Index, MMSE = Mini-Mental State Examination, DASS-21 = Depression Anxiety and Stress Scale, SF-12 Mental = SF-12 Patient Questionnaire mental subscales, SF-12 Physical = SF-12 Patient Questionnaire physical subscales.

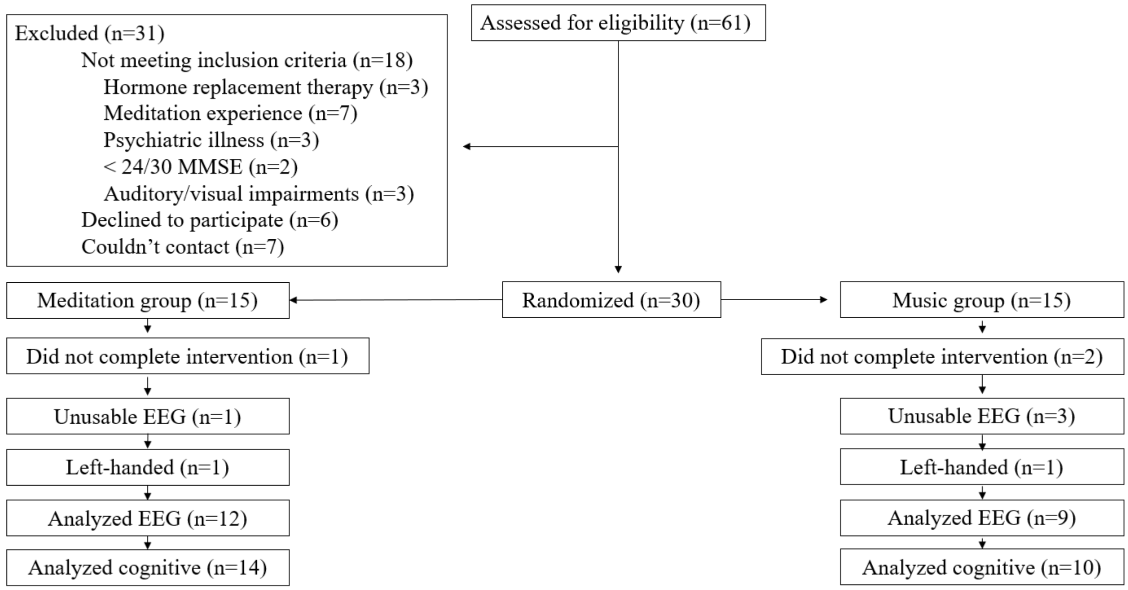

Figure 2: Number of participants assessed for eligibility and final number analyzed.

3.2 Cognitive measures

To address the hypothesis regarding the meditation group performing better on behavioural measures of attention and other cognitive measures, all 24 participants were included in the analysis.

For the independent *t*-tests, there were no differences between groups at endpoint, using the Bonferroni-corrected alpha value at p = .001. There were no significant differences between groups based on reaction time, $t(19) = -2.39$, $p = .037$, $d = 1.05$ (Figure 3), or accuracy, $t(19) = -1.86$, $p = .078$, $d = .87$ (Figure 4). As with the EEG results, since there were no significant *t*-test results, we did not calculate regressions.

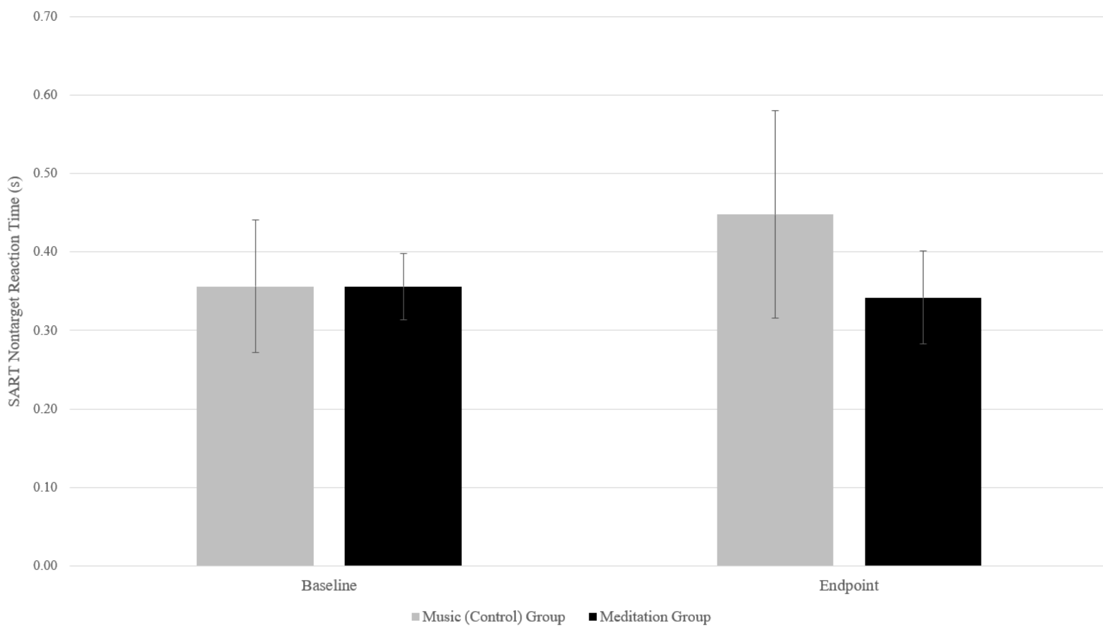

Figure 3: Reaction time (s) across time and groups. No significant differences were reported. Error bars outline confidence intervals.

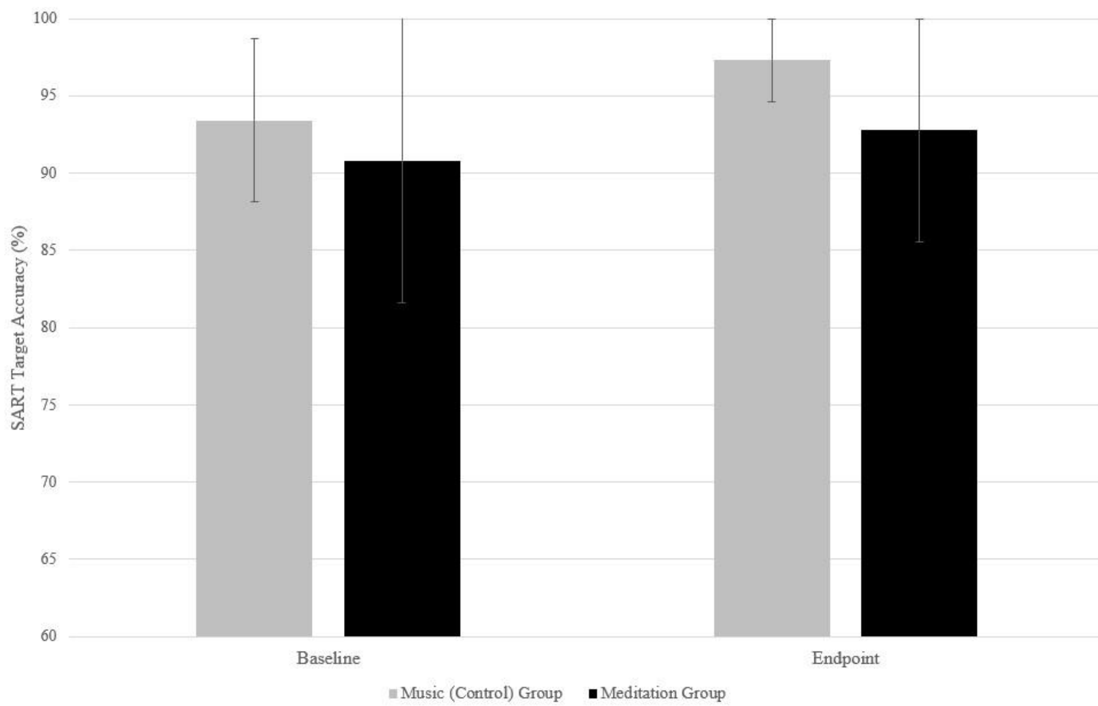

Figure 4: Target accuracy (%) across time and groups. No significant differences were reported. Error bars outline confidence intervals.

3.3 EEG measures

Thirteen participants were included in the final EEG analysis for the meditation group. Nine participants were included in the final EEG analysis for the music group. There were no significant differences between groups at baseline for any EEG measures with all Bonferroni-corrected p-values > .002.

For the independent *t*-tests to examine between-group differences at endpoint, there were no significant differences to report. The meditation and music group did not show significant differences in FAA at endpoint, $t(19) = 1.93$, $p = .068$, $d = 0.82$ (Figure 5) or iAPF, $t(10.22) = 0.19$, $p = .85$, $d = 0.09$. As there were no significant *t*-test results, regressions were not calculated.

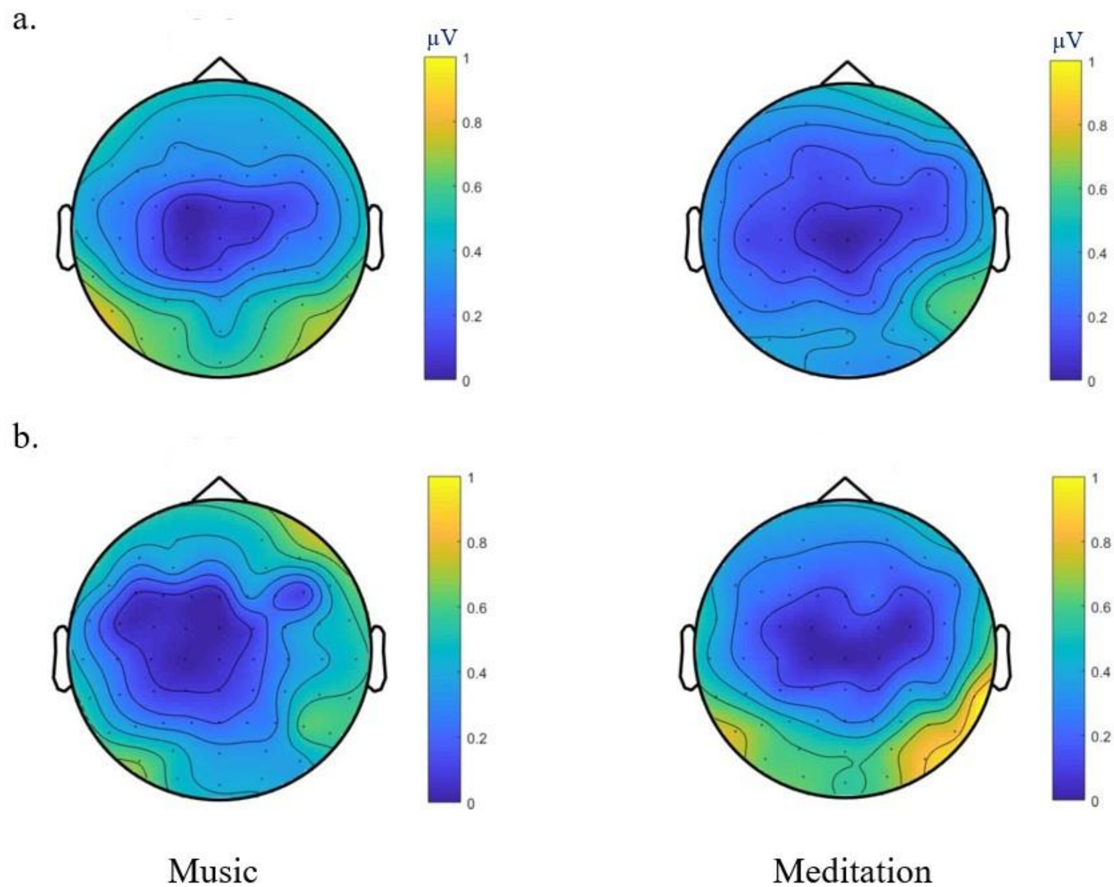

Figure 5a: Baseline FAA between groups. No significant differences were reported.

Figure 5b: Endpoint FAA between groups. No significant differences were reported.

3.4 Correlations between behavioural performance and EEG measures

There were no significant relationships between the EEG and behavioural measures across all participants. There were no significant correlations between iAPF and any of the paper-and-pencil questionnaires used, including the SF-12 mental scores r = -.38, p = .1, the SF-12 physical scores r = .39, p = .09, cognitive failures questionnaire r = .29, p .22, DASS-D r = .25, p = .29, DASS-A r = .21, p = .38, DASS-S r = .22, p = .36, RAVLT interference r = .22, p = .36, Stroop r = 54, p = .02, TMT r = .35, p = .14, digit span r = .46, p = .04, SART reaction time r = .12, p = .6, or SART accuracy r = .15, p = .52. No significant correlations were reported with FAA, including correlations with SF-12 mental scores r = .17, p = .48, the SF-12 physical scores r = .21, p .37, cognitive failures questionnaire $r = -.22$, $p = .34$, DASS-D $r = -.24$, $p = .31$, DASS-A $r = -.04$, $p = .87$, DASS-S $r = .01$, $p = .98$, RAVLT interference $r = -.54$, $p = .01$, Stroop $r = .06$, $p = .81$, TMT $r = .10$, $p = .67$, digit span $r = -.31$, $p = .18$, SART reaction time $r = -.18$, $p = .45$, or SART accuracy $r = -.23$, $p = .34$.

Chapter 4 - Discussion

In this thesis, it was hypothesized that the FA meditation group would: 1) exhibit an increase in both rightward FAA compared to left, and iAPF when compared to the music controls and baseline, 2) improve in behavioural performance (accuracy and/or reaction time) in the SART and other behavioural measures of attention compared to the music control group and baseline, and 3) have behavioural improvements in attention be related to improvements in neurophysiological measures of attention. Our results did not support any of our hypotheses. No significant improvements were seen in any of the measures used in this thesis. This includes the EEG measures of iAPF and FAA, as well as behavioural measures such as accuracy and response time on the SART. There are several factors that may have contributed to the null findings of this thesis. They are discussed below.

4.1 Cognitive results

There were no reported differences in performance on the SART in both accuracy and reaction time. It has been hypothesized by Malinowski (2013) that the underlying reason as to why meditation helps improve performance on tasks such as the Stroop or the SART is that meditation helps with emotion regulation. More specifically, previous researchers who have used tasks to identify changes in sustained attention due to meditation practice have reported some null results. Malinowski has indicated that in these studies there is typically no improvements or low levels of emotion regulation that are important for sustaining focus and maintaining motivation to complete the task. Malinowski has also pointed out that researchers who have reported an improvement in Stroop performance also saw an improvement or already existing high levels of emotion regulation. Therefore, as I did not see any changes in mood, it is possible that this unchanging level of emotion regulation was present in both the meditation and music groups, and therefore did not improve their performance on the SART. As mentioned above, it is possible that with more intensive training or a longer intervention, that the meditation group may improve their emotion regulation and consequently their ability to perform better on the SART.

4.2 EEG Results

We found no significant differences between groups in iAPF values or in FAA. Previous studies have used various interventions to increase iAPF values in older adults successfully (Angelakis et al., 2007). However, Angelakis and colleagues used a neurofeedback intervention which provided real-time feedback as to whether the participants were increasing or decreasing their iAPF. Furthermore, significant increases in iAPF were not reported until around the 15th session. These findings suggest that the current study was not long enough to see any changes in iAPF as there were only 12 sessions. Also, this study provided no feedback as to whether the participants were in a meditative state or if they were increasing or decreasing their iAPF. Therefore, if this study had included more sessions or a form of feedback it is possible that participants may have been able to increase iAPF.

In terms of FAA, there were also unexpectedly no differences seen between groups. However, previous studies which found significant changes in FAA have used more intensive programs such as MBSR, which is a program that lasts eight weeks and includes 45 minutes or more of meditation everyday. This study asked participants to meditate for 20 minutes for three days a week and did not include other aspects of mindfulness training that are present in programs such as MBSR (Kabat-Zinn, 2005). Therefore, it is possible that the underlying mindfulness and meditation training that influenced the changes seen in other studies was not present in the current study. These results suggest that if the current study had required participants to meditate for longer periods of time or if the program was longer than four weeks, there may have been significant shifts in FAA.

4.3 Correlation between behavioural and EEG measures

There were no significant correlations between any of the behavioural or EEG measures. Although there were no significant changes in any of our measures post-intervention, it was still possible that there would be detectable relationships in our EEG and behavioural measures. However, due to the nature of the multiple comparisons that we conducted, no correlation met the alpha threshold for significance. It is possible that with a larger sample size and a reduction in comparisons, that there would be detectable correlations between our main measures. Furthermore, previous researchers have found relationships between FAA, iAPF and behavioural measures of cognition and attention, however they had a larger sample size and did not need to correct for as many corrections as the current thesis (Ambrosini & Vallesi, 2016; Angelakis et al., 2004). Therefore, with a larger sample size and a smaller number of multiple comparisons we may be able to find relationships between our EEG and behavioural measures. It is also possible that contrary to the research cited in this thesis that no significant results were found because meditation does not, in fact, improve attention.

4.4 Strengths, limitations and future directions

Although no significant results were found, there were several strengths to this study. First, a relatively beginner-friendly meditation style was used, FA meditation, and the practice anecdotally became easier as the sessions progressed. Few participants reported that they were struggling with focusing their attention by the end of the study, which can suggest that they were progressing in their ability to meditate. Secondly, both neurophysiological and behavioural measures of attention were used in an attempt to investigate any changes that might occur after the intervention. Furthermore, this study used both FAA and iAPF to investigate their relationship to attention and to report if they can be influenced by an intervention lasting one month. The null results may indicate that the one month intervention was not long enough to induce the changes hypothesized. As noted in previous sections, iAPF is a stable trait and is therefore difficult to change. For example, Angelakis and colleagues (2007) used neurofeedback to induce changes in iAPF, which is assumed to be a more direct way of increasing this measure, and did not find significant increases until over 12 sessions. Since this thesis conducted only 12 sessions with no form of feedback other than informal discussion, there may not have been enough sessions for participants to show these changes reported by Angelakis and colleagues.

Another area of the study that might have led to the null results is the meditation and music group being too similar to one another in the techniques and skills used by participants. For example, participants in the music group often reported using relaxation techniques similar to meditation techniques, such as relaxing imagery and using the breath as an anchor for their attention. This occurred despite the fact that music group participants were not instructed to use any particular technique, and just to use their time to relax in anyway they wished. Therefore, in the future the music group may need some more direction as to what they can do to relax during their sessions. Alternatively, another control group may help to parse apart any changes seen as a result of meditating. For example, some meditation researchers have used mental effort-based control groups to investigate differences between meditation practice and other practices using cognitive control. Furthermore, more guidelines on how and when to practise the interventions outside of the sessions would help to keep the groups similar in the frequency of their practice. This could be done by introducing at-home practice assigned for a certain number of days or hours a week.

Another limitation, as discussed above, is this study was sample size. Our sample size was low due to difficulty recruiting, therefore there may have been some relationships that we did not have enough power to uncover. A longer intervention also might have uncovered some relationships. Many meditation studies last for eight weeks or longer, however we aimed to investigate if these previous results could be found in a shorter intervention, as some other researchers have found (McHugh, Simpson, & Reed, 2010; Zeidan et al., 2010). It is also possible that, although there were anecdotal reports of experiencing progress with their meditation practice, participants were not yet producing a meditative state during their practice. For example, some studies have reported neurophysiological changes after participants are receiving real-time neurofeedback indicating if they are in a meditative state, compared to sham conditions where the participants are deceived to think they are in a meditative state but, in fact, are not (Chow, Javan, Ros, & Frewen, 2016). Therefore, a longer intervention may give participants the practice to develop the skills to enter a meditative state during their regular meditation practice.

In addition, anecdotally, participants in the meditation group often reported using their newly learned techniques and skills to help them fall asleep, and not as a formal meditation practice. This practice may have interfered with the effectiveness and the experience of their meditations, as they may have felt sleepy and tired more than being in a meditative state during the formal practices. However, this is speculative, and more research should be done to investigate the effect of meditation when used in a formal practice versus being used to fall asleep.

4.5 Conclusions and implications

In conclusion, this thesis found that there was no change in iAPF, FAA or behavioural performance on attention tasks such as the SART. We conclude that a longer intervention with more education about meditation would further unveil any existing relationships between attention and meditation in older adults. A larger sample size with an increase in power may help to identify any relationships that were not detected in this study. Also, a wait-list control group would offer insight into if the meditation intervention simply maintained declining attention, or if it genuinely did not affect attention in older adults.

In closing, the results of this study suggest that a one month FA meditation practice does not induce neurophysiological or behavioural changes in sustained attention in older adults. With that being said, it is possible that the reported null results are due to confounding factors or limitations. Therefore, future research should be conducted to identify whether meditation may be an appropriate intervention to improve or maintain sustained attention in healthy, older adults.

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Appendix A

General Questionnaire

1) Date of Birth: __________

2) What is the highest degree or level of school of you completed? *Circle one.*
   (A) School to 9th grade
   (B) Some high school, no diploma
   (C) High school graduate, diploma or equivalent
   (D) Some college, no degree
   (E) Trade/technical/vocational training
   (F) Bachelor's degree
   (G) Graduate degree

3) What is your marital status? *Circle one.*
   (A) Single, never married
   (B) Married or domestic partnership
   (C) Widowed
   (D) Divorced
   (E) Separated

4) Is your total annual income before taxes $20,000 or more, or is it less than $20,000? *Circle one.*
   (A) Under $20,000
   (B) Over $20,000

5) What is your current employment status? *Circle one.*
   (A) Employed full time
   (B) Employed part time
   (C) Not employed
   (D) Retired
   (E) Volunteer

6) How would you consider your general health today? *Circle one.*
   (A) Excellent
   (B) Above average
   (C) Average
   (D) Below average
   (E) Poor
   (F) Unsure/do not wish to answer

Appendix B

Western

Weekly Questionnaire

1. How did you feel over the past week?:

a) How focused did you feel overall? Circle the number you feel is appropriate.

Very unfocused	Somewhat unfocused	Neutral	Somewhat focused	Very focused
1	2	3	4	5

b) How stressed did you feel overall? Circle the number you feel is appropriate.

Very unstressed	Somewhat unstressed	Neutral	Somewhat stressed	Very stressed
1	2	3	4	5

c) How relaxed did you feel overall? Circle the number you feel is appropriate.

Very unrelaxed	Somewhat unrelaxed	Neutral	Somewhat relaxed	Very relaxed
1	2	3	4	5

2. How did you feel during today's session?

a) How focused did you feel overall? Circle the number you feel is appropriate.

Very unfocused	Somewhat unfocused	Neutral	Somewhat focused	Very focused
1	2	3	4	5

b) How stressed did you feel overall? Circle the number you feel is appropriate.

Very unstressed	Somewhat unstressed	Neutral	Somewhat stressed	Very stressed
1	2	3	4	5

c) How relaxed did you feel overall? Circle the number you feel is appropriate.

Very unrelaxed	Somewhat unrelaxed	Neutral	Somewhat relaxed	Very relaxed
1	2	3	4	5

Version Date: 21/11/2017

Western

Have you completed any sessions on your own over the past week? If so, please write the number of times you have done so here: ______________________.

Please briefly describe your sessions on your own over the past week (outside the group sessions) below: (e.g., length of session, how focused/relaxed/stressed you were, etc..)

____

____

____

____

Participant ID:

Appendix C

Session number	**Technique/practice outline**
1-2	No techniques – introduction to focusing on the breath with many reminders
3-5	Counting the breath – many reminders
6	Imagining the breath flow through the body – many reminders
7-8	Using the breath to sit straighter and release tension – many reminders
9-12	Participants choose which technique to use out of the ones learned

Appendix D

Date: 8 February 2019

To: Dr. Lindsay Nagamatsu

Project ID: 110598

Study Title: Meditation strategies, attention, and mobility in older adults

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

REB Meeting Date: 26/Feb/2019

Date Approval Issued: 08/Feb/2019

REB Approval Expiry Date: 15/Feb/2020

Dear Dr. Lindsay Nagamatsu,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Daniel Wyzynski, Research Ethics Coordinator, on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Curriculum Vitae

Name:	Sabrina Ford
Post-secondary Education and Degrees:	Western University London, Ontario, Canada 2012-2017 B.A.
Honours and Awards:	Canadian Institutes of Health Research Summer Program in Aging May 28 - June 1, 2018
	Written Grant Summary Award, Canadian Institutes of Health Research Summer Program in Aging May 2018
	Innovators of Tomorrow Certificate, AGE-WELL Network of Centres of Excellence September 2018
	Travel Award to AGEWELL Conference**:** October 16-18, 2018
Related Work Experience	Student Research Assistant Child and Parent Resources Institute August 2016 - August 2017
	Teaching Assistant Western University September 2017 - December 2017
	Teaching Assistant Western University January 2018 - April 2018
	Research Assistant: Simon Fraser University STAR Institute June 2018 – February 2019
	Teaching Assistant Western University September 2018 - December 2018
	Guest Lecture Western University October 31, 2018
	Teaching Assistant

Western University
January 2019 - April 2019

Leisure and Support Volunteer
Canadian Mental Health Association
March 2014 - June 2017

Research Assistant
Western University
September 2015 - February 2016

Graduate Editor
Western Undergraduate Psychology Journal
September 2017 - Present

Peer Reviewer
University of Western Ontario Medical Journal
September 2017 - Present

Co-Chair, Retiring with Strong Minds
Western University
February 2018 – Present

Publications:

Nagamatsu, L. S., & Ford, S. D. (2019). Can meditation improve attention in older adults with a history of falls? Study protocol for a four-week intervention. *Pilot and Feasibility Studies*, *5*(22), 1-6. doi: 0.1186/s40814-019-0413-x