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THE EXPERIENCE OF MEDITATION, AND ITS EFFECTS ON ATTENTION, FOR ADULTS WITH STROKE OR ATTENTION DEFICIT HYPERACTIVITY DISORDER: A THREE-PART DISSERTATION WITH QUALITATIVE AND QUANTITATIVE EVIDENCE

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DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Health Sciences
at the University of Kentucky

By

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ABSTRACT OF DISSERTATION

THE EXPERIENCE OF MEDITATION, AND ITS EFFECTS ON ATTENTION, FOR ADULTS WITH STROKE OR ATTENTION DEFICIT HYPERACTIVITY DISORDER: A THREE-PART DISSERTATION WITH QUALITATIVE AND QUANTITATIVE EVIDENCE

Impairment of attention is common after stroke; is a defining characteristic of attention deficit hyperactivity disorder (ADHD); and has been shown to correlate significantly with difficulties in daily life for individuals with these conditions. More research is needed to establish effective interventions addressing impaired attention in such cases. Meditation is not a standard-of-care intervention for this purpose but may have therapeutic potential. Meditation has been broadly defined as an activity which has self-regulation of attention as its main aim. In other words, it can be considered a training of attention. To shed light on the therapeutic potential of meditation, including its objective effects on impaired attention due to stroke or ADHD, the author of this dissertation conducted three original studies.

Study 1 was a qualitative phenomenological investigation of the experience of meditation after stroke. Participants were individuals aged 18 or older who self-reported that they were in the chronic stage of stroke recovery and had participated in meditation (broadly defined) after stroke. A main utility of the Study 1 findings was to lay groundwork for generating testable hypotheses about how clinical and research protocols may be tailored to afford participation in (or targeted outcomes of) meditation in cases of impaired attention after stroke. Study 1 findings can also serve as an intervention-design resource on meditation after stroke. For example: findings indicated that while participation in meditation after stroke can be afforded by non-traditional elements (e.g., chair seating as opposed to the tradition of sitting cross-legged on the floor), traditions may also enhance participation in meditation after stroke (e.g., candle-lighting; a consistent time for meditation). Findings such as these speak not only to practical feasibility but also tenets of occupational therapy that explicitly designate routines as structures by which life is organized and health may be promoted; and rituals, as meaningful actions that contribute to a client’s identity (American Occupational Therapy Association [AOTA], 2020).

Study 2 used a quantitative, non-concurrent, multiple-baseline, across-subjects, single-case design. The main objective was to test whether mantra meditation would have a therapeutic effect on impaired sustained attention for adults between the ages of 18 and 70 with attention impairment in the chronic stage of recovery after right-hemisphere ischemic stroke. Mantra meditation was operationalized as audible utterance of the syllable *um* by the subject for 30 consecutive minutes per intervention day. For each subject, the study comprised 11 one-hour days evenly spaced throughout four consecutive weeks, which included time for not only intervention but also testing. Results showed evidence in favor of a therapeutic effect for one out of a total of three enrolled subjects. Thus, further research is recommended to support more than limited clinical use of Study 2's mantra meditation to target impaired attention after stroke. Practitioners who employ the protocol of Study 2 based on its anecdotal and incidental evidence should monitor attention and related functional status during treatment as well as consider modifying the salience-related aspects of the meditation in keeping with clinical judgement and client preferences.

Study 3 was a phase II, single blind, randomized controlled superiority trial with two arms (active versus comparison). The main objective was to evaluate the effects of mantra meditation on sustained attention impairment for adults with ADHD. Active mantra meditation was operationalized as having the subject say the syllables *sa ta ma na* out loud at a comfortable pace and volume while touching the thumb to each successive fingertip in time with the syllable's intonation. Mantra meditation in the comparison condition was designed to be more motorically passive than active mantra meditation. Specifically, subjects in the comparison condition were instructed to sit quietly with thumb touching index fingertip while attentively listening to an audio recording of the continual sound of the syllable *om* repeated over ambient background sound. For all subjects, the assigned dose was 15 minutes, once per day, for six consecutive days. Because results of Study 3 indicated significant promise that mantra meditation can improve impaired attention in adult ADHD, they support the judicious application of either the active or the comparison protocol as interventions to remediate impaired attention due to adult ADHD.

Overall, findings from this dissertation may be used to inform future research related to meditation, occupation, neuroplasticity, and rehabilitation for adults with pathologically impaired attention. More specifically, future mixed-methods investigation of associations between meaning- or salience-related variables of mantra meditation (e.g., ascribed meaning; complexity of enunciation); neurophysiological and behavioral indices of attention; and functional outcomes for adults with impaired attention due to stroke or ADHD is recommended.

KEYWORDS: meditation, impaired attention, occupational therapy, rehabilitation, attention deficit hyperactivity disorder, stroke

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CHAPTER 1. INTRODUCTION

1.1 Preface

Impairment of attention is common after stroke (Winstein et al., 2016). It is also a defining characteristic of attention deficit hyperactivity disorder (ADHD; American Psychiatric Association [APA], 2013). The specific type of attention that is commonly impaired in cases of stroke or ADHD is called *sustained attention* (Bálint et al., 2009; Gmehlin et al., 2016; Spaccavento et al., 2019). Sustained attention depends on top-down, endogenous maintenance of responsiveness without external cues or reminders (Spaccavento et al., 2019). Sustained attention impairment after stroke is particularly associated with right-hemisphere lesion (Robertson et al., 1997a; Spaccavento et al., 2019). In such cases, sustained attention impairment has been shown to correlate significantly with impairment of motor function and daily life participation (Robertson et al., 1997a). In cases of adult ADHD, sustained attention impairment has been shown to correlate significantly with self-reported difficulties in daily life (Gmehlin et al., 2016) and to be related to neurological impairment in the right hemisphere (Ulke et al., 2017), as well as the left (Sudre et al., 2017). Abnormalities in the default mode network (DMN) can also characterize these conditions (Park et al., 2014; Sudre et al., 2017).

Clinical limitations and gaps in evidence hinder rehabilitation addressing sustained attention impairment due to stroke or ADHD. Meditation is not a standard-of-care intervention for this impairment but may have therapeutic potential in this regard. Meditation can be defined as an activity predicated on volitional self-regulation of attention (Nash et al., 2013)—in short, it can be considered a “mental training of attention” (Kosaza et al., 2012, p. 745). To shed light on the therapeutic potential of meditation, including its effects on impaired attention due to stroke or ADHD, the author of this dissertation conducted three original studies. These studies are briefly summarized below and fully detailed in later chapters.

1.1.1 Study 1

Study 1 was a qualitative phenomenological investigation of two research questions: 1) What do stroke survivors experience in association with their participation in meditation practice?; and 2) What contexts, situations, or factors have typically played a part in stroke survivors' experience of meditation practice? The main objective was to facilitate understanding of the subjective experience of meditation after stroke. Participants were individuals aged 18 or older who self-reported that they were one year or more post-stroke and that they had had participated in meditation after stroke. In keeping with historic meditation styles and their modern derivatives (e.g., Dorjee, 2016; Lutz et al., 2008; Nash et al., 2013), meditation was defined as a circumscribed period of volitional regulation of attention/awareness with a general aim of achieving a desired state of mind or well-being. In keeping with the American Heart Association's and American Stroke Association's consensus guidelines (Sacco et al., 2013), stroke was defined as "an episode of acute neurological dysfunction presumed to be caused by ischemia or hemorrhage, persisting ≥24 hours" (p. 2066). Recruited individuals for Study 1 were informed of these operational definitions at screening. Enrollment was open to individuals who self-reported meeting these and other inclusion criteria detailed in later chapters of this dissertation.

1.1.2 Study 2

Study 2 was a quantitative, non-concurrent, multiple-baseline, across-subjects, single-case experiment. The main objective was to test the central hypothesis that a form of meditation called *mantra meditation* would have a therapeutic effect on impaired sustained attention after stroke. Mantra meditation was operationalized as audible utterance of the syllable *um* by each subject for 30 consecutive minutes per intervention day in the company of the principal investigator (PI; author of this dissertation) in a private area of an outpatient rehabilitation research clinic. Subjects were between the ages of 18 and 70 who had sustained right-hemisphere middle cerebral artery (MCA) ischemic stroke more than one year prior to enrollment as verified by a study physician. All subjects also had baseline attention impairment as verified with an objective neuropsychological test called the *Sustained Attention to Response Test (SART;* Robertson et al., 1997b, as cited in Manly et al., 2003). In keeping with standard single-case methodology (Kratochwill et al., 2013), replication of therapeutic effect across at least three subjects out of a maximum total sample size of four was the benchmark for concluding likelihood of a functional relationship between the independent variable and the dependent variable. The study period comprised 11 one-hour days evenly spaced throughout four consecutive weeks, which included time for not only intervention but also testing.

1.1.3 Study 3

Study 3 was a quantitative, phase II, single blind, randomized controlled superiority trial. The main objective was to evaluate the effects of mantra meditation on sustained attention for adults with ADHD. The primary hypothesis was that there would be significantly more mean pre-post change in sustained attention (i.e., SART score) associated with active versus comparison mantra meditation. Active mantra meditation was operationalized as having the subject repeat the syllables *sa ta ma na* out loud at a comfortable pace and volume while touching the thumb to each successive fingertip in time with the syllable's intonation. Comparison mantra meditation was designed to be more motorically passive in that subjects were instructed to sit quietly with thumb touching index fingertip while listening to an audio recording of an anonymous male individual repetitively intoning the syllable *om*. For all subjects, the assigned dose was 15 minutes, once per day, for six consecutive days. Inclusion criteria comprised baseline attention deficit per subject self-report as well as SART score. All subjects were students aged 18 or older enrolled at the university where the PI was employed at the time of the study.

1.2 Significance of the Research

The utility of the qualitative inquiry was to lay groundwork for generating testable hypotheses relevant to how clinical and research protocols may be tailored to afford participation in (or targeted outcomes of) meditation in cases of impaired attention after stroke. The utility of the quantitative inquiry was to afford preliminary proof-of-concept that mantra meditation may have potential as a therapeutic intervention to improve behavioral indices of sustained attention for adults with impaired sustained attention due to stroke or ADHD. Findings from this dissertation may be used to inform future research related to meditation, occupation, neuroplasticity, and rehabilitation for adults with pathologically impaired attention.

1.3 Main Abbreviations

ADHD: attention deficit hyperactivity disorder

CPT: continuous performance test

DLPFC: dorsolateral prefrontal cortex

DMN: default mode network

MBSR: mindfulness-based stress reduction

SART: Sustained Attention to Response Test

1.4 Introduction

Attention is a cognitive function by which individuals allocate information-processing resources to select stimuli most relevant to adaptive behavior (Klein & Lawrence, 2012). Attention is commonly impaired due to stroke (Winstein et al., 2016), with a prevalence rate as high as 92% acutely and anywhere from 20-50% at subacute stages and beyond (Loetscher et al., 2019). The severity of impaired attention after stroke can depend on lesional variables, with proneness to impairment generally associated with right-hemisphere stroke (Robertson et al., 1997a; Spaccavento et al., 2019).

Impaired attention is also a defining characteristic of ADHD. ADHD is a neurodevelopmental disorder that is usually first diagnosed in childhood and that can persist into adulthood (American Psychiatric Association [APA], 2013). Prevalence of ADHD in the general adult population is estimated at 8.2% (Ustun et al., 2017). The etiology of ADHD can include abnormalities in a region of the brain known as the *dorsolateral prefrontal cortex (DLPFC*; Hart et al., 2013; Ulke et al., 2017) and a network known as *the default mode network (DMN*; Christakou et al., 2013; Sudre et al., 2017). The next sections describe manifestations of impaired attention for adults with stroke or ADHD.

1.4.1 General Manifestations of Impaired Attention Due to Stroke or ADHD

After stroke, general manifestations of impaired attention include deficient concentration, proneness to error, mental fatigue, degraded memory, and distractibility (Loetscher et al., 2019). Impaired attention after stroke is also related to impairment of motor function and participation in daily life. For example, Watson et al.'s (2020) meta-analysis of neuropsychological predictors of outcomes after stroke or other non-traumatic acquired brain injury found attention to be a significant predictor of performance in activities of daily living. Similarly, and specific to stroke alone, Mullick et al.'s (2015) meta-analysis of associations between cognitive deficit and recovery of upper extremity function revealed a positive correlation between attention at baseline and short-to-long-term recovery of upper extremity movement function.

In cases of ADHD, inattention that causes significant detriment to personal, social, academic, or occupational activities is a diagnostic criterion (APA, 2013). Serious and morbid functional outcomes associated with ADHD include mood disorders, academic underperformance, accidents, and injuries (Boland et al., 2020).

1.4.2 Impairment of Sustained Attention Due to Stroke or ADHD

Impairment of a specific type of attention known as *sustained attention* is common in cases of stroke (Spaccavento et al., 2019) as well as ADHD (Bálint et al., 2009; Gmehlin et al., 2016). The next sections describe sustained attention and how its impairment due to stroke or ADHD is problematic.

1.4.2.1 What is Sustained Attention?

Sustained attention has been described as the ability to maintain alert responsiveness over time (Spaccavento et al., 2019). It is normally a function of both bottom-up responsiveness to exogenous cues, such as an alarm; and the top-down, endogenous maintenance of responsiveness without cues (Spaccavento et al., 2019). Neuroimaging evidence indicates that the DLPFC is preferentially activated by abstract rules as well as tasks that require mental manipulation of information held in working memory (Miller & Wallis, 2013). The DLPFC has been demonstrated to play a crucial role in sustained attention, leading to its labeling as "the endogenous activator" (Manly et al., 2003, p. 344). The DLPFC has also been shown in normal healthy volunteers to have connectivity with the DMN (Park et al., 2014), a network that is normally active during resting-state mind-wandering and that normally deactivates during sustained attention to task (Norman et al., 2017). Brain regions that comprise the DMN include the precuneus (Christakou et al. 2013; Norman et al., 2017; Park et al., 2014; Sudre et al., 2017) and posterior cingulate cortex (PCC; Norman et al., 2017; Park et al., 2014; Sudre et al., 2017), among others.

1.4.2.2 How Is Sustained Attention Measured?

A class of tests known as *continuous performance tests (CPTs*) have a long history of use for measurement of sustained attention (Shalev et al., 2011). A CPT requires the individual to sustain attention throughout a continuous stream of serially presented stimuli in order to enable appropriate response to a pre-specified target that appears during the stream. The *Sustained Attention to Response Test (SART*; Robertson et al., 1997b, as cited in Manly et al., 2003) is an example of a CPT that has been used in research on interventions to improve impaired attention in adults with ADHD (e.g., O'Connell et al., 2008) or chronic stroke (e.g., Levine et al., 2011). Using Manly et al.'s (2003) specifications for the SART, one administration of the test lasts about five minutes, in which time the tested individual views a computer monitor that displays a regularly repeating run of numerals *1* through *9*, one numeral at a time, in sequential (not random) order for a total of 25 runs before automatically stopping. The tested individual is instructed to press the keyboard's spacebar when a numeral appears, except for the numeral *3*. Pressing for *3* is counted as an error. The total number of errors constitutes the final score, with a higher score indicating worse attention. Studies have shown that this SART protocol can discriminate between neurologically impaired individuals versus controls (Manly et al., 2003) as well as electrocortical signatures of sustained attention versus response inhibition (O'Connell et al., 2009). This SART protocol has also been shown sensitive to DLPFC function (Manly et al., 2003). Later chapters detail how this SART protocol was used as a primary outcome measure in the original research conducted for this dissertation.

1.4.2.3 Characteristics of Sustained Attention Impairment Due to Stroke Or ADHD

Impairment of endogenous responsiveness commonly constitutes the etiology for neurologically impaired sustained attention after stroke (Robertson et al., 1997a; Spaccavento et al., 2019). One manifestation of sustained attention impairment often associated with right-hemisphere stroke is a syndrome called *neglect* (Robertson et al., 1997a). Neglect entails diminished responsiveness to the contralesional environment, which can cause severe, long-term difficulties with participation in daily life and rehabilitation after stroke (Winstein et al., 2016). Even in the absence of neglect, sustained attention impairment in both short- and long-term recovery after stroke has been shown to have a significant relationship with impairment of motor function and daily life participation (Robertson et al., 1997a).

Relative to ADHD, Gmehlin et al. (2016) reported that impairment of sustained attention has long been regarded as a core impairment despite an evidence gap on its functional impact in such cases. Gmehlin et al. (2016) addressed this evidence gap in a small study (n = 48) to establish whether there is a relationship between subjectively measured daily difficulty and objectively measured sustained attention in adults with ADHD versus healthy controls. Results demonstrated worse objective test performance for the ADHD group as well as a significant correlation with self-reported everyday difficulties, such as inability to concentrate on conversations, overreliance on others to stay organized, and frequent procrastination.

1.4.3 Standard and Novel Therapeutic Interventions for Impaired Attention Due to Stroke or ADHD

The following sections describe mechanisms of action, evidence gaps, and clinical limitations associated with some standard-of-care and novel interventions to address impaired attention due to stroke or ADHD. These interventions commonly target attentional substrates, such as the DLPFC, and/or behavior predicated on attention. The clinical limitations and evidence gaps associated with these interventions point to a need for more research on interventions aimed to improve attention and related function in cases of stroke or ADHD.

1.4.3.1 Interventions Directly Targeting Neural Substrates

In an expert review representing the American Heart Association and American Stroke Association's consensus guidelines for adult stroke recovery and rehabilitation, Winstein et al. (2016) reported that there is a small evidence base but lack of high-quality evidence on possible benefits of pharmacotherapy targeting the neural substrates of attention after stroke. The reviewers noted that the small evidence base on this topic indicates promise relative to drugs that modulate prefrontal cortical activity. Other preliminary research in stroke has shown that neuromodulation in the form of transcranial direct current stimulation (tDCS) targeting the DLPFC can improve performance on sustained attention testing (Eun Kyoung Kang, et al., 2009).

Relative to ADHD, tDCS targeting the DLPFC has been associated with improvement on various tests of attention, as indicated by a recent systematic review of randomized controlled trials on treatment of pediatric through adult ADHD (Salehinejad et al., 2020). However, the reviewers reported a need for further, more rigorous research and thus did not recommend tDCS as routine clinical treatment for ADHD. In contrast, routine clinical treatment for adult ADHD includes the drug methylphenidate (Cortese et al., 2020). Volkow et al.'s (2012) investigation of methylphenidate treatment for adults with ADHD found a significant correlation between its dopaminergic effects on the DLPFC and reduced inattention. Yet while methylphenidate is widely prescribed for adults with ADHD, a recent systematic review of evidence on various drugs to treat symptoms of adult ADHD did not support its comparative tolerability in such cases (Cortese et al., 2020).

1.4.3.2 Cognitive Rehabilitation

Cognitive rehabilitation is a behavior-based, standard-of-care intervention aimed to restore cognitive function and/or to compensate for lost function in cases of impaired attention after stroke (Loetscher et al., 2019). Examples of cognitive rehabilitation in occupational therapy include approaches called *skill-task-habit training* and *metacognitive strategy training* (Radomski & Giles, 2014). Radomski and Giles (2014) have described these approaches as occupation-oriented, meaning they are based on valued, naturalistic daily-life tasks such as grooming or dressing. In contrast, they indicated that an approach called *process-specific training* is not occupation-oriented since it uses pencil-and-paper or computerized tasks to exercise the impaired cognitive process (e.g., attention) in isolation (Radomski & Giles, 2014). More research is needed to establish the effectiveness of post-stroke cognitive rehabilitation (generally defined), as Loetscher et al.'s (2019) Cochrane systematic review and meta-analysis revealed a lack of high-quality evidence in support of its short- or long-term effects on sustained attention and daily life activities. Of note, these reviewers explicitly excluded meditation from their definition of cognitive rehabilitation, yet also acknowledged its potentially beneficial impact on attention.

1.4.4 Meditation and Its Therapeutic Potential for Impaired Attention Due to Stroke or ADHD

It is conceivable that the therapeutic potential for meditation to remediate impairment of attention after stroke or ADHD may owe to similar mechanisms and/or targets of action as the interventions just described. The term *meditation* has historically referred to a heterogenous set of activities predicated on volitional regulation of attention and/or emotion in diverse religious and secular contexts for the purpose of attaining well-being, balance, or various other ends (Lutz et al., 2008). Insofar as meditation trains attention and is compatible with tenets governing adaptive neuroplastic change, meditation may have therapeutic potential for adults with impaired attention due to stroke or ADHD. The following sections will expand on these ideas.

1.4.4.1 Meditation as Attentional Regulation

Contemporary researchers have devoted considerable effort to shoring up the historic definitional bounds for meditation. To this end, meditation has recently been defined as a neurocognitive task (Newberg et al., 2010) or contemplative (i.e., contemplation-based) activity (Dorjee, 2016) with volitional self-regulation of attention as a main aim (Dorjee, 2016; Lutz et al., 2008; Nash et al., 2013) and an enhanced mental state as a generally intended outcome (Nash et al., 2013). The following passage is a general description of how meditation may relate to thought processes and neural substrates related to attentional functioning:

> The DMN is related in general to internally oriented thought processes, including evaluative self-reference .., predicting and planning (Raichle and Snyder 2007; Preminger et al., 2011) and mind-wandering (Mason et al., 2007). Importantly, in many contemplative traditions, mind wandering is considered a distraction and a gateway to rumination, anxiety and depression. (Berkovich-Ohana et al., 2015, p.2)

This conceptualization lays groundwork for understanding mind-wandering and other DMN-related processes as antithetical not only to sustained attention but also to meditation and/or an enhanced mental state.

In a seminal rubric identifying attentional regulation as a defining aim of meditation, Lutz et al. (2008) described two commonly studied, overarching styles of meditation:

> Meditation can be conceptualized as a family of complex emotional and attentional regulatory training regimes developed for various ends, including the cultivation of well-being and emotional balance. Among these various practices, there are two styles that are commonly studied. One style, focused attention meditation, entails the voluntary focusing of attention on a chosen object. The other style, open monitoring meditation, involves nonreactive monitoring of the content of experience from moment to moment…. As [focused attention meditation] advances, the well-developed monitoring skill becomes the main point of transition into [open monitoring meditation] practice. (pp. 163-164)

In other words, focused-attention meditation may be considered entry-level or have less complex attentional demands compared with open monitoring, insofar as typical focused-attention meditation instructions do not compel the individual to monitor emotional reactivity. Rather, typical focused-attention meditation instructions state that attention is to be sustained on a chosen object and, when the attention wanders, to recognize the wandering and to bring the attention back to the chosen object (Lutz et al., 2008).

One example of a chosen object for focused-attention meditation is a *mantra*. A mantra is a repeated word, phrase, or syllable in meditation—i.e., a "single salient percept" (Fox et al., 2016, p. 220)—by which "attention is more easily sustained and distractors more easily ignored than without the mantra…" (Fox et al., 2016, p. 220). Insofar as a mantra is a "voluntary verbal-motor production…spoken aloud or silently in one's head" (Fox et al., 2016, p. 211), mantra meditation differs from typical focused-attention meditation that uses non-verbal objects of focus, such as sensations of breathing (Fox et al., 2016). The syllable *om* (Kalyani et al., 2011) and the syllables *sa ta na ma* (Newberg et al., 2010) are examples of mantras reported to have a traditional history of use in meditation as well as in contemporary research on the attention-related effects of meditation.

1.4.4.2 Meditation in Terms of Neuroplasticity

Neuroplasticity has been described as the lifelong capacity for change in central components of the nervous system (Alia et al., 2017). Neuroplastic change associated with behavioral and cognitive experiences is widely regarded as an underpinning of adaptive change in behavior, even in cases of adult neurological impairment (Alia et al., 2017). Kleim and Jones (2008) have delineated principles of neuroplasticity for application in neurorehabilitation. One such principle is that “repetition matters” (Kleim & Jones, 2008, p. S229)—meaning that neuroplastic change can hinge in part on how often the stimulus to induce neuroplastic change occurs. It is conceivable that therapeutic effects of meditation may occur in keeping with this principle, insofar as meditation compels repetitive attending as the defining action. For example, and as previously noted, typical instructions for focused-attention meditation are to sustain attention on a chosen object and, when the attention wanders, to recognize the wandering and bring the attention back to the chosen object (Lutz et al., 2008). Table 1 shows how mantra meditation typifies this process with repetitive focusing of attention as its main steps.

Table 1. Mantra Meditation: A Stepwise Practice

Steps
1. Attend to intonation: 1a. Initiate intonation of the mantra; 1b. then sustain intonation of the mantra; 1c. then end intonation of the mantra.
2. Attend to silence: 2a. Initiate and sustain a short silence (e.g., a breath) after step 1c; 2b. then recognize/act on sustained silence as a cue to initiate step 1 immediately following the sustained silence.

A separate neuroplasticity principle known as "use it and improve it” (Kleim & Jones, 2008, p. S227) associates tasks impelling exercise/acquisition of new skill with significant neuroplastic change in substrates of that skill. Evidence that neuroplastic change is associated with new skill in meditation has been described by Debarnot et al. (2014) in a narrative review of expertise-related neuroimaging changes associated with various tasks, including meditation, in various non-clinical populations. The reviewers concluded that frontal activation appeared more characteristic of meditation novices than meditation experts. The extent to which such evidence might generalize to the target populations of this dissertation could depend in part on the extent to which their neurological impairment engenders difficulty with repetitive attending (i.e., executing the meditation instructions). At the same time, it is conceivable that any prohibitive difficulty might be mitigated and task performance rendered achievable if the meditation were structured to have optimal salience and intensity, which are additional principles of neuroplasticity (Kleim & Jones, 2008). How these additional principles of neuroplasticity may inform the therapeutic potential of meditation is further explained below.

The principle of “salience matters” (Kleim & Jones, 2008, p. S227) holds that sufficient salience must characterize an experience in order for it to conduce neuroplastic change. Kleim and Jones (2008) described salience as the weighted importance of an experience, subject to the influence of reward, motivation, attention, and engagement and whereby neural encoding occurs. The principle of “intensity matters” (Kleim & Jones, 2008, p. S227) holds that an experience must be optimally intense for it to conduce adaptive neuroplastic change. That mantra meditation may conscribe salience, as well as intensity of attentional demand, is apparent in Fox et al.’s (2016) assertion that the “single salient percept” (p. 220) of mantra meditation eases its attentional demand and sharpens focus compared to other meditation techniques. The implication is that attending to multiple (or non-) salient percepts in forms of meditation other than mantra might have comparatively different intensity—i.e., be more difficult, complex, and/or diffusive of attention—than attending to the single salient percept of mantra. In turn, and particularly for novice meditators with impaired attention due to stroke or ADHD, it is conceivable that mantra meditation might be optimal (i.e., not too difficult, complex, and/or diffusive of attention) as a vehicle for training or entraining attention.

Other evidence of how salience or its rudiments may be related to mantra meditation was evidenced in an fMRI study by Kalyani et al. (2011). These investigators demonstrated that repeatedly chanting the syllable *om* aloud had significant impact on limbic structures (i.e., amygdala, hippocampus, parahippocampal gyrus, and insula) as well as other brain structures they described as influential on the limbic system, including orbitofrontal cortex, anterior cingulate cortex (ACC), and thalamus. Some of these impacted regions of interest (i.e., insula; ACC) are considered nodes of the salience network, which is part of the ventral attention network (Norman et al., 2017). Additionally, the impact of chanting the *om* syllable was described as a response pattern similar to that associated with vagal nerve stimulation used in clinical treatment of depression (Kalyani et al., 2011). In short, this evidence suggests that reward and/or other constructs associated with salience may be inherently related to meditation, particularly mantra meditation. Still other mechanisms by which salience may be immanent in meditation are described later in this chapter.

To summarize: principles of neuroplasticity can be understood as potentially manifest in meditation, along with a relationship to sustained attention (Table 2). These principles may therefore inform a conceptual rationale for research on meditation to effect therapeutic change in sustained attention for adults with impaired attention due to stroke or ADHD.

1.4.5 Further Empirical Evidence on Meditation, Neuroplasticity, and Attention

The next sections give further examples of empirically derived evidence on meditation and its relationship with indices of attention, such as change in neural substrates or performance on neuropsychological tests of attention. Evidence from

Table 2: Relating Neuroplasticity, Meditation, and Sustained Attention

Neuroplasticity principle	Meditation example	Sustained attention
Repetition	Mantra meditation	A stepwise practice of sustaining attention to repeated cycles of attentional action (i.e., initiate intonation/silence)
Use it and improve it	Focused-attention/mantra meditation	Brain and behavior changes from novice to expert when skill is gained in carrying out instructions of meditation
Salience	Mantra meditation (*salient* percept; limbic/attentional impact; reward)	Dynamic relationship between reward, motivation, attention, engagement, and salience
Intensity	Mantra meditation (*single* salient percept)	Optimal attentional demands for novice meditators with impaired attention

populations without stroke or ADHD is summarized first, followed by evidence from studies in stroke or ADHD. Overall, this evidence indicates some promise that meditation may have beneficial impact on indices of attention. However, there are notable evidence gaps on the experience of meditation, and/or its attentional effects, in cases of stroke or ADHD. For example, no studies have investigated mantra meditation to improve sustained attention in adults with impairment of attention due to stroke or ADHD.

1.4.5.1 The Effects of Meditation on Attention in Non-stroke/Non-ADHD Populations

Several studies indicate that meditation can impact behavioral indices of attention (i.e., psychological test performance) in a variety of clinical and non-clinical populations.

For example, Chiesa et al.’s (2011) systematic review of evidence on meditation (defined as mindfulness and open monitoring with or without focused-attention meditation) found preliminary support for the effectiveness of meditation to improve performance on behavioral tests of attention, including sustained attention, for a variety of clinical and non-clinical (healthy volunteer) samples without stroke or ADHD.

Other evidence indicates that meditation characteristically modulates activity of the DLPFC and/or the DMN. For example, Marchand’s (2014) scoping review of neuroimaging studies in various clinical and non-clinical populations without stroke or ADHD found support for consistent impact of meditation on the DMN. However, the reviewers noted that their review findings were limited by heterogeneity of meditation across studies. In contrast, comparatively well-differentiated categories of meditation were studied in Fox et al.’s (2016) systematic review and meta-analysis of neuroimaging evidence from healthy volunteers. Categories of interest included mantra meditation as a subset of focused-attention meditation. Findings indicated that dissociable patterns of connectivity were associated with each meditation category’s psychological or behavioral aims. More specifically, the reviewers reported that there were consistent associations between focused-attention meditation (including mantra meditation) and activity of the DLPFC and the DMN.

Of further note, these reviewers (i.e., Fox et al., 2016) recommended that more research was needed to investigate the subjective dimensions of meditation, as this topic was addressed in only one of their reviewed studies—i.e., Brewer et al.’s (2011) neuroimaging study of well-differentiated categories of meditation, including focused-attention meditation. Findings from this study indicated that meditation-related changes affecting the DMN were related to subjective reports of better attention (i.e., decreased mind-wandering) for expert healthy volunteers compared with novice healthy volunteers (Brewer et al., 2011). Relative to their objective findings, the investigators concluded support for the notion that attentional substrates—specifically, markers of DMN connectivity and its connections with the DLPFC—may serve as reliable mechanistic indices of meditation (Brewer et al., 2011).

In a similar vein, several other studies in healthy volunteers have yielded evidence that mantra or mantra-like meditation can impact behavioral indices of attention (i.e., psychological test performance). For example, a study by Menezes and Bizarro (2015) investigated the effects of meditation operationalized in part as mental counting of each breath (one number per exhalation), in meditation-naïve healthy adults. Subjects (n = 33) were randomized to either the meditation condition (n = 14) or waitlist control (n = 19). Selective attention was measured at pre- and post-intervention with the *Concentrated Attention Test* (*CAT*; Cambraia, 2003; as cited in Menezes & Bizarro, 2015), a five-minute pencil-and-paper test of identifying a pre-specified stimulus randomly presented among a group of other stimuli. The intervention period was five consecutive weekday sessions, with the breath-counting meditation lasting 15 to 30 minutes in each session. Results showed significant differences between groups favoring the meditation condition. A highly similar intervention (i.e., counting during attention-to-breath meditation) was used in a study by Menezes et al. (2013) that randomized 26 subjects to the meditation condition; 26, to a progressive relaxation control condition; and 24, to waitlist control (total n = 74). The intervention took place once per week for six weeks. Significant pre-post improvement of selective attention on the CAT was evident relative to the mantra condition only.

Other research in healthy volunteers has revealed how mantra meditation may impact neurological substrates of attention. For example, Berkovich-Ohana et al. (2015) investigated fMRI activity during meditation in 23 healthy normal subjects with no prior meditation experience. Meditation was operationalized as non-verbalized, silent repetition of the word *one.* Each subject performed this technique at a regular, self-selected pace, for five blocks lasting 21 seconds each, interspersed with rest periods lasting 12 seconds each. Results showed that compared with the rest condition, mantra meditation significantly downregulated regions with DMN overlap, including the precuneus, posterior cingulate cortex (PCC), ACC, medial frontal gyrus, insula, and right inferior parietal lobule. The investigators noted that the DLPFC may have played gatekeeper to the downregulation.

Mantra meditation has also been shown to impact behavioral and neurophysiological indices of attention for subjects with mild to moderate cognitive age-related decline or suspected Alzheimer's pathology. In such subjects, Newberg et al. (2010) measured the attentional effects of mantra meditation (n = 14) compared with a comparison condition (i.e., listening to music; n = 5). Mantra meditation was operationalized as 12 minutes of repeated intonation of four standardized traditional mantra syllables (i.e., *sa ta na ma*), once per day for eight weeks. Attention was measured at pre- and post-intervention timepoints with the *Trailmaking Test Part B*, a pencil-and-paper test that has been described as a test of divided attention (Johansson et al., 2012); working memory and task-switching (Sanchez-Cubillo et al., 2009); and sustained attention (Langenecker et al., 2007; as cited in Sanchez-Cubillo et al., 2009). Cerebral blood flow to the DLPFC during meditation and at rest was also measured at these timepoints. At post-intervention, only the mantra meditation group showed significant change in resting-state cerebral blood flow to attentional substrates and structures with connections to the DMN, including right DLPFC. Additionally, only the mantra meditation group showed significant change in DLPFC activity during meditation as well as significant correlation between cerebral blood flow in this region and improved test performance. These results indicate that even in cases of impaired cognitive function, mantra meditation can have significant effect on indices of attention.

1.4.5.2 Evidence Gaps on Meditation, Neuroplasticity, and Attention After Stroke

Fox et al. (2016) and Lazaridou et al. (2013) have noted that there is no research on neuroplastic change associated with meditation after stroke; and, likewise, that there is limited evidence on meditation-related change in cognition, behavior, or other health-related outcomes after stroke. Additionally, and specific to mantra meditation, a systematic review of the characteristics and quality of meditation in clinical trials found that of 141 trials involving mantra, none enrolled subjects with stroke (Ospina et al., 2008). In a systematic review of research on the health-related effects of meditation practices in stroke rehabilitation, Lazaridou et al. (2013) concluded that there was sparse evidence, but preliminary support, for various benefits including attentional. However, none of the studies used mantra meditation; and only one study in the review (i.e., Johansson et al., 2012) employed a quantitative measure of attention. This small waitlist-controlled study investigated the attentional effects of a form of a meditation program called *mindfulness-based stress reduction (MBSR)* for subjects with mental fatigue after stroke (*n* = 12) or traumatic brain injury (*n* = 10). Standard MBSR is an educationally oriented program centered on mindfulness meditation with a dose of approximately 80 hours over 8 weeks, including 31 hours of direct instruction from practitioners with specialized training (University of Massachusetts Medical School, Center for Mindfulness in Medicine, Health Care, and Society (UMass), 2017). Johansson et al. (2012) reported modifying the MBSR protocol to accommodate their subjects' need for increased time to process information. Attention was measured at pre- and post-intervention with the Trailmaking Test Part B. Results showed significant within- and between-groups differences favoring the MBSR condition compared to waitlist control (Johansson et al., 2012). However, study limitations included the neurological heterogeneity of the sample as well as not designating impaired attention as an inclusion criterion.

A meditation-related study in stroke that did not appear in the aforementioned review by Lazaridou et al. (2013) was Orenstein et al.'s (2012) multiple baseline single-case experiment to determine the effects of focused-attention meditation on attention (i.e., reaction time and accuracy in a card-sorting task). Focused-attention meditation was operationalized as attention to breath (i.e., not mantra). The investigators characterized findings as indicative of improved attention in one of a total of four subjects but no "obvious" (Orenstein et al., 2012, p. 682) effect. A limitation was that all subjects demonstrated near-perfect scores on the attention tests before meditation was introduced.

1.4.5.3 Evidence Gaps on Meditation to Improve Attention in Adult ADHD

There is an evidence gap on meditation to improve attention in cases of adult ADHD, per Krisanaprakornkit et al.'s (2010) Cochrane systematic review of randomized controlled trials of meditation to address core symptoms of ADHD in pediatric through adult populations. Meditation was defined generally in keeping with the focused-attention/open monitoring rubric—that is, as either (a) concentrative meditation (i.e., "sustained attention directed towards a single object or point of focus" (Krisanaprakornkit et al., 2010, p. 5), such as a mantra; or (b) mindfulness meditation (i.e., "open awareness to any contents of the mind … [and] the continual maintenance of … a non-reactive attitude…with equanimity" (Krisanaprakornkit et al., 2010, p. 5). Inclusion criteria for the review focused on trials delivering these meditation types in singularity or in combination. Outcome measures included psychological tests of attention (e.g., CPTs) and psychophysiological measures (e.g., electroencephalography (EEG)). Reviewers concluded some support for the efficacy of meditation to improve attention, but conclusions were based on a total of only four trials deemed worthy for inclusion. None of these trials enrolled adults; and only two were studies of mantra meditation (e.g., Kratter, 1983; as cited in Krisanaprakornkit et al., 2010; and Moretti-Altuna, 1987; as cited in Krisanaprakornkit et al., 2010). Both of these small pediatric studies (combined total $n = 47$) indicated an association between mantra meditation and significant improvement in selective attention but did not designate sustained attention as an outcome of interest.

Despite this lack of evidence on mantra meditation to improve sustained attention for adults with ADHD, there is a small evidence base on mindfulness meditation for this purpose, as evidenced by the following literature that was published subsequent to the aforementioned review by Krisanaprakornkit et al. (2010). Bueno et al. (2015) conducted a randomized controlled study in which 21 subjects with ADHD, as well as eight healthy controls, were randomized to a meditation condition; and 22 additional subjects with ADHD, as well as nine additional healthy controls, were randomized to a no-intervention condition. Outcomes included self-reported inattention using the *Adult ADHD Self-Report Scale (ASRS*; Kessler et al., 2005; as cited in Bueno et al., 2015); and two CPTs including the *Attentional Network Test (ANT*; Fan et al., 2002; as cited in Bueno et al., 2015) and *Conner's Continuous Performance Test (CPT II*: Conners, 2002; as cited in Bueno et al., 2015). Meditation was reportedly operationalized in line with standard MBSR (i.e., UMass, 2017). Results showed significant improvements in attention only among those in the meditation groups, irrespective of ADHD diagnosis. A separate study of the attentional effects of standard MBSR in adults with ADHD was conducted by Tarrasch et al. (2016). Twelve adults with dyslexia and 13 with ADHD were enrolled; and a CPT (Tsal, 2005; as cited in Tarrasch et al., (2016) was used to measure sustained attention at pre- and post-intervention. Results showed that for subjects with ADHD, MBSR significantly improved sustained attention.

1.4.6 Summary and Translation of Evidence on Meditation for Adults with Impaired Attention Due to Stroke or ADHD

The evidence summarized above indicates some promise for meditation (broadly defined) to serve as a clinical intervention to improve impaired attention (also broadly defined), although more evidence is needed in cases of stroke or adult ADHD. There is a particular lack of evidence on the efficacy of mantra meditation to improve impaired sustained attention due to stroke or adult ADHD. With specific regard to mindfulness/MBSR for this purpose, a possible limitation is its greater complexity and/or resource-demand compared with mantra meditation. For example, mindfulness/MBSR typically entails training in emotional/affective regulation (UMass, 2017), whereas mantra meditation typically does not (Fox et al., 2016). Further, and unlike mantra meditation, the standard MBSR protocol is an educational program that explicitly notes the potential stressfulness and importance of its time commitment and "immediate change in lifestyle" (UMass, 2017, p. 45) as well as advanced training of practitioners to teach/deliver it (UMass, 2017). Insofar as mantra meditation may be comparatively less resource-demanding than MBSR/mindfulness, so it becomes conceivable that mantra meditation may have comparatively enhanced translational potential.

By the same token, the simpler demand of mantra meditation may render it optimal for cases of more severe impairment and/or non-responders to mindfulness or similarly complex forms of meditation. Occupational therapists may be uniquely qualified to address issues such as these because analysis of task demands to facilitate appropriate, therapeutic task selection and grading is a foundation of occupational therapy (Piersol, 2014). The next sections further situate meditation within the purview of occupational therapy, particularly in light of a connection between occupation and salience.

1.4.7 Meditation and Constructs of Occupational Therapy

The American Occupational Therapy Association's (AOTA) *Practice Framework* (2020) is AOTA's official summary of what constitutes the core constructs, principles, and purview of occupational therapy. In this document, occupation is situated a distinguishing therapeutic medium of the profession: "Only occupational therapy practitioners focus on the therapeutic use of occupations to promote health, well-being, and participation in life" (AOTA, 2020, pp. 17 – 18). The *Practice Framework*'s glossary defines occupation as "everyday personalized activities that people do as individuals, in families, and with communities to occupy time and bring meaning and purpose to life" (AOTA, 2020, p. 79). The *Practice Framework* also specifies that occupations "… can be observed by others (e.g., preparing a meal) or be known only to the person involved (e.g., learning through reading a textbook)" (AOTA, 2020, p. 7). In keeping with these definitions, meditation may be conceptualized as an occupation. Table 3's summary of the *Practice Framework*'s several other defining bounds for occupation further elucidates a conceivable relationship between occupation and salience, thus reinforcing the understanding of meditation as within the purview of neuroplasticity-based occupational therapy.

Table 3. Salience-related Aspects of Occupation

Description	Quote	Presumed connection to salience
What the term *occupation* denotes	"The term *occupation* denotes personalized and meaningful engagement in daily life events …. Occupations occur over time; have purpose, meaning, and perceived utility to the client" (AOTA, 2020, p. 7).	Purpose; meaning; perceived utility
Significance of occupation to client	"Occupations are central to a client's…health, identity, and sense of competence and have particular meaning and value to that client" (AOTA, 2020, p. 7).	Meaning; value; centrality of importance

Table 3 Note. The American Occupational Therapy Association (AOTA)'s *Practice Framework* (2020) defines occupation in terms of meaningfulness and similar or related factors. These defining bounds may be understood to highlight an integral connection between salience and occupation—and, by extension, the occupation of meditation.

Finally, given the apparent relationship between salience, meaning, and occupation/meditation, it is clear that meaning-related research on meditation could lay needed groundwork for advancing knowledge on how to optimize meditation for neuroplasticity-based interventions addressing the needs of individuals with impaired attention due to stroke or ADHD. A qualitative methodology such as phenomenology would be particularly suited to this purpose because this methodology reveals meanings that may influence mechanisms or outcomes related to a phenomenon, via first-person data from people who have experienced that phenomenon (Creswell, 2013, Chapter 4). In populations without stroke, there appears to be a robust qualitative evidence base on meditation, as indicated by an April 2022 database search of peer-reviewed scholarly journals via Academic Search Complete, CINAHL with Full Text, Medline, APA PsycINFO, and Psychology and Behavioral Sciences Collection (keywords *qualitative* AND *meditat** NOT *stroke* (1863 results)). The same search using keywords *qualitative* AND *meditat** AND *stroke* yielded eight results, none of which used standard qualitative procedures and identified the experience of meditation after stroke as the sole, primary focus of inquiry. The present dissertation sought to address this evidence gap as well as the quantitative evidence gap on attentional effects of meditation after stroke or ADHD.

1.4.8 Statement of the Problem

Impairment of attention is common for adults who have sustained a stroke or who have ADHD. There are considerable limitations relative to evidence and interventions addressing this problem. Meditation is not standard-of-care for this problem but may have therapeutic potential insofar as it is (or entails) training of attention. The extent to which meditation may be structured to capitalize on neuroplasticity may optimize its therapeutic potential for adults with impaired attention due to stroke or ADHD. However, the translational potential of meditation for evidence-based practice, as well as knowledge of how to structure meditation protocols to capitalize on neuroplasticity, is hampered by the evidence gap on the experience of meditation, and/or its effects on attention, for adults with impaired attention due to stroke or ADHD.

1.4.9 Statement of Purpose

The purpose of this three-part dissertation was to conduct original research with adult subjects on the experience of meditation after stroke as well as on the attentional effects of mantra meditation after stroke or in cases of ADHD. This purpose was accomplished by means of three original studies conducted by the author of this dissertation, with assumptions, limitations, delimitations, and operational definitions of these studies noted below.

1.4.10 Assumptions

- That Kleim and Jones' (2008) list of principles by which rehabilitation may capitalize on neuroplasticity accurately reflects the neuroscientific principles it purports to summarize and is a valid frame of reference with regard both to the larger field of rehabilitation and to the particular topic of this dissertation.
- That in Study 1, participants' self-report was valid relative to inclusion criteria (e.g., medical history; post-stroke meditation experience).
- Assumptions for Study 2 were:
    - that the protocol's mantra would be uniformly meaningless (e.g., no inherent semantic meaning) across subjects; and
    - that compliance with the protocol would afford a means by which both meditation and training of attention could be instantiated.
- Assumptions for Study 3 were:

- that for both groups, compliance with the protocol would afford a means by which both meditation and training of attention could be instantiated, though differentially between groups;
- that for subjects assigned to the active mantra condition (not the comparison condition), the mantra would have optimal meaning/salience (e.g., afforded an option for inherent semantic meaning if needed and/or other salient stimuli necessary and sufficient to entrain attention); and
- that subjects who reported compliance with the protocol actually complied (i.e., did not submit false affirmation of compliance).

1.4.11 Delimitations

- This dissertation briefly summarizes standard-of-care and novel, non-meditation interventions to address impaired attention. It was beyond the scope of this dissertation to provide an exhaustive list of such interventions.
- It was beyond the scope of this dissertation to provide more than a general overview of parts of the attentional connectome and whether meditation or other interventions or agents may affect connectivity. Likewise, it was beyond the scope of this dissertation to measure (or provide more than speculation about) the neurological substrates (e.g., sites/mechanisms/targets of action) upon which meditation in Studies 1 – 3 may have acted or effected therapeutic change.
- The bounds used to define meditation for this dissertation are explicated to the extent that such boundaries were made manifest in cited literature. The basis for operationalizing meditation in Studies 1 – 3 is also explicated. However, this

dissertation’s main aims did not include establishing or advancing a taxonomy of meditation.

  - For example:
    - because Studies 1 – 3 did not operationalize meditation in terms of mindfulness, it is beyond the scope of this dissertation to 1) provide more than a cursory definition of mindfulness, as appropriate in light of cited literature; 2) analyze the validity of operationalizing meditation as mindfulness; or 3) posit whether mindfulness was a pertinent or present construct in the meditation protocols of Studies 1 – 3.
    - It was beyond the scope of this dissertation to interrogate the definition for *contemplative activity* or to establish whether mantra meditation falls in this category.

- It was beyond the scope of this dissertation to interrogate why neurological impairment associated with impaired attention, or response to meditation, may differentially manifest in stroke versus ADHD, e.g.,
  - why neglect may manifest in cases of stroke but not ADHD; or
  - whether or how each condition may or may not differentially predict response to meditation.
- The scope of inquiry for Study 1 did not cover the experience of meditation for individuals without a stroke diagnosis nor how such experience may or may not differ from the experience of meditation after stroke.

1.4.12 Limitations

- Constraints affecting the execution of Studies 1—3 included:

- suboptimal rate of response to recruitment and/or eligibility for enrollment;
- change in study site and target population after Study 2; and
- effects of the pandemic (e.g., safety to enroll; institutional limitations).

1.4.13 Operational Definitions

- *Meditation*: a circumscribed period of volitional regulation of attention/awareness with a main general aim of achieving a desired state of mind or well-being:

  > "Meditation can be conceptualized as a family of complex emotional and attentional regulatory training regimes developed for various ends, including the cultivation of well-being and emotional balance. Among these various practices, there are two styles that are commonly studied. One style, focused attention meditation, entails the voluntary focusing of attention on a chosen object. The other style, open monitoring meditation, involves nonreactive monitoring of the content of experience from moment to moment" (Lutz et al., 2008 p. 163).

  - *Focused-attention meditation*: a common, comparatively simple or entry-level type of meditation to train attention:

    > "FA [Focused-attention] meditation [is] a widespread style of…practice [that] involves sustaining selective attention moment by moment on a chosen object, ... At first, the attention wanders away from the chosen object, and the typical instruction is to recognize the wandering and then restore attention to the chosen object…..The initial use of FA [focused-attention] training [is] to calm the mind and reduce distractions. As FA [focused-attention meditation] advances, the well-developed monitoring skill becomes the main point of transition into [open monitoring meditation] practice" (Lutz et al., 2008, p. 164).

  - *Mantra meditation*: a subset of focused-attention meditation that may heighten the effectiveness of focused-attention meditation via repetition of a linguistic/verbal (usually non-semantic) stimulus:

    - "FA [focused-attention] meditation itself may be subdivided into distinct practices… in particular, mantra recitation meditation involves … the repetition of a sound, word, or sentence (spoken aloud or silently in one's head) with the goals of calming the mind, maintaining focus, and avoiding mind-wandering. While mantra meditation therefore clearly overlaps with other forms of focused attention [meditation] in regard to its aims, it differs in that the object of focus is a voluntary verbal-motor production, rather than naturally arising body sensations (like the breath) or external physical objects (such as a point in space upon which the gaze is focused)" (Fox et al., 2016, p. 211).

  - "One of the reasons mantra is employed is to heighten the effectiveness of focused attention meditation. The mantra is intended as a tool for focusing attention, but is not usually meant to be understood semantically" (Fox et al., 2016, p. 220).

- *sustained attention*: "the ability to endogenously maintain vigilant responding, in contrast to the ability to be exogenously alerted by external novel or salient stimuli" (Robertson et al., 1997a, p. 291).

CHAPTER 2. LITERATURE REVIEW

This chapter provides a detailed review of literature used to inform Studies 1-3. Definitional bounds for attention and meditation will be explained in behavioral, cognitive, and neuroscientific terms. An overview of the manifestations of impaired attention due to stroke or attention deficit hyperactivity (ADHD) will be provided, along with a description of related therapeutic interventions. The chapter will conclude with a summary of empirical evidence on meditation and attention in various populations, including stroke and ADHD, that can inform a rationale for further research on how meditation may have potential as a therapeutic intervention for individuals with impaired attention due to stroke or ADHD.

2.1 Definitional Bounds for Attention

Klein and Lawrence (2012) reported that while there is no one universally accepted definition or test for attention, it can be generally defined as a living organism's allocation of information processing resources to support selection of stimuli most relevant to adaptive behavior. They based this general definition on the broad history of empirical attention research as well as their own theoretical framework situating attention as a cognitive function that operates in terms of domain (i.e., space, time, sensory modality, or task) and mode (i.e., exogenous or endogenous). The exogenous mode is a bottom-up, reflexive response; whereas the endogenous mode is top-down, non-reflexive, and driven by individual contingencies and goals (Klein & Lawrence, 2012).

2.2 General Manifestations of Impaired Attention Due to Stroke or ADHD

A Cochrane systematic review reported that the estimated prevalence of attention impairment after stroke is as high as 92% in the first month post-ictus and anywhere from 20-50% at 6 or more months post (Loetscher et al., 2019). General manifestations can include deficient concentration, proneness to error, mental fatigue, degraded memory, and distractibility (Loetscher et al., 2019). A positive correlation between integrity of attention (no specific subdomain identified) and post-stroke motor improvement (objective indices of upper extremity impairment and/or related activity limitations) was evidenced in Mullick et al.'s (2015) systematic review and meta-analysis of five studies rated fair-to-good and representing a total of 112 subjects ($r = 0.25$; 95% CI: [0.04, 0.45]; $p = 0.023$). A similar, subsequent meta-analysis by Watson et al. (2020) revealed a slightly stronger positive correlation between behavioral tests of general attention and performance in activities of daily living for adults in various stages of chronicity after stroke or other non-traumatic acquired brain injury ($r = .38$, 95% CI: [.30,.46]) in a pooled sample of $n = 2384$.

Relative to ADHD, a core diagnostic criterion is attention deficit that interferes significantly with personal, social, academic, or occupational activities (APA, 2013). While ADHD is often first diagnosed in childhood (APA, 2013), it can persist into adulthood. Ustun et al. (2017) found an estimated prevalence rate of 8.2% in the general adult population when validating the screening sensitivity (91.4%) and specificity (96.0%) of a DSM-5 calibrated version of the *World Health Organization Adult ADHD Self-Report Scale* (*ASRS*) screening tool. To evidence how attention impairment is problematic, Boland et al. (2020) conducted a systematic review and meta-analysis of big data (sample sizes from $n = 5718$ to $> 146,000,000$) comparing functional outcomes for pediatric through adult populations medicated for ADHD versus unmedicated ADHD controls. Results showed that in the medicated condition, there were comparatively decreased odds for mood disorders (n = 2 studies; pooled odds ratio (OR) = 0.69, 95% CI [0.64, 0.74]; $p < 0.001$); accidents and injuries (n = 2 studies; pooled OR = 0.72, 95% CI [0.59, 0.87]; $p = 0.001$); and poor academic performance (n = 2 studies; pooled OR = 0.80, 95% CI [0.76, 0.84]; $p < 0.001$).

2.3 Sustained Attention: A Particular Subtype

Klein and Lawrence's (2012) framework for endogenous and exogenous modes of attention is evident in a particular subtype of attention known as *sustained attention*, which is a primary variable of interest in the present dissertation. In Spaccavento et al.'s (2019) study of the prevalence of sustained attention impairment after stroke, the top-down, endogenous ability to maintain responsiveness without reliance on cues was termed *tonic alertness*; whereas bottom-up, exogenously driven responsiveness was termed *phasic alertness*. In a similar vein, Robertson et al. (1997a) identified diminished tonic (endogenous) alertness as the core deficit in cases of impaired sustained attention after stroke. This top-down endogenous deficit has also been identified as a core impairment in adults with ADHD (O'Connell et al., 2008).

2.3.1 Sustained Attention Is Measured with Continuous Performance Tests (CPTs)

CPTs, known also as *go/no-go* tests (Manly et al., 2003), are a class of tests that have a long history of use as behavior-based measures of sustained attention (Shalev et al., 2011). CPTs typically require the individual to sustain attention throughout a continuous stream of serially presented stimuli to facilitate an appropriate behavioral response (e.g., pressing a button) to a pre-specified target in the stream (Shalev et al., 2011). While Borgaro et al. (2003) reported that various versions of CPTs have generally equivalent construct validity, more recent research has established divergent validity and other psychometric properties of various CPTs (e.g., Shalev et al., 2011). The next sections detail the CPT that was used as a primary outcome measure in the present dissertation.

2.3.2 Primary Outcome Measure: The Sustained Attention to Response Test (SART)

The SART is a computerized CPT that uses a go/no-go paradigm to measure sustained attention (Manly et al., 2003; O'Connell et al., 2009). It has been used in research with healthy volunteers as well as neurologically impaired subjects. For example, the SART prototype was developed by Robertson et al. (1997b) to measure sustained attention in a sample of 34 subjects with right-hemisphere acquired brain lesions, in whom investigators showed that attention failure as measured with the SART had a significant correlation ($r = .44$; $p < .05$) with self-reported failures of attention in daily life on the *Cognitive Failures Questionnaire* (*CFQ*; Broadbent et al., 1982; as cited in Robertson et al., 1997b). There was also a significant correlation ($r = -.27$, $p < .05$) between CFQ attention failures and SART attention failures in a sample of 75 healthy volunteers. Corroborating evidence from Smilek et al. (2010) showed a significant correlation between SART attention failures and CFQ attention failures ($r = .28$, $p < .01$) in a sample of 363 randomly selected healthy volunteers as well as a positive association between CFQ attention failures and SART attention failures ($r = .21$; $p < .01$; CI 95% [.03, .38]) in a pooled sample of over 3000 subjects with varied non-clinical and clinical features, including neurological impairment. Other stroke research using the SART as an outcome measure includes Levine et al.'s (2011) study of goal management training to improve executive function in a sample of 19 adults with chronic stroke. In 72 healthy adults, Malegiannaki et al., (2012) found SART attention failures correlated significantly ($r = -.723$, $p < .01$) with sustained attention failure measured on the pencil-and-paper objective *Test of Everyday Attention (TEA*; Robertson 1994; as cited in Malegiannaki et al., 2012). These investigators also found 1) no significant correlation between SART scores and TEA subtests of non-sustained types of attention; and 2) significant correlation between scores on a test of sustained attention called the *Attention Related Cognitive Errors Scale (ARCES)* and reaction time SART scores before ($r = -.327$, $p < .01$) and after ($r = -.322$, $p < .01$) correct SART responses.

In the present dissertation, the SART followed Manly et al. (2003)'s specifications in which one administration of the SART lasts about 5 minutes, during which time the tested individual views a computer monitor that displays a regularly repeating run of digits *1* through *9*, one digit at a time, in fixed sequential (not random) order for a total of 25 scored runs. Each digit is presented for 250ms in the center of the laptop screen as a black numeral against a white background. Digits are presented at a font size of 48, 72, 94, 100, or 120 points at each digit onset, with size randomly selected according to the computer program. The interval between the onset of each digit is 1150ms. A black cross on a white background (i.e., a masking pattern) appears for 900ms between presentation of each digit. Three practice runs are administered prior to the scored 25 runs. Prior to test onset, the tested individual receives instructions to press the keyboard's spacebar upon the appearance of any digit except for the digit *3*. Scoring includes the count of errors of commission (i.e., the number of times that *3* is pressed) and the count of errors of omission (i.e., the number of failures to press for digits other than *3*). A higher score indicates worse attention, as does increase in variability of reaction time (RT) to digits other than *3*. RT variability can be calculated as the coefficient of variation (i.e., the ratio between mean RT and mean standard deviation (SD) of RT (O'Connell et al., 2004; Bellgrove et al., 2006)). This protocol for administering the SART differs from the prototypical SART in that digits are presented in sequential numeric order, not random order. There is considerable evidence on the utility of this sequential approach—termed "fixed sequence" (Manly et al., 2003, p. 342) or *fixed SART,* as described below.

Manly et al. (2003) found that errors of commission in the fixed SART were sensitive to frontal lobe impairment, with subjects 2.02 times more likely to be correctly classified for each increase of 1 error (OR = 2.02, $p = .019$) in a sample of 19 adults with traumatic brain injury versus 19 healthy controls. This likelihood translated to correct classification of 80% of the total sample. The random SART was found to have utility for correctly classifying only 63% of the total sample (OR 1.11, $p = .074$). In a companion study of a subset sample (seven healthy volunteers), the investigators found the fixed SART to have significantly more sensitivity to dorsolateral prefrontal cortex (DLPFC) activity ($p < .001$) than random SART and thus labelled the DLPFC as "the endogenous activator" (Manly et al., 2003, p. 344). Corroborating research in 13 healthy adults showed that the fixed SART preferentially elicits electrocortical signatures of sustained attention (as opposed to response inhibition elicited by random SART) when errors of commission are successfully avoided (O'Connell et al., 2009). With specific regard to ADHD, O'Connell et al. (2004) found significant differences between groups in errors of commission ($p < .03$), omission ($p < .008$), and RT variability (p < .007) on the fixed SART for 15 children with ADHD versus 15 healthy controls. In 18 adults with ADHD, O'Connell et al. (2008) demonstrated that significant increase ($p <. 05$) in fixed SART RT variability was associated with placebo training as opposed to an attentional training intervention; while significant decrease in commission errors was associated with attentional training ($p < .05$) but not placebo ($p = .6$).

There is a mixed evidence base on the utility of SART metrics other than errors of commission for indexing sustained attention in both neurological and non-clinical populations. For example: while Manly et al. (2003) found significantly more fixed SART errors of both commission and omission ($p < 0.001$) for adults with chronic traumatic brain injury ($n = 19$) versus healthy controls (n = 16), the number of errors of commission was the only metric validated as sensitive for discriminating between the groups. While these investigators' sub-study of healthy volunteers ($n = 7$) showed significantly more change in DLPFC activity associated with fixed versus random SART ($p < 0.001$), no one metric of the fixed SART was identified as a particular correlate of the change (Manly et al., 2003). In a sample of adults with ADHD ($n = 18$) and healthy controls ($n = 23$), O'Connell et al.'s (2008) placebo-controlled investigation of an attentional training program showed no significant post-intervention change in RT variability or in errors of omission, which were reported as rare in the sample to begin with.

The present dissertation operationalized the defining SART threshold for impairment in terms of errors of commission and in keeping with results from five fixed-SART studies (i.e., Manly et al., 2003; McAvinue et al., 2005; McAvinue et al., 2012;

O'Connell et al., 2008; O'Connell et al., 2009). In these five studies, neither the mean commission-error score nor the mean commission-error score plus two SD ever reached as high as 4 in healthy adults (combined $n = 138$).

2.3.3 Neuroscience of Sustained Attention

According to Norman et al., (2017), scientific canon has identified the following networks as among those which normally subserve sustained attention: 1) the ventral attention network; 2) the salience network; and 3) the central executive network, which normally includes the DLPFC. O'Connell et al. (2009) reported that there is considerable neuroimaging evidence that the DLPFC plays a crucial role in sustained attention. It has been labeled "the endogenous activator" (Manly et al., 2003, p. 344) and has been shown in normal healthy volunteers to have connectivity with the default mode network (DMN; Park et al., 2014). The DMN normally deactivates when task-related attention networks are activated and is normally associated with mind-wandering and spontaneous, coordinated fluctuations of activity during the resting state (Norman et al., 2017). Brain regions that comprise the DMN include the precuneus (Christakou et al. 2013; Norman et al., 2017; Park et al., 2014; Sudre et al., 2017) and posterior cingulate cortex (PCC; Norman et al., 2017; Park et al., 2014; Sudre et al., 2017). Norman et al. (2017) also identified anterior/ventromedial prefrontal cortex (A/VMPFC), anterior cingulate cortex (ACC), and inferior temporal regions as belonging to the DMN. Pathological impairment of attention has been hypothesized to arise from abnormal DMN intrusion into task-related activity (Sonuga-Barke et al., 2007; as cited in Christakou et al., 2013). Later sections describe 1) how meditation has been shown to impact some of these networks and regions; and 2) how abnormalities of some of these networks and regions underlie impaired (and/or recovered) attention in cases of stroke or ADHD.

2.3.4 Sustained Attention Impairment is Prevalent and Problematic After Stroke

Spaccavento et al. (2019) showed that sustained attention impairment is common after stroke, particularly in cases of right-hemisphere lesion. Sustained attention of 204 patients at ≤12 months after unilateral ischemic stroke (108 with right-hemisphere lesion and 96 with left-hemisphere lesion) was compared with that of 42 healthy controls. Results showed that 44.4% of subjects with stroke had impairment (performance at or below the fifth percentile according to normative data); and 57% of the right-hemisphere sample had impaired tonic alertness, which was a significantly higher proportion ($p < .0001$) than in left-hemisphere lesion.

One manifestation of sustained attention impairment often associated with right-hemisphere stroke is a syndrome called *neglect* (Robertson et al., 1997a). Neglect, which manifests as diminished responsiveness to the contralesional environment, can cause severe, long-term difficulties with participation in daily life functioning and rehabilitation after stroke (Winstein et al., 2016). Yet even in the absence of neglect, impairment of sustained attention after stroke appears to have an integral relationship with impairment in motor function. Seminal research by Robertson et al. (1997a) examined whether sustained attention measured at 2 months and 2 years after stroke could predict performance on objective and self-reported motor function and performance in activities of daily living. Sustained attention was defined as "the ability to endogenously maintain vigilant responding, in contrast to the ability to be exogenously alerted by external novel or salient stimuli" (Robertson et al., 1997a, p. 291). Outcome measures included tests of sustained attention from the *Test of Everyday Attention (TEA*; Robertson et al., 1994; as cited in Robertson et al., 1997a) in 45 subjects with right-hemisphere lesions and 28 with left-hemisphere lesions. Subjects did not have neglect, as measured with the *Star Cancellation Task*, *Behavioral Inattention Test* (Wilson et al., 1988; as cited in Robertson et al., 1997a). Findings indicated particularly strong correlations in subjects with right-hemisphere lesion, in whom sustained attention tests at both two months (25% of the analyses) and two years post-stroke (46% of the analyses) significantly correlated with motor and functional outcomes ($p < .05$).

2.3.5 Neuroscience of Sustained Attention Impairment after Stroke

Dacosta-Aguayo et al. (2015) reported that their investigation was the first to correlate resting-state DMN activity with performance on pencil-and-paper tests of attention in a relatively homogenous sample of subjects three months' post-right-hemisphere stroke ($n = 11$) versus healthy controls ($n = 17$). While the findings elucidated the early functional magnetic resonance imaging (fMRI) signature of post-stroke DMN activity associated with attentional function, no details were provided on what rehabilitation intervention (if any) the subjects may have received during their course of care. Outcome measures included the *Line Cancellation Test* (Strauss et al., 2006; as cited in Dacosta-Aguayo et al., 2015) and the *Trail-Making Test* (Strauss et al., 2006; as cited in Dacosta-Aguayo et al., 2015), which has been described as a test of sustained attention (Langenecker et al., 2007, as cited in Sanchez-Cubillo et al., 2009); divided attention (Johansson et al., 2012); working memory and task-switching (Sanchez-Cubillo et al., 2009); and cognition/executive function (Newberg et al., 2010). General cognitive function was measured with the *Mini-Mental State Exam* (Folstein et al., 1983;

as cited in Dacosta-Aguayo et al., 2015). Results indicated significant DMN differences between groups ($p < 0.05$) at the three-month timepoint, at which time subjects in the stroke group showed significantly impaired performance ($p < 0.05$) on the *Mini-Mental State Exam* and the *Trail-Making Test* as well as a significant correlation between performance on the *Line Cancellation Test* and abnormal increase in DMN activity ($r = -0.747$; $p = 0.000$).

Lack of rehabilitation details also characterized evidence from Park et al. (2014), who reported being the first controlled study of longitudinal associations between changes in DMN activity and cognitive recovery, including attentional components, after stroke. Findings suggested that increased connectivity of the ipsilesional DLPFC with the DMN may be a linchpin for recovery. To carry out their study, the investigators used resting-state fMRI to measure DMN connectivity in a group of 11 subjects at one-, three-, and six-month timepoints after right-hemisphere stroke, with the *Mini-Mental State Exam* administered to all subjects at these timepoints. Seven also underwent the *Trail-Making Test* (Kim et al., 2001; as cited in Park et al., 2014). Eleven matched, healthy controls underwent the same fMRI procedures at a baseline timepoint in order to establish normal DMN connectivity. At the one-month timepoint, subjects with stroke had comparatively decreased DMN connectivity ($p < .05$) between posterior cingulate cortex (PCC), bilateral precuneus, and the DLPFC at the middle frontal gyrus (MFG). Over the course of the study for the stroke group, DMN connectivity with the right DLPFC increased and was significantly correlated with significant improvements in memory at the three- ($r = .775$, $p < 0.041$) and the six-month timepoint ($r = 0.821$, $p < 0.023$). Moreover, at the six-month timepoint, there was significant improvement on the *Mini-Mental State*

Examination ($\chi^2(2) = 12.867$, $p = 0.002$) and the *Trail-Making Test* ($p = 0.043$). Connectivity between the PCC and precuneus increased over the course of the study for the stroke group but remained decreased compared with the normal group (Park et al., 2014).

2.3.6 Sustained Attention Impairment is Prevalent and Problematic in ADHD

Bálint et al. (2009) conducted a meta-analysis of attentional performance on neuropsychological tests as measured in 25 studies comprising a total of 1711 adults with ADHD compared with 1731 controls without ADHD. Sustained attention was measured with CPTs in four studies, for which results showed worse performance in cases of ADHD with a medium pooled effect size for CPT commission errors ($d = -0.61$) and omission errors ($d = -0.49$); and a small pooled effect size for reaction time ($d = -0.05$). Relative to dimensions of daily life with adult ADHD, Gmehlin et al. (2016) reported a lack of research on the relationship between functional outcomes and sustained attention specifically. Thus, they conducted a study of subtypes of attention, including sustained attention, as related to difficulties in everyday life in 24 adults with ADHD and 24 healthy controls. Outcome measures included a standardized self-reported rating scale validated to measure ADHD symptoms and related difficulties (i.e., *ADHD Self-Report Scale*; Rösler et al., 2008; as cited in Gmehlin et al., 2016). Sustained attention was assessed with subtests of the *Vienna Test System (VTS*; Schuhfried, 2000; as cited in Gmehlin et al., 2016), which the investigators described as a computerized CPT. Results showed significantly worse attention for ADHD patients compared with controls [$F(2,88) = 4.08$, $p = .020$] and a correlation ($r = 0.37$; $p = .011$) between decrement in performance and self-ratings of worse ADHD symptoms/everyday difficulty, including inability to concentrate on conversations, overreliance on others to stay organized, and frequent procrastination.

2.3.7 Neuroscience of Sustained Attention Impairment in ADHD

Functional magnetic resonance imaging (fMRI) evidence indicates abnormality of the DMN and DLPFC characterizes pediatric ADHD. For example, Christakou et al. (2013) reported finding that problematic deactivation of the DMN characterizes ADHD in their study to determine neuroimaging correlates of attentional behavior in 20 pediatric subjects with ADHD compared with 20 healthy controls. fMRI was conducted during performance of a sustained attention task with a progressively increasing load. Results showed that with increased attentional load and relative to healthy controls, subjects with ADHD had significantly more reduced left DLPFC activation ($p < 0.0001$) and significantly more increased precuneus/DMN activation ($p < 0.001$). Healthy controls showed progressively more pronounced DMN deactivation with increased load. Relative to DLPFC specifically, a meta-analysis by Hart et al. (2013) that represented 171 cases of pediatric ADHD and 178 healthy controls showed significant DLPFC activation differences ($p = .002$) as measured with whole-brain fMRI analyses between groups in CPT-measured tasks of sustained attention. While this fMRI evidence indicated that abnormality of the DMN and DLPFC characterizes pediatric ADHD, Hart el al. (2013) reviewers indicated that there was a lack of available evidence on the topic in adults (but see Sudre et al., 2017 as described below).

Subsequent magnetoencephalography (MEG) and fMRI research in adult ADHD by Sudre et al., (2017) has substantiated that abnormal connectivity in the DMN, as well as abnormal connectivity between the DMN and task-positive attention networks such as the ventral attention network and the cognitive control network (cf. central executive network/DLPFC), underlies impaired attention for adults with ADHD. Regions having most atypical connectivity included the left precuneus and bilateral PCC (i.e., nodes of the DMN), with less prominent atypical connectivity extending also to lateral cortical-control regions. To conduct the study, these investigators employed MEG and fMRI during resting-state in a sample of 205 adult subjects. Fifty of the subjects had inattentive symptoms of ADHD that had persisted from childhood to adulthood. The remainder of the sample represented subjects whose childhood ADHD had remitted and subjects who had never had ADHD. Results of analysis of MEG data showed a range of significant correlations between inattentive symptoms in adulthood and disrupted stable component connectivity patterns (i.e., rho = 0.47, $p = 5.1 \times 10{-}5$ for a beta-frequency component; rho = 0.48, $p = 3.8 \times 10{-}5$ for beta band; rho = 0 0.54, $p = 1.9 \times 10{-}6$ for gamma band; rho = 0.45, $p = 1.1 \times 10{-}4$ for a theta band component). Post hoc analyses indicated that subjects with persistent ADHD had patterns of connectivity that were significantly different from patterns that characterized the remitted group ($p = 0.001$ for one of the beta components; $p = 0.01$ for the theta component) as well as the never-affected group ($p < 0.001$ for all components). The latter two groups did not differ significantly from each other in this regard. Results from fMRI echoed the MEG findings: there was a significant association between fMRI-indicated disruptions in connectivity and inattentive symptoms (rho = 0.31, $p = 0.0062$ for one component). There was also a between-groups difference driven by abnormal connectivity in the adult ADHD group compared with the remitted group ($p = 0.03$) as well as the never-affected group ($p = 0.008$). Here again, the latter two groups did not show significant between-groups difference ($p = 0.85$).

Other neuroimaging research specific to adult ADHD demonstrated that impaired attention as indexed by clinical, neuropsychological, and neurophysiological measures is related to decreased norepinephrine transporter availability in the right-hemisphere attention network as measured with positron emission topography (PET)-MRI data for 20 unmedicated adults with ADHD versus 20 healthy controls (Ulke et al., 2017). In subjects with ADHD, the decrease was associated with more errors (rho =p0.43; p = .007) on a sustained attention CPT called the *Test of Attentional Performance* (*TAP*: Zimmermann, et. al., 2013; as cited in Ulke et al., 2017); greater electroencephalography (EEG) theta current density in the right DLPFC (rho = −0.41; p = .009); and greater ADHD symptom severity (rho = −0.46; p = .003) for inattention as indexed by the *Conners' Adult ADHD Rating Scale Self-Report* (*CAARS-SR*; Christiansen et al., 2012; as cited in Ulke et al., 2017).

2.4 Definitional Bounds for Meditation

Like attention, meditation has a history of heterogenous definitions. The following sections introduce definitional bounds that are historic, common, or otherwise relevant to this dissertation.

2.4.1 Meditation as Historically Defined

According to Lutz et al. (2008), the recorded history of meditation generally characterizes it as a practice characterized by regulation of attention and/or emotion in diverse religious and secular contexts. Contemporary research has sought to refine its definitional bounds, as summarized below.

2.4.2 Meditation in Psychological/Behavioral Terms

Nash et. al (2013) identified meditation as a process entailing cognitive exercises or stages aimed to subserve attainment of an enhanced mental state, with training of attention identified as one of the defining exercises. Dorjee (2017) conceptualized meditation as a contemplation-oriented activity that, via engagement of sustained attention, can enhance the metacognitive self-regulatory capacity of the mind. These definitions hearken to a seminal rubric formulated by Lutz et al. (2008), which was among the first in modern research to explicate how regulation of attention is a defining aim across a wide swath of approaches representing traditional Buddhist contemplative techniques as well as secular or clinical derivatives:

> Meditation can be conceptualized as a family of complex emotional and attentional regulatory training regimes developed for various ends, including the cultivation of well-being and emotional balance. Among these various practices, there are two styles that are commonly studied. One style, focused attention [FA] meditation, entails the voluntary focusing of attention on a chosen object. The other style, open monitoring meditation, involves nonreactive monitoring of the content of experience from moment to moment. The potential regulatory functions of these practices on attention and emotion processes could have a long-term impact on the brain and behavior. (p. 164)

Of these two styles, focused-attention meditation was described in terms of its typical instructions, which hinge on sustained attention:

> FA [focused-attention meditation] involves…*sustaining* [emphasis added] selective attention moment by moment on a chosen object,…At first, the attention wanders away from the chosen object, and the typical instruction is to recognize the wandering and then restore attention to the chosen object. (Lutz et al., 2008, p. 164)

As focused-attention meditation is typically a precursor to open monitoring meditation, so may it be considered comparatively easy, simple, and/or streamlined in terms of attentional demand (Lutz et al., 2008). A style of focused-attention meditation called *mantra meditation* may be considered the easiest or most streamlined form of focused-attention meditation, per Fox et al.'s (2016) assertion that the mantra (which is a repeated word, phrase, or syllable) serves as a "single salient percept" (Fox et al., 2016, p. 220) by which "attention is more easily *sustained* [emphasis added] and distractors more easily ignored than without the mantra…" (Fox et al., 2016, p. 220). (Meta-analytic research by Fox et al. (2016) to substantiate this claim is detailed later in this chapter.) Insofar as a mantra is a "voluntary verbal-motor production…spoken aloud or silently in one's head" (Fox et al., 2016, p. 211), mantra meditation differs from typical focused-attention meditation that uses non-verbal objects of focus, such as sensations of breathing (Fox et al., 2016). The syllable *om* (Kalyani et al., 2011) and the syllables *sa ta na ma* (Newberg et al., 2010) are examples of mantras used in historical settings as well as contemporary research discussed later in this chapter.

2.4.3 Meditation in Terms of Cognitive Neuroscience

The following passage is a general description of how meditation, thought processes, and neural substrates of attention may relate to each other:

> The DMN is related in general to internally oriented thought processes, including evaluative self-reference .., predicting and planning (Raichle and Snyder 2007; Preminger et al., 2011) and mind-wandering (Mason et al., 2007). Importantly, in many contemplative traditions, mind wandering is considered a distraction and a gateway to rumination, anxiety and depression. (Berkovich-Ohana et al., 2015, p.2)

In this conception, mind-wandering and other processes that characterize DMN activity may be understood as antithetical to meditation, sustained attention, and/or an enhanced mental state. Later sections of this chapter shed further light on these relationships via a summary of empirical evidence relevant to a possible neuroscientific signature of meditation.

2.5 Therapeutic Interventions for Individuals with Impaired Attention Due to Stroke or ADHD

Medical and rehabilitation literature describes standard-of-care interventions, as well as novel/experimental interventions, that aim to effect therapeutic change for individuals with impaired attention due to stroke or ADHD. The following sections summarize targets of action, clinical limitations, and evidence gaps about these interventions in order to lay groundwork for framing how meditation may have potential as this type of intervention.

2.5.1 Pharmacotherapy

Winstein et al. (2016) reported using expert consensus, as well as best evidence according to the American Heart Association's framework for levels of evidence, to formulate practice guidelines for healthcare professionals in adult stroke rehabilitation. They ascertained that while impairment of attention is common after stroke, and that while drugs are commonly used to treat cognitive disorders in general, there is a lack of high-quality evidence examining whether pharmacotherapy targeting attentional substrates after stroke benefits attention. They further reported that the small evidence base on this topic indicated promise with regard to drugs that modulate prefrontal activity. On the other hand, pharmacotherapy affecting DLPFC activity is standard-of-care in ADHD, such as a psychostimulant called methylphenidate. Volkow et al. (2012) assessed the long-term clinical response of 20 adults with ADHD before and after 12 months of a methylphenidate drug regimen. Outcomes of interest included 1) indices of change in dopaminergic activity affecting DLPFC as measured with PET; and 2) symptoms of inattention as measured with the Conners' Adult ADHD Rating Scale (Conners, 1998; as cited in Volkow et al., 2012). Results showed a significant decrease (*p*

= 0.000; cluster size 2457) in dopamine receptor activity in the DLPFC, which the investigators noted was a presumable effect of increased drug-induced dopamine. This change moderately correlated ($r = 0.55$) with a reduction in inattention. In a subsequent systematic review (52 double-blind randomized controlled trials representing an n of 10296 adults) of the efficacy and tolerability of drugs used in therapy for adult ADHD, Cortese et al. (2020) reported methylphenidate as a first-line clinical treatment although it had a significantly less tolerability compared with placebo (OR 2.39; .95 CI [1·40–4·08]).

2.5.2 Neuromodulation of DLPFC

In formulating practice guidelines for healthcare professionals in adult stroke rehabilitation, Winstein et al. (2016) reported that there is sparse but promising experimental evidence (i.e., two published studies) that tDCS delivered to the DLPFC can improve attention after stroke. An additional promising example of tDCS evidence not reviewed by Winstein et al. (2016) is Eun Kyoung Kang et al.'s (2009) double-blind, sham-controlled, crossover study in 10 subjects with post-stroke cognitive decline (per Mini-Mental State Exam score of <25 at baseline) versus 10 age-matched healthy controls. Each subject received one session of active tDCS to left DLPFC and, after a two-day washout, one session of sham tDCS. Attention was operationalized as accuracy and speed scores on a go/no-go CPT at baseline, immediately following intervention, and at 1- and 3-hours post-intervention. Result showed that the healthy volunteers had no significant changes; whereas the subjects with stroke had significant ($p < 0.05$) improvement in response accuracy at all timepoints after active tDCS ($p = 0.024$ at 1 hour post; $p = 0.041$ at 3 hours post). Sham tDCS did not significantly improve response accuracy.

In ADHD research, Salehinejad et al. (2020) conducted a systematic review of randomized controlled trials of tDCS to address ADHD symptoms for pediatric through adult populations with diagnosed ADHD. Outcomes of interest in ten of the 14 total reviewed studies addressed the efficacy of tDCS for improving indices of cognitive function, including attention, as measured with standardized computerized CPTs and/or standardized self-report scales of symptoms of inattention. Left and right DLPFC were the brain regions most often targeted in the reviewed studies. Partial support was found for benefit; but conclusions were limited by methodological limitations of the reviewed evidence (e.g., heterogeneity of dosing, subject age, and instrumentation).

2.5.3 Cognitive Rehabilitation

Cognitive rehabilitation is a broad term that has been used to refer to a general family of interventions aimed to improve cognitive functioning and related areas of participation (Loetscher et al., 2019; Radomski & Giles, 2014). Cognitive rehabilitation interventions are considered standard-of-care for problems associated with impaired attention after stroke and often take place within the context of occupational therapy (Radomski & Giles, 2014). Radomski and Giles' (2014) described several approaches to cognitive rehabilitation commonly used in occupational therapy for neurocognitive disorders. First, *process-specific training* was described as cognitive exercise targeted to stimulate an isolated cognitive process (such as attention) using pencil-and-paper or computerized exercises. Because this approach was reported to eschew functional activities or occupations, it was characterized as possibly appropriate within occupational therapy only as an adjunct to other approaches (Radomski & Giles, 2014). Second, *skill-task-habit training* was characterized as occupation-oriented and thus recommended as a first-line approach. It was described as a strategy aimed to establish or reestablish routines and habit sequences within daily occupational performance areas, such as self-care or home management, with outcomes described as automaticity of skill execution and enhanced participation in the targeted occupational performance area. It was asserted that this approach can be used to remediate impairment-related disruption to longstanding life habits and/or to establish entirely new skills or behaviors (Radomski & Giles, 2014). Third, *metacognitive strategy training* was likewise characterized as a recommended, occupation-oriented approach that is always taught in the context of an occupational performance goal, not simply in the abstract. It was described as training the client in a self-monitoring approach to problem-solving intended for use in naturalistic settings when occupational performance problems arise due to cognitive impairment. As an example, Meichenbaum's (1977) strategy of "goal, plan, do, check" (Radomski & Giles, 2014, p. 738) was cited.

Not specific to occupational therapy, Loetscher et al.'s (2019) Cochrane systematic review and meta-analysis of controlled clinical trials and randomized controlled trials of cognitive rehabilitation for individuals with attention problems after stroke defined cognitive rehabilitation as follows:

> For people with attentional deficits, cognitive rehabilitation interventions include tasks designed to restore attention abilities, such as computerised activities and pencil-and-paper tasks requiring attention. The alternative approach is teaching people strategies to compensate for their attention impairments. (p. 6)

Results of this review revealed a lack of high-quality evidence to support short- or long-term effects of cognitive rehabilitation on subjective and objective measures of sustained attention, alertness, and functional impact on daily life activities. The reviewers defined sustained attention as “ability to maintain attention over a long period of time” (Loetscher et al., 2019, p. 6); and alertness, as “ability and readiness to respond” (Loetscher et al., 2019, p. 6).

In short, there remains a need for further research on rehabilitation interventions to effect therapeutic change for adults with impaired attention due to stroke or ADHD. Further empirical evidence that is relevant to how meditation may have potential as this type of intervention is summarized below.

2.6 Empirical Evidence on the Experience and Attentional Effects of Meditation in Stroke, ADHD, and Other Populations

The following sections summarize evidence that is relevant to questions of how, whether, and for whom meditation may be experienced or have effects, including therapeutic impact on indices of attention such as neuropsychological tests and/or DMN activity. Such evidence holds promise that meditation may effect improvement in indices of attention and that it is feasible in cases of stroke or ADHD. However, there is an evidence gap relative to the experience and/or attentional effects of meditation in adults with stroke or ADHD, particularly with regard to mantra meditation addressing impairments in sustained attention. Furthermore, there is evidence to suggest that in cases of cognitive impairment, a simplified style of meditation may render the demands of meditation optimal in terms of attentional demand.

2.6.1 Empirical Evidence on Meditation and Attention: Non-Stroke/Non-ADHD Studies

There is substantial evidence associating meditation with change in attentional behavior and/or substrates for members of non-clinical populations as well as individuals with conditions other than stroke or ADHD. This evidence is summarized below.

2.6.1.1 Effects of Meditation (Generally Defined) on Attentional Behavior and/or Substrates in Non-Stroke/Non-ADHD.

A scoping review by Marchand et al. (2014) analyzed 36 functional and structural neuroimaging studies of meditation in various clinical and non-clinical populations without stroke or ADHD. Meditation-related keywords for the literature search were *meditation* and *mindfulness*. The reviewers found consistent indications that meditation generally impacts DMN function, largely as associated with medial cortex although not exclusive of impact on the DLPFC. However, findings were reportedly limited by heterogeneous methodologies, subject characteristics, and meditation styles across the reviewed studies. In contrast, Chiesa et al. (2011) used comparatively more homogenous bounds to define meditation in a systematic review of the effects of mindfulness practice on cognitive function in studies of adult healthy volunteers or subjects with major depression, traumatic brain injury, chronic pain, suicidality, or stress risk. To qualify for inclusion, each study had to clearly describe the meditation training so the reviewers could determine whether the study used a mindfulness practice. Additionally, included studies had to use mindfulness/open monitoring either alone or combined with focused-attention meditation. Of the 23 included studies, seven were randomized controlled trials; eight were controlled trials; and eight were case-control studies. Cognitive function, including sustained attention, was measured with a variety of behavioral tests. Of the seven controlled or randomized controlled trials measuring sustained attention, two were reported to indicate significant improvements favoring the meditation conditions as compared with controls (i.e., Chambers et al., 2008; and Jha et al., 2007; as cited in Chiesa et al., 2011); and one found significant improvements for both groups (Anderson et al., 2007; as cited in Chiesa et al., 2011). All three case-control studies were reported to show significantly better sustained attention in meditators compared with controls (i.e., Josefsson & Broberg, 2010, as cited in Chiesa et al., 2011; Pagnoni & Cekic, 2007, as cited in Chiesa et al., 2011; and Valentine & Sweet, 1999, as cited in Chiesa et al., 2011). The reviewers concluded preliminary support for the effectiveness of mindfulness practices to improve various domains of cognition, including attention. They also recommended that future research with more methodological robustness (e.g., even stricter definitions of both meditation and attention) would be needed for firm conclusions.

However, the definitional bounds for meditation were comparatively less strict in Debarnot et al.'s (2014) narrative review that compared novices with experts relative to neurophysiology associated with motor and mental tasks, including meditation. Twenty-two articles, two of which were meta-analyses, comprised the reviewed evidence base for neuroimaging-based correlates of meditation. While the reviewers concluded support for the idea that neuroplastic change is associated with new skill in meditation in various non-clinical populations, with frontal activation more characteristic of novices than experts, the limitations of the review included lack of explicit inclusion criteria for reviewed articles as well as type of meditation.

2.6.1.2 Effects and/or Experience of Specific Meditation Styles on Attentional Behavior and/or Substrates in Non-Stroke/Non-ADHD.

With more categories and explicit definitional bounds for meditation than the aforementioned studies, Fox et al. (2016) conducted a systematic review and meta-analysis of functional neuroimaging studies measuring cerebral blood flow associated with meditation in healthy normal subjects. Meditation in each study was characterized as focused-attention, open monitoring, or a style called compassion meditation. Of note, mantra meditation was designated as a separately analyzed subcategory of focused-attention meditation. Included studies represented 31 meditation experiments comprising 527 subjects in total, most of whom were categorized as experts by the reviewers. Peak foci of activation or deactivation in the neuroimaging meta-analysis were drawn from 25 studies representing 250 total foci. Eight of these studies were characterized as focused-attention, and seven were separately characterized as mantra. There was an approximately medium effect size for each category of meditation (mean Cohen's $d = -0.74$ for deactivations and 0.59 for activations), although a larger effect size was present for mantra meditation (Cohen's $d > 1.0$). Overall calculations held even when evidence from novice meditators was excluded. Focused-attention meditation in general was associated with (a) two significant clusters of PFC activation (i.e., in dorsal ACC and premotor cortex); and (b) slightly sub-threshold clusters of activation in the DLPFC and left middle insula. The investigators further reported that clusters of deactivation were present in the DMN (i.e., ventral PCC and left inferior parietal lobule). Specific to mantra meditation, they reported that (a) significant activation was found in the posterior DLPFC; (b) that activations were also evident in the cuneus, anterior precuneus, and fusiform gyrus; and (c) that deactivations were present in areas associated with auditory comprehension as well as somatosensory and interoceptive awareness, including the left inferior parietal lobule (i.e., an area of the DMN). Findings overall were reported to constitute preliminary support for dissociable patterns of connectivity associated with each meditation category, which the investigators further interpreted as consistent with each category's psychological/behavioral aims. For example, mantra was substantiated as a tool that obviates otherwise distracting stimuli from the environment or from within, thus allowing focus to sharpen more easily than with other approaches to focused-attention meditation. Of note, the reviewers noted that differential affective meaning or other subjective mechanisms potentially at play in mantra meditation could have influenced objective outcomes and recommended further research in this regard.

While no study in Fox's (2016) review investigated differential affective meaning at play in mantra meditation, a study by Brewer et al. (2011) did, in fact, measure subjective outcomes related to different styles of meditation—namely, focused-attention meditation, open monitoring meditation, and compassion loving-kindness meditation. Mantra meditation was not explicitly named as such. The investigators concluded support for the hypothesis that markers of DMN connectivity may be used to index mechanisms of meditation and, in accordance with the subjective outcomes, that changes in the DMN are related to decreased mind-wandering. In this study, fMRI was administered during resting state as well as during each style of meditation. Each style had standardized instructions provided by investigators. The sample included 12 healthy subjects with over 10 years of meditation experience as well as 12 meditation-naïve, healthy control subjects. Analyses of focused-attention meditation revealed less activation of PCC and left angular gyrus for experts compared with novices. Across all meditation conditions, areas of the DMN identified as main nodes (i.e., PCC/precuneus; superior, middle, and medial temporal gyri) were significantly more deactivated during meditation for experienced meditators than for novices, with a similar (but non-significant) pattern relative to medial prefrontal cortex. During resting-state, as well as during the meditation conditions, the DMN connectivity patterns between bilateral DLPFC, PCC, and dorsal ACC was stronger for experts than for novices. There was significantly less mind-wandering during meditation for experts than for novices, per subject self-report.

Studies specific to mantra (or mantra-like) meditation in healthy adult volunteers have demonstrated that it can improve performance on neuropsychological tests of attention behavior. For example, Menezes & Bizarro (2015) investigated the effects of a form of meditation in which the instructions mandated paying attention to each breath, along with mental counting of each breath (one number per exhalation). According to the investigators, the superimposition of this count on the breath was intended to facilitate attention to breath, even as this count was differentiated from mantra understood as a spirituo-philosophical practice:

> However, so as to characterize the focused attention meditation, as well as to make it possible for the participants to maintain the focus of their attention on breathing, the same were instructed to mentally count each exhalation (it is noted that other types of focus, such as mantras, were not used, in order to avoid any link with philosophical or spiritual traditions). (Menezes & Bizarro, 2015, p. 396)

Attention was measured with a standardized pencil-and-paper test of selective attention called the *Concentrated Attention Test* (Cambraia, 2003; as cited in Menezes & Bizarro, 2015). Thirty-three meditation-naïve healthy adults were randomized to either the meditation condition (n=14) or waitlist control (n = 19). The intervention period for meditation was five consecutive weekdays, with one session of meditation per day. The first three sessions entailed repeated cycles of mentally counting from *1* to *10*; and the last two sessions, counting backwards from *100*. This process occurred in concert with paying attention to breath as a form of meditation, a condition which the investigators called "focused meditation" (Menezes et al., 2015, p. 395). This process lasted 15 minutes in the first session; 20 minutes in the second; and 30 minutes in each session thereafter. Additionally, each session incorporated some elements of group process, as well as unspecified instructional content, about the meditation. Sessions were overseen by a psychologist with reported expertise in group work, yoga, and meditation. In all, these procedures were reported to last around 90 minutes per session. Attention was measured at pre- and post-intervention timepoints. Data was analyzed using general linear modeling with respect to factors of group (meditation versus control) and time (pre-test versus post-test), with ANOVA conducted for post-hoc comparisons. For all the analyses, significance was set at $p < 0.05$. Results for general linear modeling showed a main effect for time with respect to the rate of correct responses [$F(1, 31) = 13.30$, $p = .001$, $\eta^2 = .30$] and an accompanying interaction between group vs time [$F(1, 31) = 4.21$, $p = .05$, $\eta^2 = .10$] which favored the meditation group. Post-hoc analysis showed the difference lay in comparison of pre-post increased rate of correct responses for the meditation group [$F(1, 13) = 14.77$, $p = .002$, $\eta^2 = .53$] compared with the control group [$F(1, 18) = 1.9$, $p = .18$, $\eta^2 = .09$].

A similarly designed study by Menezes et al. (2013) randomized 26 healthy adult subjects to a mantra condition; 26, to a progressive relaxation control condition; and 24, to waitlist control (total $n = 74$). The intervention was delivered once per week for six weeks, with each session lasting one hour and 30 minutes. In the mantra condition, practice of meditation in the first session lasted 15 minutes; in the second, 20 minutes; and in all remaining sessions, 30 minutes. The counting of breaths (one per exhalation) was executed in cycles from *1* to *10* in the first half of the intervention period; and thereafter, by counting backwards from *100* to *1*. Student's *t*-test revealed significant findings ($p < 0.05$) indicative of improved selective attention only for the mantra meditation group—namely, a significant decrease in omission errors from pre- to post-intervention.

Other non-stroke/non-ADHD research on neurophysiological effects of mantra meditation has focused on healthy volunteers identified as meditation-naïve. Berkovich-Ohana et al. (2015) investigated fMRI activity during a meditation condition in 23 healthy normal subjects with no prior meditation experience. Meditation was operationalized as non-verbalized, silent repetition of the word *one.* This design was reportedly aimed to isolate the effects of silent repetitive speech with no spiritual or otherwise contextually meaningful connotations, which the investigators asserted as usually characteristic of mantra in meditation. Each subject performed this technique at a regular, self-selected pace, for five blocks lasting 21 seconds each, interspersed with rest periods lasting 12 seconds each. Random-effects general linear modeling revealed that compared with the rest condition, meditation significantly downregulated regions with DMN overlap ($p < 0.01$), including the precuneus; bilateral PCC and ACC; medial frontal gyrus; insula; and right inferior parietal lobule. The investigators noted that the DLPFC may have played gatekeeper to the downregulation (Berkovich-Ohana et al., 2015).

In a separate fMRI study of mantra meditation in healthy volunteers (*n* = 12), Kalyani et al. (2011) measured neurohemodynamics during three conditions performed in blocked fashion: 1) audible enunciation of the syllable *om*; 2) a rest state; and 3) audible enunciation of the syllable *ssss*. Each block consisted of 15 seconds of *om*, followed by 15 seconds of rest, followed by 15 seconds of *ssss*, followed by 15 seconds of rest, then progression to the next block, for a total of 10 blocks. Investigators concluded that *om* meditation was associated with limbic deactivation in a pattern similar to that of vagal nerve stimulation used in clinical treatment of depression. Insofar as such deactivation may be understood to constitute a reward, so may it be conceivable as a mechanism by which *om* meditation may effect reward. Further, to the extent that reward is integral with salience (Kleim & Jones, 2007), so may the findings have implicated how salience may be an inherent feature of this type of meditation. This implication becomes even clearer in consideration of Norman et al.'s (2017) summary of canonical research on attention networks, which identified anterior insula and dorsal ACC (i.e., affected substrates in Kalyani et al., 2016) as nodes of the salience network. Further details of Kalyani et al. (2011) were as follows. In *om* meditation, the subject enunciated the vowel *o* for 5 seconds and continued into the consonant *m* for 10 seconds, with no break between *o* and *m* (i.e., enunciated a single syllable). The investigators reported that this method of chanting *om* is a well-known meditation technique (Telles et al., 2010; as cited in Kalyani et al., 2011) and that it effects aural vibratory sensation. For *ssss*, the subject enunciated the *ssss* sound for 15 seconds. This condition controlled for possible effects of expiratory sensation while also eliminating aural vibratory sensation (i.e., an avenue for vagal nerve stimulation). Regions of interest included limbic structures (i.e., amygdala, hippocampus, parahippocampal gyrus, and insula) as well as other brain structures the investigators described as influential on the limbic system, including orbitofrontal cortex, ACC, and thalamus. Results showed significant deactivation in all limbic regions of interest, as well as orbitofrontal cortex, ACC, and thalamus, during *om* enunciation. Compared with rest, *om* enunciation also led to significantly more deactivation in bilateral orbitofrontal, anterior cingulate, parahippocampal gyri, thalami, and hippocampi. No significant activation or deactivation was present during the *ssss* condition.

2.6.1.3 Effects of Mantra Meditation on Impaired Attentional Behavior and Substrates: Non-Stroke/Non-ADHD.

Other research on mantra meditation in non-stroke/non-ADHD populations has focused on subjects with mild to moderate cognitive impairment due to normal age-related decline or developing dementia. For example, Newberg et al. (2010) compared the effects of mantra meditation versus a comparison music-listening condition in a sample of these subjects (n = 14 meditation; n = 5 comparison) and found preliminary support for mantra meditation to have significant effect on attention in terms of behavioral testing as well as DMN activity. Mantra meditation was operationalized as repeated intonation of four syllables (i.e., *sa ta na ma*) in concert with touching the thumb to each finger, one finger per syllable. Each individual in the mantra meditation group carried out this practice at home individually while a CD of the intonation played in the background to aid the rhythm of chanting. In contrast, each individual in the comparison group was instructed to listen attentively to a standardized music recording. These practices took place once per day for 12 minutes, for eight weeks. Attention was measured at pre- and post-intervention timepoints with the Trailmaking Test Part B.

Cerebral blood flow to the DLPFC was also measured at these timepoints using single photon emission computed tomography during a resting-state listening task. For this task, subjects in the meditation group listened to an informational recording about the benefits of meditation, whereas the music group listened to the standardized music recording that was used as their intervention condition. Individuals in the meditation group were also scanned at these timepoints while performing the meditation. Improvement on the Trailmaking Test was reported to trend towards significance $p <. 05$ within the mantra group ($p = .05$) but not for the comparison group ($p = .19$). No between-groups significant differences were reported in this regard. At post-intervention, only the meditation group showed significantly higher resting-state cerebral blood flow to attentional substrates and structures with connections to the default mode network, including right DLPFC ($p = .007$), right inferior frontal lobe ($p = .002$), right superior frontal lobe ($p = .007$), right superior parietal lobe ($p = .007$), and left superior frontal lobe ($p = .006$). Additionally, at post-intervention, only the meditation group showed significantly decreased right DLPFC activity during meditation ($p = .001$); and significant correlation between cerebral blood flow in this region versus the Trails Test ($R = -0.61$, $p = 0.02$).

2.6.2 Empirical Evidence on Meditation and Attention in Cases of Stroke or ADHD

The following sections provide a summary of evidence indicating that meditation may effect change in indices of attention for adults with stroke or ADHD. These sections also show that there is an evidence gap in this regard, particularly with regard to mantra meditation and impairments in sustained attention.

2.6.2.1 Effects and/or Experience of Specific Meditation Styles on Attentional Behavior and/or Substrates After Stroke.

There are several reviews pertinent to this topic. Ospina et al. (2008) conducted a systematic review of the characteristics and quality of meditation in clinical trials. Results showed that of 141 trials involving mantra, none enrolled subjects with stroke. Fox et al.'s (2016) aforementioned systematic review of functional neuroimaging studies of meditation noted that no studies have yet investigated whether neuroplastic change is associated with meditation after stroke. Lazaridou et al. (2013) reported finding sparse evidence for their systematic review of research on the health- and cognition-related effects of meditation practices in stroke rehabilitation. These investigators searched peer-reviewed journal articles published in English between 1990–2013 that reported on randomized controlled trials, case-control studies, or cohort studies (final n = 10 studies). Their search strategy used combinations of keywords *stroke; mindfulness; MBSR; yoga; pranayama; dhyana; asanas; yogic; meditation; meditat∗; transcendental meditation*; and *mindfulness*. Findings indicated preliminary support for various benefits including attentional. Only one study was reported to have investigated whether meditation improves performance on quantitative neuropsychological tests of attention behavior after stroke. This study was conducted by Johansson et al. (2012) and is described next.

Johansson et al. (2012) conducted a randomized, waitlist-controlled trial to examine the effects of a meditation program on various aspects of cognitive function in subjects with chronic neurological impairment (i.e., stroke; n=12 or traumatic brain injury; n=10). While the results showed that the meditation program improved attention in their sample, these investigators did not designate impaired attention as an inclusion criterion. Additionally, they did not use the SART; and their sample represented not only stroke but also brain injury. Attention was measured with the Trail-Making Test, which the investigators identified as a measure of divided attention. The meditation program was based on standard MBSR, which is an 8-week program based on systematic, intensive training in mediation and yoga characterized by "familiarizing one self with awareness itself (mindfulness)" (UMass, 2017, p. 1). Specifically, standard MBSR comprises approximately 80 hours of focused-attention, open monitoring, and other meditative practices—but not mantra—and is administered by personnel with specialized training over an 8-week period of contact in group classes and home assignments (UMass, 2017). Johansson et al. (2012) reported modifying the standard MBSR tempo to accommodate subjects' greater-than-normal-time-needed for information processing. ANCOVA results showed significant between-groups differences on the Trail-Making Test favoring their MBSR program over waitlist control (F = 7.39, p = 0.013). Paired t-testing showed also showed significant improvement only for the MBSR group (p = 0.017).

In a separate study in stroke, Orenstein et al. (2012) used a multiple baseline single-case research design (n=4) to examine the effects of 8 to 10 sessions of focused-attention meditation for subjects with aphasia. Outcome measures included tests of attention (i.e., reaction time and accuracy in a card-sorting task). All subjects reported that focused-attention meditation was easy to learn and perform. The investigators characterized findings as indicative of improved attention in one subject but no "obvious" (p. 682) effect. An additional limitation to this study was that all subjects demonstrated near-perfect scores on the attention tests before meditation was introduced.

Meditation after stroke is also underrepresented as a topic of qualitative research. In non-stroke populations, there is a robust qualitative evidence base on meditation, as indicated by an April 2022 database search of peer-reviewed scholarly journals via Academic Search Complete, CINAHL with Full Text, Medline, APA PsycINFO, and Psychological and Behavioral Sciences Collection (keywords *qualitative* AND *meditat** NOT *stroke*; 1863 results). Yet the same search using keywords *qualitative* AND *meditat** AND *stroke* yielded eight results, none of which used standard qualitative procedures and/or identified the experience of meditation after stroke as the sole, primary focus of inquiry.

2.6.2.2 Effects of Specific Meditation Styles on Impaired Attentional Behavior in ADHD.

There is an evidence gap on mantra meditation to improve sustained attention for adults with ADHD, per Krisanaprakornkit et al.'s (2010) Cochrane systematic review of randomized controlled trials of meditation to address core symptoms of ADHD (2010). The reviewers defined meditation as either (a) concentrative meditation (i.e., "sustained attention directed towards a single object or point of focus" (Krisanaprakornkit et al., 2010, p. 5); or (b) mindfulness meditation (i.e., "open awareness to any contents of the mind … [and] the continual maintenance of … a non-reactive attitude…with equanimity" (Krisanaprakornkit et al., 2010, p. 5). Inclusion criteria for the review focused on trials delivering these meditation types in singularity or in combination. Outcome measures included psychological tests of attention (e.g., CPTs) and psychophysiological measures (e.g., electroencephalography (EEG)). Reviewers concluded some support for the efficacy of meditation to improve attention based on four included trials total. However, these trials were in children and did not measure sustained attention but rather, selective attention (which has been defined in Loetscher et al.'s (2019) Cochrane systematic review and meta-analysis of cognitive rehabilitation as the "ability to focus on specific stimuli while ignoring irrelevant stimuli" (p. 6)). These pediatric studies are described next.

The first trial was a dissertation study (Kratter, 1983) comparing effects of mantra meditation to control conditions in 24 boys (ages six-13) with ADHD. Mantra meditation was repetitive intonation of the term *Ahnam*, an ancient Sanskrit word meaning "nameless" (Kratter, 1983, p. 30). Sessions lasted from one to eight minutes and took place three times per week for four weeks. Attention was measured with a timed pencil-and-paper test of selective attention called the *Fruit Distraction Test* (Santostefano, 1978; as cited in Kratter, 1983) in which the tested individual is asked to name colors accurately despite distractions such as a contradictory color name presented in the field of view. Data analysis with ANOVA and post hoc tests revealed a significant improvement in attention (i.e., decreased number of errors; $p < 0.01$) for the meditation group only.

In the second trial—also a dissertation study in pediatric ADHD—Moretti-Altuna (1987) compared mantra (i.e., repetitive intonation of the word *one*) versus control conditions (drug therapy; standard therapy) in 23 boys (ages six-13) with ADHD. Sessions lasted from one to eight minutes and took place three times per week for four weeks. Selective attention was measured with the *Fruit Distraction Test*. Data were analyzed using ANOVA and post hoc tests to reveal no significant differences between groups, although each group did demonstrate significant improvement ($p < 0.05$).

Aside from the need for further, high-quality research on mantra meditation to improve sustained attention for adults with ADHD, there is a small evidence base on mindfulness meditation for this purpose. For example, and subsequent to the aforementioned review by Krisanaprakornkit et al. (2010), Bueno et al. (2015) conducted a randomized controlled study of the attentional effects of mindfulness meditation in adult subjects with ADHD versus healthy controls. Twenty-one subjects with ADHD, as well as eight healthy controls, were randomized to participate in this form of meditation. Twenty-two additional subjects with ADHD, as well as nine additional healthy controls, were randomized to a no-intervention condition. Outcomes included subjective rating of ADHD symptoms, including inattention, as measured with the *Adult ADHD Self-Report Scale (ASRS*; Kessler et al., 2005; as cited in Bueno et al., 2015); and two CPTs including the *Attentional Network Test (ANT*; Fan et al., 2002; as cited in Bueno et al., 2015) and *Conner's Continuous Performance Test (CCPT II*: Conners, 2002; as cited in Bueno et al., 2015). Meditation was operationalized as an eight-week program of individual daily home exercises including formal meditation as well as mindfulness in daily living. These individual exercises progressed from five-minute daily sessions in the first and second week to 10 minutes in the third to fifth week, and 15 minutes each week thereafter. Additionally, subjects attended group sessions once per week, each lasting 2.5 hours and comprising 15 minutes of meditation as well as group discussion and instruction on u new forms of meditation to be performed for the upcoming week at home. The investigators did not specify what the new forms of meditation entailed, other than to designate them as mindfulness practices. Results showed that symptoms decreased significantly only among those in the meditation groups ($p < 0.01$). There was a similar pattern with respect to the ANT, as the meditation condition showed an interaction with session for a reaction time metric (F (1,56) = 8.16; $p = 0.01$), with *post hoc* analyses showing significantly improved scores only for the meditation groups (both healthy and with ADHD). Likewise on the CCPT II, there was an interaction between session and intervention (commission errors F (1,56) = 8.74; $p < 0.001$), with *post hoc* analyses showing significantly improved scores only for the meditation groups (both healthy and with ADHD). This evidence indicated that the mindfulness practices/meditation significantly improved attention for all subjects and that ADHD status did not mediate this change. The investigators noted that possible practice effects relative to at least one measure (i.e., the ANT) may have limited the study. Additionally, the ANT did not indicate baseline attentional impairment for subjects with ADHD. In contrast, both ADHD subjects and healthy controls were indicated to be attentionally impaired on the CCPT II at baseline; all subjects also rated themselves as attentionally impaired on the ASRS at baseline. This apparent lack of differential baseline attentional impairment between the groups may have engendered the lack of between-groups difference with respect to the effects of intervention.

Other research on non-mantra meditation indicating its efficacy to improve sustained attention in adult ADHD included Tarrasch et al.'s (201)) study of standard MBSR in 12 adults with dyslexia and 13 with ADHD (six of whom also had dyslexia, thus potentially confounding the sample). A CPT (Tsal, 2005; as cited in Tarrasch et al., (2016)) was administered to all subjects at pre- and post-intervention. All subjects completed intervention, which was described in keeping with the standard MBSR protocol (cf. UMass, 2017). Data analyses used paired *t*-tests for assessing changes in attention. To compare changes in ADHD versus non-ADHD subjects, repeated measurement ANOVA was used relative to the standard deviation of reaction times. The within-subjects factor was measurement timepoint and the between-subjects factor was ADHD (present versus absent). Results showed significant improvement in attention as indexed by change in standard deviations of CPT reaction times ($p < 0.001$). ANOVA revealed a significant time by ADHD-diagnosis interaction [$F(1,16) = 9.21$, $p = 0.008$]. *Post hoc* analyses showed that only for subjects with ADHD, MBSR significantly improved sustained attention by 54.2% as indexed both by change in standard deviations of reaction times ($p = 0.0003$) and significantly fewer errors of commission ($p = 0.015$).

CHAPTER 3. STUDY 1. MEDITATION AFTER STROKE: A PHENOMENOLOGICAL STUDY

Research on the health benefits of meditation has proliferated in recent years, along with efforts to establish a scientific consensus on the definition of meditation (Nash et al., 2013). A broad general definition is that meditation is a regimen of mental training or contemplation in which self-regulation of attention and/or emotion is a defining aim (Lutz et. al., 2008; Nash et. al., 2013). While no studies to date have investigated neuroplastic change associated with meditation after stroke (Fox et. al., 2016; Lazaridou, et. al., 2013) studies in non-stroke populations indicate that meditation is associated with neuroplastic change in attentional substrates (Fox et. al., 2016; Newberg et. al., 2010) as well as improvement on neuropsychological tests of attention (Chiesa et. al., 2011; Menezes, et. al., 2013; Menezes et. al., 2015; Newberg et. al., 2010). This evidence, as well as the neuroplasticity tenet of "use it and improve it" (Kleim & Jones, 2008, p.S227), suggests that meditation may have potential to drive adaptive neuroplastic change in attentional substrates. In turn, meditation may thus have potential promise as an intervention addressing impaired attention after stroke, which is a common problem Winstein et. al., 2016). Lazaridou, Philbrook, and Tzika's (2013) systematic review found sparse evidence on the benefits of meditation relative to attention or other health-related domains addressed in stroke rehabilitation. They concluded that further research is needed on whether and how meditation may support stroke recovery. Additionally, in a systematic review of functional neuroimaging evidence on meditation, Fox et al. (2016) recommended that future research should investigate the subjective experience of meditation because of its potential influence on objective outcomes.

Qualitative research is a process of scientific inquiry into subjective experience (Creswell, 2013). Phenomenology is a qualitative approach that elucidates knowledge about a phenomenon of interest (such as meditation) via first-person data from people who have experienced that phenomenon (Creswell, 2013, Chapter 4). Phenomenology is thus designed to reveal subjective meanings that may influence mechanisms of, or outcomes related to, a given phenomenon (Garrett et. al., 2011). Phenomenology has been recommended to generate testable hypotheses about neurophysiological mechanisms of meditation (Awasthi, 2013). In non-stroke populations, there is a robust qualitative evidence base on meditation, as indicated by an April 2022 database search of peer-reviewed scholarly journals via Academic Search Complete, CINAHL with Full Text, Medline, APA PsycINFO, and Psychological and Behavioral Sciences Collection (keywords *qualitative* AND *meditat** NOT *stroke*; 1863 results). Yet the same search using keywords *qualitative* AND *meditat** AND *stroke* yielded eight results, none of which used standard qualitative procedures and/or identified the experience of meditation after stroke as the sole, primary focus of inquiry.

To address the qualitative evidence gap on meditation after stroke, the present article reports on a phenomenological investigation of the following, overarching questions: 1) What do stroke survivors experience in association with their participation in meditation?; and 2) What contexts, situations, or factors have typically played a part in stroke survivors' experience of meditation? The main objective was to facilitate understanding of the experience of meditation after stroke (i.e., the central phenomenon) and thereby lay groundwork for future, hypothesis-driven studies on meditation to improve attention or other domains related to functional recovery after stroke.

3.1 Methods

3.1.1 Approach

This study was approved by the authorized institutional human research review board (IRB) at the institution governing the research. All study procedures were followed in accordance with institutional guidelines. Phenomenology was the qualitative approach. The guiding theory was that a post-positivist framework using transcendental phenomenology would yield trustworthy understanding of the central phenomenon, via a focus on participants' experiences as well as the researcher's systematic explication of his or her own experiences as related to the investigation (Creswell, 2013, Chapter 4).

3.1.2 Personnel

During the study, the principal investigator (PI) was a master's degree-level licensed occupational therapist employed in a neurorehabilitation research lab as well as a doctoral student in rehabilitation sciences. At the time of study initiation, she had completed a doctoral-level course in qualitative research and had eight years of professional experience in quantitative research and clinical care specializing in neurorehabilitation and functional recovery after stroke. She had a personal daily practice of meditation in the year preceding study initiation, in which time she completed an 80-hour layperson's course on meditation to elicit mindfulness, stress reduction, and/or enhanced health and well-being. The second author was a dual-doctorate occupational therapist with 18 years' experience specializing in qualitative research in health sciences. She served as professor in the course on qualitative research that the first author took immediately prior to the inception of the study.

3.1.3 Recruitment and Sampling

This study used purposive sampling to identify adults who self-reported participation in post-stroke meditation. Participants were in the chronic stage of recovery (i.e., >1-year post-ictus) and had sufficient communication capacity (i.e., no severe aphasia) in order to participate in interviews. Target sample size was set in accordance with saturation, a metric wherein data collection persists only so long as novel meanings are continuing to emerge (DePoy & Gitlin, 2016, Chapter 13) – which generally occurs with a sample size ranging from three to ten participants (Creswell, 2013, Chapter 7). Criteria for deciding that no further sampling would occur included saturation or no new enrollment for any consecutive six-month period. Recruitment tools included flyers placed at a variety of sites, such as hospitals offering stroke-related or meditation-related events. Referrals were accepted from local and regional researchers and clinicians with expertise in rehabilitation and adult neurological impairment. Additionally, recruitment occurred via snowball sampling.

3.1.4 Procedures

All participants had intact consent capacity and provided written informed consent after receiving a verbal and written explanation of the purposes, procedures, and potential risks of the study. This explanation included specification that the PI was conducting the research as part of her dissertation under the supervision of her doctoral committee chair (second author). The consent process also included participants' consent to the inclusion of material pertaining to them in future dissemination and publication, with acknowledgement that they would not be identified in such efforts (e.g., the present article, which is fully anonymized and uses only pseudonyms).

The PI (first author) collected first-person data from each participant using a semi-structured, one-on-one, face-to-face interview format using pre-specified as well as unplanned prompts (Table 4). The prompts were not pilot tested but were vetted in the qualitative research course that the PI completed immediately prior to study inception.

Table 4. Interview Guide

Prompts
Describe your experience of meditation practice.
Describe your thought processes during meditation.
Has your meditation practice had any effects on your thought processes? If so, please describe.
Do you experience emotions during your meditation practice? If so, please describe.
Has your meditation practice had any effects on your emotions? If so, please describe.
What do you experience in terms of physical or body sensations during meditation?
Has your meditation practice had any effects on your physical sensations? If so, please describe.
Has your meditation practice had any effects on your daily life activities or daily life participation? If so, please describe.
Are there any other areas of life that your meditation practice has affected? (examples: spirituality).
What is your favorite aspect of meditation? Why? What is your least favorite? Why?

Table 4 Note. Pre-specified interview prompts inquired about the experience of meditation and its possible effects. Unplanned prompts aligning with the overarching questions of the study, including inquiries about attention, were also posed.

Participants were allowed to choose an interview site with adequate privacy, comfort, and accessibility. Field notes were composed during and after the interviews. Each interview was audio-recorded in real-time via a password-protected device belonging to the PI (Sony Vaio Duo 13). The PI generated transcripts of each interview using an open source web app (oTranscribe) downloaded to the PI’s password-protected computer. To protect confidentiality, all data was coded to exclude identifying information and was stored on password-protected technology or in a locked cabinet in a locked room at the PI’s employment site (i.e., a neurorehabilitation research lab at a regional freestanding rehabilitation hospital).

3.1.5 Qualitative Validation Strategies

Multiple strategies to validate the findings were used, thus exceeding Creswell's (2013, Chapter 10) recommendation to use two or more qualitative validation strategies. Specifically, to analyze data, the PI used the following 7-step procedure for promoting "the trustworthiness, reliability and generalizability of phenomenological research for the novice" (Sanders, 2003, p. 293): 1) repeated readings of transcript to get a sense of the data as a whole; 2) identification of significant statements, which are phrases that help elucidate the research question; 3) construction of formulated meanings, or a restatement of the meaning, for each significant statement; 4) organization of the formulated meanings into groups and collapsing them until the most significant meanings remained; 5) description of the essence of the phenomena using rich and thick description; 6) reducing the description to an understandable essence; and 7) returning the data to the participants for validation (member-checking), with subsequent interviews available for each participant. Additional strategies to enhance trustworthiness included clarification of researcher bias via the PI's reflexivity journal that was maintained from original conception of the study throughout data analysis; maintenance of an audit trail throughout iterations of data analysis; peer-debriefing conducted by the second author; and triangulation based on converging data from multiple participants (as opposed to use of a single participant). Themes were derived from the data (i.e., were not specified in advance).

3.2 Results

Seven individuals contacted the PI to be screened. Two of the seven did not meet inclusion criteria (i.e., both had neurological conditions other than stroke). The final sample size was n=5, as seen in Table 5 along with other characteristics of the sample.

Table 5. Characteristics of the Sample

Characteristics	Number
Sex	
Men	1
Women	4
Race	
White	5
Stroke site (per subject report)	
Left hemisphere	1
Right hemisphere	2
Unknown	2
Pre-stroke meditation experience	
Extensive	1
Some	1
None	3

Table 5 Note. The final sample comprised five participants with varied demographics, sites of stroke, and levels of pre-stroke meditation experience.

The PI conducted interviews at each participant's chosen site (one chose home; two chose a private room in a community library; one chose a private room in a university library; and one chose a private office at work). Each participant was interviewed once. Each participant determined the desired duration of interview, which varied among participants and ranged from 24 minutes to 58 minutes. The PI transcribed each interview verbatim, which yielded five transcripts. No one indicated a desire for more than one interview or had corrections after the de-identified, analyzed data was returned for member-checking. Data analysis by the PI as overseen by the second author yielded 135 significant statements, 259 formulated meanings, 109 meaning clusters, five themes, and a descriptive essence. Table 6 shows an example coding tree.

Table 6. Organization of Meaning Units (Coding Tree)

Significant Statement	Formulated Meaning	Meaning Cluster	Theme
V: "…that trying to concentrate on not concentrating? It's really hard, um, but it, yeah, I would say that's the bulk of my energy goes toward that not concentrating...."	Thought processes in meditation are concentrating on not concentrating.	Meditation can be trying to relax one's mind.	Action and Non-Action
M: "…I just sit down and try (or lay there, rather) and try and just relax my mind the same as I would do if I was listening to my tapes…."	Meditation without audio guidance means simply trying to relax one's mind as if one was listening to audio guidance.		
A: "…you're holding your hands in Anjali which is prayer … you hold it right at your forehead."	Meditation can entail mudras.	Meditation can be physical positioning or doing.	
K: "…you go into the labyrinth and you go around, you just try to keep an open mind; and then when you get to the center of it, you pause, you try to be receptive, and then you finally go back out. And it's whether you're doing it physically or if you're just doing the little, the little hand one."	Labyrinth meditation has different ways of doing it physically and you try to keep the mind open.		

Table 6 Note. Significant statements (first column) were direct quotes from each transcript. The investigator used each significant statement to inform formulated meanings (second column), which were then collapsed into meaning clusters (third column), then themes (fourth column). Only a partial selection of data informing one of the themes is shown. Abbreviations (pseudonyms): V=Victoria; M=Mark; A= Alice; K= Kate.

The trial ended when no new enrollment occurred for a consecutive six-month period after the enrollment of the final participant. The trial concluded due to slow enrollment rather than saturation. The descriptive essence of the data is presented below, followed by explication of themes using direct quotes for support. All themes are of equal importance.

3.2.1 Descriptive Essence of the Central Phenomenon

As described by participants, meditation after stroke is constituted by mental and/or physical actions as well as non-action. While meditation after stroke may be understood or experienced in terms of individual senses or discrete parts, it can also seem primarily synthesized, holistic, or even nebulous. Place, time, and direction serve as contexts by which one is oriented to the experience. It can carry generally very positive value for domains ranging from individual daily life to transcendence. The perceived relevance of stroke or stroke-related impairment to meditation may vary and can have crucial importance for recovery.

3.2.1.1 Theme 1. Action and Non-Action (What Meditation Is): "Concentrate on Not Concentrating."

When describing what one does in order to meditate, participants mentioned a variety of mental and physical actions as well as non-actions. In other words: what one does and what one does not do—i.e., action and/or non-action, or an antithesis of action—can be what meditation *is*. For example, Victoria stated, "…that trying to concentrate on not concentrating? It's really hard, um, but it, yeah, I would say that's the bulk of my energy goes toward that not concentrating." Alice described various elements of her meditation, some of which were actions and some of which were the lack thereof:

> The first is posture, [including] letting your eyes rest on the floor, have your eyes open just resting on the floor. Then the next major element is the breath. And there's no alteration of breathing, you just breathe naturally. And so all you're doing is focusing on your, feel the feeling of the body breathing. And the third component is working with your mind. And what you do, you welcome the emotions, you welcome the thoughts, but you don't entertain them, you don't invite them in to stay.

Elizabeth described placing focus: "When I'm doing my meditation, it's like you, um, take your focus [and] place it someplace else." Kate described "just trying to focus on something positive" as well as maintaining receptivity: "if you think of something, just let it pass. You just have to let it go." Mark stated that doing meditation is "try[ing to] just relax my mind."

Some participants mentioned more overt physical actions such as writing, or as Kate said, "getting it out on paper." Victoria stated, "I like to write people notes, and emails, and thank you's, and that's not really a meditation—well, it may be! It is a gratitude thing. And I really like that, and it fits in real neatly with meditation." Meditation-as-movement was also described, as with Kate's labyrinth: "There's an actual physical one at our church that I occasionally walk. I have a small one that you can hold in your hand that has a little stylus that you can go through the, the pathway." In a similar vein, Victoria described "the walking-around activity," saying: "I'll be real conscious of things and very aware of things. Like the gravel under my feet, you know, I'm like 'there's a rock there!' or the wind blowing across the field."

The numerous other doings of meditation after stroke included lighting a candle to signify the beginning; ringing a Tibetan bowl; humming to align or attune with a universal wavelength; holding the hands in prayer position; and listening to sounds designated to have healing properties. Kate reported, “I listen to those daily as another time to just meditate.” She also described different activity levels needed:

> For the Tibetan bowl to work, you have to do something physically to it…. and the other, you just put on the headphones and listen, and it’s not really an active thing, more just lying there listening to it. It’s kind of like, you know, when they put on relaxing music when you go get a massage. It’s a little bit more than that. The purpose could be the same and just a way to relax and open yourself too. Being relaxed.

3.2.1.2 Theme 2. Separate Senses, Yet Synthesis (How Meditation is Perceived)—“It’s the Way One Perceives the World.”

Participants described meditation after stroke in terms of synthesis or undifferentiated aspects as well as discrete parts of experience or self. In other words, the experience can manifest via discrete avenues yet also seem synthesized or holistic in character. This character was described by Victoria as “a nebulous thing;” and Alice explained,

> It’s the way one perceives the world…. It’s about the mind and the heart—there is more a holistic, more of synthesis. And we can make those separations, but that’s a mental action we’re taking. To make the separations is an intellectual discrimination or an intellectual discernment.

Accordingly, participants described different dynamics of connections between aspects. Mark put the body, mind, and emotion in conjunction: “It does make you feel at ease—your body feels relaxed, my mind feels relaxed, I don’t have any tensions or anything…. It definitely changes your emotions because it makes you more relaxed when you keep your mind free and easygoing, from any troubles…you can just let it all go.” Elizabeth mentioned a specific body part: “One day last week, my arm was just really tight and it was bothering me, the right arm by the stroke. And when I did [meditation], it relaxed and it was, I mean, just almost like getting a massage.”

Other specific senses or parts of experience were also highlighted. With regard to visual perceptions, Kate described "closing your eyes, trying to focus on something positive, like a scene. I'll focus on that one visual image;" and, alternately, "just to observe the thoughts as they pass through. And not hold onto them, just watch it pass, like fast forwarding through a video." Likewise, Mark described visual imagery: "I have actually seen things [in] deeper meditation, like the shadowy or the lacy, the lacy white figure that come towards me." Finally, Alice stated that "Light becomes such a fundamental part of the meditation at the level that I am now. My appreciation of light is just beyond words to be able to tell you."

Other discrete senses included spirituality. Kate, when questioned about thought processes in meditation, stated: "I try to be receptive to what the other, the higher being wants to tell me, to what the universe wants to tell me. It is a spiritual aspect. I don't think you need to be spiritual to meditate, but I believe that through meditation you'll become more spiritual." On the other hand, Alice described meditation as "non-theistic. We don't talk about gods or god. We don't, that's not what we're doing." Victoria laughingly described being "almost evangelical" about meditation classes but was "in a church where we're comfortable." For Elizabeth, the soul was healed: "It heals, [SIGHS] ok, how do I explain it? It makes me quieter. To um, like heal my soul. When I do the meditation, the quietness of the meditation allows me to regain my soul, in a quiet atmosphere."

Participants also mentioned a sense of what one can do. Victoria described how putting gratitude into meditation "just gives you this sense of 'I can do this' kind of thing... put it in this context of 'I'm grateful that I was able to do this! I'm grateful that I had this opportunity!'" For Kate, "usually it [meditation] will result in my body relaxing more. And I can do whatever it is I couldn't do before."

3.2.1.3 Theme 3: Contexts of Place, Time, and Direction (Orientation to and Within Meditation)—"Just Go Into My Zone Somewhere."

Participants described place, time, and directions as contexts by which they were oriented to the meditation experience. Place was described in both real and metaphorical terms. For example, Mark described an inward zone in a public setting: "I do go and do acupuncture so when I'm laid on the plinth, they have some, uh, very quiet music playing in the room. But I try to basically ignore that and just go into my zone somewhere. Back into myself." Kate described meditation in public: "I can do [a type of] meditation when I'm doing, say, something in therapy that's difficult. It might even hurt." She also described the felt need for a private place: "I feel I have to do [another type of meditation] in private. I can't just do it anywhere." Elizabeth described material logistics of place: "For me to get up and down off the floor is an ordeal [LAUGHS] because of the stroke. I have a high chair that I sit in, um, with the big armrests so it's, um, relaxing for me." Yet she also used metaphor: "You take your focus, and place it someplace else. But it's not a sleepy place that you put it. It's just a quiet place." Alice also referred to metaphorical place:

> My experience is—let me just suffice it to say that it becomes more open. So it's like giving a horse a bigger pasture to roam around in because the horse is now tamed and trained and will come to you when you call it immediately. It wants to be there.

Contexts of time were described, such as what happens when and the relative importance. Victoria indicated unwanted mental activity could co-occur: "There are days that I sit down to meditate, and everything else intervenes, and everything's marching through my mind." On the other hand, Mark described intent to think—and move—during meditation: "I do sometimes when I'm meditating, try and think of moving my [stroke-affected] arm, and sometimes you get a sense that it's a little bit different. Just feels like [during the meditation] maybe the arm is a little lighter." Kate described immediacy of effects: "And, I can focus on that one visual image and I'll immediately calm down and be more peaceful." Time was also seen as a constraint. For example, when asked whether meditation is challenging, Kate stated "…if I have to be somewhere at a certain time early in the morning, and I don't have time to meditate." Victoria also stated: "It's not difficult. It's just effort. Carve out that time." Patterns related to time also carried meaningful significance. Kate stated:

> Well, I like to meditate first thing in the morning every day. I don't always get to but I—that's when I prefer. I light a candle to signify the beginning of the meditation, where I choose time and I go in and I light—it's a ritual. I really need that time to set myself in line with what's going to happen the rest of the day.

Likewise, Victoria said, "My personal experience is I try to meditate every day, usually in the morning somewhere between 5 and 7 am. It is just a way to set the tone for the day for me."

With regard to meaningful change over time, Mark speculated, "For a while, when I first started doing it, I could get into the deep meditation part where I actually saw images...When you see something like that, maybe it does mean something. Maybe like good coming into me, or some of the bad leaving me." Elizabeth also described change in meaning over time:

> You know, I thought meditation, you sit crosslegged, and you put your arms out, you know, did all this, and um, had some kind of outer body experience or something. But what I've experienced so far has been: yes, you can do all those things, but you are um, it's something that I, now I want to do more often. Because I'm seeing where I'm getting something out of it. The first couple of

> times I did meditation I got something out of it, but it's just a little something. You know, hard to put my fingers on exactly what. Then as I started doing it more frequently, it was, um the quietness. And it was the, um, you know, giving your soul back.

Alice described how her mind had changed over time: "My mind is way more stable, there's much more stability compared to the way it was when I began meditation."

With regard to directions or sources of guidance, Elizabeth said, "I have to have something guiding me to do it." Victoria reported that explicit, real-time external direction was not always used: "I would say probably 60 to 70 percent of the time I [listen to recordings]. Let's say about a third of the time I do not. I'll just sit there and do quiet seated meditation." She also described turning in a direction: "I have to make sure that I'm turned away from everything, I mean both physically and mentally. I have to do that, to get concentration at all." Mark described being directed by sound as well as depth that could be achieved:

> … theta and beta waves, I think, but they all have delta waves in too, so, there's 3 types of waves mainly, that these CD's have. They seem to maybe get me into the deeper meditation, … I'll say the words I was reading on the brochure about it when I got it, you know, to release myself, to see if I can get that a little bit deeper in meditation, … and try and just relax my mind the same as I would do if I was listening to my CD's.

Kate described being directed by historic precedent:

> The Tibetan bowl singing has its own set of, um, not rules but its, its own process that you chant different vocalizations. It's not just "Om." That's one of them. But you pick out, it has a way for you to pick out a song for you, an ancient Hebrew chant that I sing.

Finally, Alice indicated that light was used to direct her experience: "Light becomes, you can say, a tool for understanding, and a vehicle for expression, in the context of meditation, and in the context of life."

3.2.1.4 Theme 4: Value for Normal Daily Life and Beyond (General Evaluation): "A Lot of People Could Really Benefit From This."

Meditation was seen as having value related to general aspects of life and function. Mark stated: "It affects your well-being because it kind of lifts you out of the doldrums.... It's always been more of a positive thing—if you're a little down, to pick you up a little bit." Kate commented,

> I'm in a bad mood if I haven't meditated. I'm not focused, and I'm in an irritable mood…. I think it's enabled me to, um, experience the emotions—to get them out there so I don't—I tend to keep a lot of things inside, so being able to meditate helps me.

For Victoria, the favorite aspect "is that it has taken me 58 years to find something that I do just for myself. That is my favorite thing. And it's really hard. Self-care is hard. Meditation is hard, but it's good." Other occupations of daily living were also described favorably in relation to meditation. For example, Mark stated:

> Meditation definitely gives me a good, positive outlook to want to carry on and keep improving with things. Normal, daily things; normal daily life. Whether it's just like trying to put a polo shirt on, which is ridiculously difficult compared to what it used to be pre-stroke, you know. It's like today, I did actually manage to do that, and I think this is, is all part and parcel of it, is the meditation definitely helps me try to do better, and I don't get so angry—and I don't get angry at all, actually. Very little do I get down on myself. And I think that's because of meditation. It keeps me in a better frame of mind.

Others mentioned work. For example, Alice stated, "It affects insight. So, it affects my ability to, um, hold my mind just open without content. It's enormously helpful in the work that I do." Elizabeth said, "I'll do meditation at lunch, and it really switches, uh, your whole focus to where you're now more relaxed, and you don't listen to all of you know, little sniblets of stuff going from the other people that you work with."

Non-effects, as well as unexpected/unclear effects, were indicated. For example, Elizabeth stated, "Oddly enough, it relaxes the muscles." Yet no participant reported improved sleep. Kate said, "Some people could probably use it to go to sleep at night. I don't have a problem going to sleep." Similarly, Elizabeth stated "I go to sleep, and I'm out like a log. I don't think [meditation has] really affected [sleep]." Regarding general response to life events, Victoria stated: "I think [meditation] has helped me moderate the intensity with which I respond to events, both good and bad." She then mused,

> I've wondered in fact, where does passion fit in with the equanimity? Because you know I, I, it's like the extremes are not as extreme. It's moderated. And I don't know if at this point in my life it that's a good thing or not, but it seems to make my life a little easier.

She clarified how meditation is helpful while not perfect:

> You know, trying to get that time where you're actually peaceful and calm, and, that's my goal. That's not always my experience, [but] that's what I'm after. And I think that's the biggest lesson for me in all this is that it doesn't have to be perfect for it to help. It doesn't have to do everything you want it to do. And I would love for it to clear my foggy mind. I'd love for it to strengthen my back! [LAUGHS] You know, I'd love for it to do all these things. But that's not what it's there for. That's not what it is.

Participants also ascribed favorable values in terms of far-reaching or transcendental qualities. Kate stated that in meditative chanting, "Shalom means 'Peace,' so any time you say it you're asking for peace or you're putting peace out to the world." Alice remarked, "I think one of my favorite things about it, it's so holistic. It includes everything. It includes the light and the dark, it includes what we call good and bad, it includes everything." She described personal and social goodness:

> The basic purpose of [a certain tradition of meditation] is to help people realize their own basic goodness and to really realize it without doubt. And not only to realize their own, but of society and how we can help this society be a more enlightened place to be. And so, it's about social transformation.

Victoria described connection: "And I feel like it seems ironic, but to me, meditation connects you to people, even though you're just sitting there alone, doing your own thing, you know, there can be a room full of 20 people, and you still feel connected to them. It is just amazing." She commented on the potential for widespread benefit and beauty: "A lot of people could really benefit from this. There's a beauty to that, that I want them to experience. I mean it has had far-reaching effects on me." Similarly, Mark stated: "I would definitely say, you know, to anyone who's never done it—I would try it."

3.2.1.5 Theme 5: Varied Relationship to Stroke and Impairment (Stroke-Related Evaluation): "It's a Crucial Part of My Recovery."

Participants indicated varied extents to which their meditation had a relationship with their stroke, including how crucial it was for recovery. For Kate, meditation after stroke facilitated moving through emotions: "I really think it's a crucial part of my recovery. At least in my case, I would have had so much anger and resentment if I hadn't done meditation, that I couldn't move past the fact that I had two strokes." Elizabeth described feeling like she was before:

> Before my stroke, um, I used to think of myself as a very old person. Not old like "70- 80 old;" I mean "I-have-lived-many-lives" old. And so, um, when I talk of my soul, it is my being. Since I've had the stroke, I've not felt like the old person, or the old soul. And this is, the meditation has really touched on putting me back in touch with that being that I could be. Now I can get back to being that person I was before the stroke.

Mark described a change in belief relative to stroke: "I definitely didn't believe in doing anything like this prior to my stroke. But after my stroke, I felt 'what have I got to lose,' you know?"

Participants also described varied effects of stroke on meditation and, conversely, how meditation had affected impairment. Kate described meditation before and after stroke: “Before the stroke I did yoga, and that was—that’s part meditation. Um, I haven't done that since the strokes because I’ve been unable to physically. …But, um, I've tried new types of meditation since my strokes.” On the other hand, Alice indicated that stroke had not affected her meditation:

> It is not any different than it was prior to the stroke, as far as I can discern or remember [LAUGHS], both of which are systems that don’t work quite as well as they used to. It’s hard to know what to attribute to the stroke and what is just aging.

Mark described how meditation related to stroke-impaired arm movement: “Sometimes I’ve actually tried to envision it when I’m having meditation that I see [my impaired arm] moving, you know, in my meditative state. And I’ve not experienced that yet, but I keep trying.”

Specific to attention, Alice described how benefits seemed discernible before stroke rather than after: “I think the gains that I made were made [in meditation before stroke], and any gains that I might have made since then are gains more in the intellectual understanding of why they’re teaching what they’re teaching.” On the other hand, Elizabeth indicated that meditation had been:

> …increasing attention to the point that um, you know, I used to be a really good wordsmith. And so I was really [LAUGHS] abysmal at it after the stroke. Um, but now I’m doing, um, wonders. I mean, I did my resume and I had a friend look at it last night, and she was like “oh my gosh, I can’t believe you did all this stuff!” I was writing stuff that would compare to what I used to write like, if that makes sense—very technical jargon.

She also described how the improvement seemed relevant in later stages of recovery:

> I don’t think I would have the results from this meditation that I personally have had, had I tried it earlier, because I was getting my brain back. It may have helped, in different ways. I might have had different, like I wouldn’t be able to write a resume earlier on, but I would have been able to do something else.

Kate described a change in ability to focus, as well as meditate, after stroke:

> Interviewer: Prior to yoga [i.e., prior to stroke], did you have a regular meditation practice?
> Kate: No, I tried, I tried meditating several times and I kept getting stuck with the, the, uh, thoughts, and I couldn't focus. I just couldn't focus.
> Interviewer: But after your stroke, you, uh, have persisted, and now you can?
> Kate: Yes.

On the other hand, Victoria stated:

> Since my stroke, I feel very diminished intellectually. It's, um, probably the most frustrating thing I've been through. And I have not found that meditation has necessarily made me focus or concentrate any better. I mean, I could be concentrating better than I think I am, but [during meditation], I'll sit there and I'll wander. I remember at the fourth or fifth week [of a meditation class], almost in tears saying "It's so elusive!"

She then described how acceptance mediated these dynamics:

> [But] I got to a point of accepting its elusiveness. I don't know that I'm the world champion meditator. But my acceptance of that is what's changed. I can live with it. Yes, it can be elusive still. But I feel like "that's ok," it's acceptable not to be a perfect meditator.

3.3 Discussion

The main objective of this study was to facilitate understanding of the experience of meditation after stroke. To that end, the first-person evidence from this study shed light on how and why meditation after stroke takes place.

In terms of how meditation after stroke takes place, participants indicated that it can be constituted by mental and physical actions as well as non-actions. Further, they indicated that while meditation may be perceived or manifested via discrete constructs (e.g., senses; faculties; parts of the self), it may also have a synthesized, nebulous, or otherwise undifferentiated (non-discrete) character. Other evidence revealed contexts of orientation to or within the meditation. These contexts included place, time, and direction. Place referents included material reality (e.g., size of a chair; public versus private surroundings) as well as metaphor (e.g., imagined locus with or without geographical features). Time referents included mundane relationships, such as scheduling or daily routine of the meditation, as well as deeper signified meaning of the meditation time (e.g., ritual). Direction was described as being gleaned from external and/or internal sources, including historic precedent; expert guidance; natural environmental stimuli; or personal intention, habit, or skill.

As to why meditation after stroke was practiced, participants described value relative to numerous dimensions of life—some stroke-related and some potentially irrespective of stroke. These dimensions included psychological (e.g., emotion; sense of capability); parts of the self (e.g., body/mind); various occupations (e.g., activities of daily living; self-care; work); and transcendent domains (e.g., connection to others; universal power). That the ascribed value was generally positive is encouraging from a rehabilitative perspective because it lends credibility to the idea that meditation may be fruitful as a technique to help enhance function and participation in life after stroke. Indeed, some participants strongly indicated that meditation has particular relevance to stroke recovery. This finding further supports the potential clinical value of meditation, as adherence to a protocol would presumably be enhanced by the belief that the protocol can positively impact recovery.

While attention was not designated as a major theme, attention appeared to be a consistent factor in meditation after stroke, with some participants indicating that meditation improved their attention. While there is scant evidence on whether meditation improves performance on objective neuropsychological indices of attention after stroke (Lazaridou et. al., 2013), one of the largest investigations in this regard was Johansson, Bjuhr. and Rönnbäck's (2012) randomized, waitlist-controlled trial examining the effects of meditation on attention as measured with the Trail-Making Test (TMT). Results showed significant within- and between-groups differences on the TMT favoring the meditation condition. Of note, the investigators did not designate impaired attention as an inclusion criterion; and their sample was small and heterogeneous (i.e., stroke, n = 12; or traumatic brain injury, n = 10). Findings from the present study may support delineation of salient variables for future research specific to individuals with impaired attention after stroke. For example, it may be fruitful to investigate the effects of different sources of meditation guidance (e.g., audio recordings versus abstract or internalized rules) on attention. Present findings may also be potentially useful in terms of what clinical structure may afford participation in meditation after stroke (e.g., incorporating elements of ritual but using a supportive chair as opposed to cross-legged seating on the floor). However, further research would be needed to establish conclusive evidence on optimal parameters in this regard.

Limitations of this study included restricting eligibility criteria to the chronic stage of recovery in order to remove the potential confound of spontaneous neuroplastic reorganization, which predominates subacute stroke recovery (Winstein et. al., 2016). Future qualitative studies could address this limitation by studying meditation during subacute recovery. An additional limitation is that the PI knew some of the participants prior to their enrollment, as they had previously participated in unrelated studies with her at her place of employment (i.e., a neurorehabilitation research lab). Participants who did not already know the PI may have been less likely to disclose information than those who had an established history of trust. A separate, possible limitation is that the PI disclosed to each participant how she was conversant with meditation via personal practice. This disclosure was intended to build interpersonal rapport and thereby facilitate robust data. Had the PI obscured her familiarity with the experience of meditation, the depth or breadth of information from subjects would potentially have been different. Another potential limitation was the PI's conceptualization of meditation in terms of thoughts, emotions, sensations, attention, and other constructs as recommended by peers and professors who vetted the research design. While participants were compelled to frame their experiences accordingly, the PI sought to overcome any associated potential limitation by also posing open-ended questions. Heterogenous meditation methods across participants were also a possibility, in order for the study to allow common meanings to emerge. Although heterogeneous meditation methods may be sufficiently parsimonious to achieve targeted outcomes, quantitative studies are needed to establish experimentally derived evidence in this regard. Finally, the trial concluded due to slow enrollment rather than saturation.

In sum, findings from this study shed light on how meditation after stroke can be perceived as having relationships with numerous aspects of experience and function, including what one does (e.g., dressing; work; therapy); what one thinks or feels (e.g., mind; body; mood; attention); and stroke recovery itself. In turn, the findings give preliminary insight regarding what design features may equip a clinical or research protocol to afford participation in (or targeted outcomes of) meditation after stroke. Future research is recommended on how to tailor meditation to effect targeted outcomes (e.g., improved attention; adherence/engagement) according to client characteristics (e.g., impaired attention after stroke) and various settings (e.g., formal rehabilitation; home/community programs).

CHAPTER 4. STUDY 2. MANTRA MEDITATION FOR CHRONICALLY IMPAIRED ATTENTION AFTER STROKE: A TRIAL USING SINGLE-CASE EXPERIMENTAL DESIGN

Impaired attention after stroke is a common problem (Winstein et. al., 2016), with prevalence as high as 90% during the acute stage and up to 50% in chronic stages (Loetscher et. al., 2019). General manifestations of the problem include deficient concentration, distractibility, proneness to error, mental fatigue, and degraded memory (Loetscher et. al., 2019). Systematic review evidence indicates a positive correlation between attention and motor recovery following stroke (Mullick et.al., 2015). In particular, sustained attention capacity at two months after right-hemisphere stroke has been shown to predict motor recovery and related functional status at both two months and two years post-ictus (Robertson et. al., 1997a). Sustained attention depends on top-down, endogenous maintenance of responsiveness without external cues or reminders (Spaccavento et al., 2019). Problems with this endogenous capacity often constitute the basis for sustained attention impairment after stroke (Robertson et. al., 1997a; Spaccavento et al., 2019) and can be measured with a neuropsychological instrument called *the Sustained Attention to Response Test (SART*) (Manly et. al., 2003; Robertson et. al., 1997b). Because spontaneous remediation of impaired attention after stroke can be minimal (Barker-Collo et. al., 2010), rehabilitation to address this problem is indicated. Yet there is a lack of high-quality evidence establishing the effectiveness of interventions to improve attention after stroke (Loetscher et. al., 2019).

Meditation may have potential as an intervention to improve attention after stroke, insofar as meditation is a “training of attention” (Kozasa et. al., 2012, p.745). Two overarching styles of meditation have been described in this vein:

> Meditation can be conceptualized as a family of complex emotional and attentional regulatory training regimes developed for various ends,… Among these various practices, there are two styles that are commonly studied. One style, focused attention [FA] meditation, entails the voluntary focusing of attention on a chosen object. The other style, open monitoring meditation, involves nonreactive monitoring of the content of experience from moment to moment. The potential regulatory functions of these practices on attention and emotion processes could have a long-term impact on the brain and behavior. (Lutz et. al., 2008, p.164)

Of these two styles, focused-attention meditation may be easier or simpler in terms of attentional demand, as it is typically a precursor to open monitoring meditation (Lutz et. al., 2008). The main instructions in focused-attention meditation are to sustain attention on a chosen object and, when the attention wanders, to recognize the wandering and then bring the attention back to the chosen object (Lutz et. al., 2008). One example of a chosen object is a mantra, which is a repeated word, phrase, or syllable that may be considered a "*single* [emphasis retained] salient percept" (Fox et. al., 2016, p.220) by which "attention is more easily sustained and distractors more easily ignored than without the mantra…" (Fox et. al., 2016, p.220). In other words, mantra meditation may be considered a comparatively easy or simplified form of focused-attention meditation.

Studies in healthy volunteers have shown that mantra meditation can modulate neurological substrates of attention (Berkovich-Ohana et. al., 2015) and improve performance on neuropsychological testing of attention (Menezes et. al., 2013; Menezes & Bizarro, 2015). In cases of Alzheimer's-related cognitive impairment, mantra meditation has been shown to modulate neurophysiological substrates of attention and improve performance on neuropsychological testing of attention (Newberg et. al., 2010). Yet there is an evidence gap on whether meditation—mantra or otherwise—improves attention after stroke (Lazaridou et. al., 2013). One of the largest such studies relevant to this topic was a randomized, waitlist-controlled trial by Johansson, Bjuhr, and Rönnbäck

(2012) to examine the effects of a meditation program on various aspects of cognitive function in subjects with chronic impairment (i.e., stroke; *n* = 12 or traumatic brain injury; *n* = 10). Attention was measured with a pencil-and-paper instrument known as the *Trail-Making Test* (Armitage, 1946), which the investigators identified as a measure of divided attention (Johansson et; al., 2012). The meditation condition was based on a standardized protocol called *mindfulness-based stress reduction (MBSR*). Standard MBSR comprises approximately 80 hours of focused-attention and other meditative practices—but not mantra—and is administered by personnel with specialized training over an 8-week period (UMass, 2017). Results showed significant within- and between-groups differences on the Trail-Making Test favoring the meditation condition (Johansson et. al., 2012). Of note, the investigators did not designate impaired attention as an inclusion criterion; they did not use the SART; and their sample represented not only stroke but also brain injury. Also, the investigators modified the standard MBSR tempo to accommodate subjects' greater-than-normal-time-needed for information processing.

In summary: preliminary evidence has begun to substantiate the notion that meditation may be useful as a technique to improve attention in cases of neurological impairment. The simplicity and characteristic aims of mantra meditation may make it particularly suitable for translation to stroke rehabilitation addressing impairments in sustained attention. Yet no studies have investigated whether mantra meditation has an effect on chronic impairments in sustained attention after stroke. Thus, the present study tested the central hypothesis that mantra meditation (independent variable) would have a therapeutic effect on chronically impaired attention after stroke, as measured with tests of attention including the primary outcome measure SART (dependent variable). The study purpose was to yield evidence on the likelihood of a therapeutic functional relationship between mantra meditation and sustained attention, for people with chronically impaired attention after stroke.

4.1 Methods

4.1.1 Protection of Human Subjects

This study was approved by the authorized institutional human research review board (IRB) at the institution governing the research. All aspects were conducted in accordance with institutional guidelines; and the study was registered at ClinicalTrials.gov (NCT03229902) prior to subject enrollment. Signed informed consent was obtained from individuals who wanted to enroll in the study, after the principal investigator (PI) provided them with a verbal and written explanation of the purposes, procedures, and potential risks of the study. This included consent to the inclusion of material pertaining to subjects, with acknowledgement that they would not be identified in dissemination and publication such as the present article, which is fully anonymized.

4.1.2 Study Site

The study site was a neurorehabilitation research lab in a freestanding, regional rehabilitation hospital. Each individual sat in a comfortable seated position during testing and meditation practice. Testing and meditation were administered by the PI in a one-to-one fashion with each subject, away from general foot traffic at a table protected from distractions with a cubicle or privacy screen.

4.1.3 Sampling and Inclusion/Exclusion Criteria

Convenience sampling was used. Recruitment tools included flyers and advertisements at a variety of sites, such as hospitals offering stroke- or meditation-related events. Self-referrals were accepted, along with referrals from local and regional researchers as well as clinicians with expertise in rehabilitation and adult neurological impairment. Individuals were screened prior to enrollment according to inclusion and exclusion criteria (Table 7).

Table 7. Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
between ages 18 – 70	conditions other than stroke that would potentially: o mitigate capacity for neuroplastic change; o destabilize baseline neuroplasticity; or o destabilize trajectory of intervention-related neuroplastic change during the study, e.g.: ▪ severe depression ▪ current or significant history of substance abuse ▪ in the 3 months preceding enrollment, change in medications that impact neuroplasticity
right-hemisphere, non-lacunar stroke ≥ 12 months prior to enrollment	concurrent participation in any other research study, cognitive rehabilitation, meditation, or mental training program
attention impairment per attentional testing as well as subject report	neurological disorder other than stroke
intact consent capacity	uncontrolled or severe mental or cognitive disorder
right-handed dominance before stroke, as well as sufficient movement and vision function, to ensure sufficiency and homogeneity of functional ability for testing	spatial attention deficit (unilateral neglect)
English language fluency and reading comprehension at 6th grade level or greater	any other impairment that would deter comprehension and/or execution of the requirements of the trial

Criteria in Table 7 were chosen to enhance experimental control, ensure ethical protections, and approximate prior studies of attention-related recovery after stroke (Robertson et. al., 1997a; Sturm et. al., 2004). The inclusion criteria for attention impairment were defined as subjective complaint of post-stroke attention impairment as well as a score of two or more errors on the SART, in keeping with previously published literature on differential SART scores between healthy normal versus attention-impaired subjects (O'Connell et. al., 2008). The exclusion criterion of neglect was defined as a score of 51 or fewer cancellations on the Star Cancellation Test (Halligan et. al., 1990; Wilson et. al., 1987). The exclusion criterion of depression was defined as a score of greater than 10 on the Beck Depression Inventory, Short Form (BDI-SF) (Beck et. al., 1961; Furlanetto et. al., 2005).

4.1.4 Design

The design for this study was determined *a priori* and is known as *single-case experimental design (SCED)*. SCED has a long history of use in behavioral science fields and, more recently, in rehabilitation research (Lane et. al., 2017; Smith, 2012). The specific SCED approach used in this report was multiple-baseline across-subjects (Gast et. al., 2014). In this approach, the effects of the independent variable are tested across at least three subjects in a series of AB designs. For each subject, the dependent variable is measured repeatedly throughout Phase A in order to establish baseline stability. When a subject achieves baseline stability, Phase B is initiated, meaning the independent variable is introduced to that subject. Measurement of the dependent variable also continues throughout Phase B.

Multiple-baseline across-subjects SCED does not conventionally rely on population-based statistical analysis (Gast & Spriggs, 2014); rather, replication of a demonstrated effect across at least three subjects is the benchmark for concluding that a functional relationship is likely (Gast, 2014). Therefore, target sample size in the present study was set to a minimum of n = 3 and a maximum of n = 4, in accordance with SCED guidelines (Gast, 2014; Kratochwill et. al., 2013). Under such guidelines, if the first but not the second subject demonstrates an effect, two more demonstrations of effect (and thus two more enrollments) are needed to achieve benchmark; however, if the third subject does not demonstrate an effect, benchmark becomes unattainable and no further enrollments occur. Main indices of effect include data trend and data level within- and across-phases (Gast & Spriggs, 2014; Lane & Gast, 2014), which are represented in Tables 11-12 and Figure 1 for the present study.

Subjects were enrolled non-concurrently. Randomization was not used.

4.1.5 Outcome Measures

The PI administered and scored all outcome measures. The primary and secondary outcome measures were standardized tests of attention as described below.

4.1.5.1 Primary Outcome Measure

The primary outcome measure was the SART. The SART is in the class of tests called continuous performance tests, which have a long history of use as behavior-based measures of sustained attention (Shalev et al., 2011). The SART prototype was developed by Robertson et al. (1997b) to measure sustained attention in a sample of 34 subjects with right-hemisphere acquired brain lesions, in whom investigators showed that attention failure as measured with the SART had a significant correlation ($r = .44$; $p < .05$) with failures of attention in daily life as measured by a subjective self-report instrument called the *Cognitive Failures Questionnaire (CFQ*; Broadbent et al., 1982; as cited in Robertson et al., 1997b). Corroborating evidence from Smilek et al. (2010) showed 1) a significant correlation between SART attention failures and CFQ attention failures ($r = .28$, $p < .01$) in a sample of 363 randomly selected healthy volunteers; and 2) a positive association between CFQ attention failures and SART attention failures ($r = .21$; $p < .01$; CI95[.03 - .38]) in a pooled sample of over 3000 subjects with varied non-clinical and clinical features, including neurological impairment. Stroke research using the SART as an outcome measure also includes Levine et al.'s (2011) study of goal management training to improve executive function in a sample of 19 adults with chronic stroke as well as Molenbergh et al.'s (2009) study of associations between SART metrics and lesion neuroanatomy in 44 adults with subacute stroke.

For the present study, previously published SART specifications (O'Connell et. al., 2009) were programmed into MATLab software package Version 7.4, 2014, on a Dell Desktop Optiplex 790 at the research site. One administration of the SART was designed to last about five minutes, in which time the subject viewed a computer monitor that displayed a regularly repeating run of numerals *1* through *9*, one numeral at a time, in sequential (not random) order for a total of 25 runs before automatically stopping. Instructions were to press the keyboard's spacebar when a numeral appeared, except for the numeral *3*. Pressing for *3* was counted as an error. The total number of errors constituted the final score, with a higher score indicating worse attention. This approach to SART has been shown to discriminate between neurologically impaired individuals versus controls. Specifically, Manly et al. (2003) found that errors of commission were sensitive to frontal lobe impairment, with subjects 2.02 times more likely to be correctly classified for each increase of 1 error (OR = 2.02, $p = 0.019$) in a sample of 19 adults with traumatic brain injury versus 19 healthy controls. This likelihood translated to correct classification of 80% of the total sample. Oher research in 13 healthy adults showed that this SART protocol preferentially elicits electrocortical signatures of sustained attention (as opposed to response inhibition) when errors of commission are successfully avoided (O'Connell et al., 2009).

4.1.5.2 Secondary Outcome Measure

The secondary outcome measure was the CFQ (Broadbent et al., 1982; as cited in Wallace et. al., 2002), a 25-item pencil-and-paper questionnaire that takes approximately five minutes to administer. The CFQ uses a self-report, Likert scale of 0 – 4 on which subjects identify difficulty in everyday cognitive function, with higher scores indicating more difficulty. Scoring was conducted in keeping with Wallace et al.'s (2002) factor analytic solution that provided evidence of construct validity for the distractibility subdomain of the CFQ. Shalev et al. (2016) found correlations between poor CFQ distractibility scores and poor scores on continuous performance testing of sustained attention in subjects with chronic stroke. Vom Hofe et al. (1998) reported a CFQ test–retest reliability of .82.

4.1.6 Intervention

The independent variable was mantra meditation, as operationalized in subsequent sections of this article. There was no sham condition and thus no blinding to intervention.

4.1.7 Working Hypotheses

The primary working hypothesis was that at least three subjects would show a demonstrated therapeutic effect of mantra meditation on attention as indicated by a change in the SART score. The secondary working hypothesis was that at least three subjects would have an improved distractibility score on the CFQ after completion of all study phases (exploratory pre-post comparison).

4.1.8 Overview of Study Timeline

Table 8 shows the timeline for each subject from enrollment forward.

Table 8. Timeline of Procedures and Phases

Week	Day	Procedures	Phase
1	1	1 CFQ (pre)	A
		1 SART (preceded by 4 practice SARTs)	
	2	2 – 11 SARTs (until stability reached; varied per subject)	
	3	1 SART + 30 minutes of mantra meditation	B
2	4	same as Day 3	
	5	same as Day 3	
	6	same as Day 3	
3	7	same as Day 3	
	8	same as Day 3	
	9	same as Day 3	
4	10	same as Day 3	
	11	same as Day 3 + 1 CFQ (post)	

*Table 8 Note***.** For each subject, the study comprised 11 one-hour days evenly spaced throughout four consecutive weeks. The Sustained Attention to Response Test (SART) was administered once per day, except for Day 2, which entailed two or more SARTs until the data showed stability. The Cognitive Failures Questionnaire (CFQ) was administered on Day 1 and Day 11. Mantra meditation was administered on Days 3 – 11 (i.e., only during Phase B).

4.1.8.1 Overview of Phase A

For each subject, Days 1 and 2 occurred during Phase A. On Day 1, the subject completed one CFQ, followed by four practice SARTs to exhaust practice effects, in keeping with prior research on short-interval cognitive function testing (Collie et. al., 2003; McAvinue et. al., 2005). The subject then completed one additional SART to be used in data analysis. Practice SARTs were not included in data analysis.

For each subject, Day 2 consisted of SART administration until the following *a priori* conditions were met. First: the subject completed multiple SARTs until the data showed stability, in keeping with standard SCED preconditions for initiating Phase B (Gast, 2014; Lane & Gast, 2014). Second: the subject completed no more than 11 SARTs so as to limit the testing burden and keep each day's procedures at an hour or less. Third: the minimum required total number of SARTs for data analysis was three, in keeping with SCED design standards (Gast & Spriggs, 2014; Kratochwill et. al., 2010) Upon meeting these conditions, the subject entered Phase B.

4.1.8.2 Overview of Phase B

Phase B occurred during days 3 through 11 and was the only phase in which mantra meditation took place. SART testing occurred on each day prior to mantra meditation. To introduce the mantra meditation, the PI verbally described it to the subject as a stepwise practice with repetitive intonation of the syllable *um* (Table 9). This syllable was selected by the PI because it has similar acoustic properties to the mantra *om,* which has a long history of use in meditation (Telles et. al., 2010). However, while *om* has a tradition of spiritual/semantic meaning (Telles et. al., 2010), *um* was presumed to be uniformly meaningless across subjects. After describing the mantra meditation, the PI then guided the subject through a two-minute meditation practice using the steps outlined in Table 9 while the subject co-participated. In short, the PI initiated each intonation of the mantra and the subject's role was to follow the PI's lead and co-intone in chorus. The subject then led a two-minute mantra meditation practice while the PI co-participated (i.e., followed the subject's lead). These brief pre-practices occurred until the subject reported and demonstrated adequate understanding to commence 30 minutes of leading the meditation practice, with the PI co-participating.

Table 9. Mantra Meditation: A Stepwise Practice

Steps	
1. Attend to intonation:	1a. Initiate intonation of the mantra; 1b. then sustain intonation of the mantra; 1c. then end intonation of the mantra.
2. Attend to silence:	2a. Initiate and sustain a short silence (e.g., a breath) after step 1c; 2b. then recognize/act on sustained silence as a cue to initiate step 1 immediately following the sustained silence.

Table 9 Note. Each subject was assigned to lead this stepwise practice for 30 consecutive minutes per day in Phase B, with the principal investigator (PI) as the only co-participant. If a subject's attention lapsed (e.g., ceased step 1 for more than a minute), the PI lightly tapped a non-startling chime to serve as an alert to the subject. However, she did not use the chime for short lapses (i.e., less than one minute) so as to preserve some challenge and thus train the subject to self-regulate attention.

On Days 4 through 9, the subject completed one SART each day, followed by leading 30 minutes of mantra meditation, with the PI co-participating. After completion of SART testing and meditation on Day 9, the subject completed one CFQ.

On each day of Phase B, the PI used a timer on her smartphone placed out of the subject's sight to ensure the day's meditation practice ended at 30 minutes. The smartphone timer emitted a low-volume electronic chime at the end of the 30-minute practice each day. The PI instructed subjects about the significance of the chime and asked them to avoid checking the time, looking around, or any other distracting behavior during the 30-minute period. She also lightly tapped a physical chime to signify the beginning of the meditation practice each day.

4.1.9 Data Analysis

4.1.9.1 Primary Data Analysis

The benchmark for concluding support for the central hypothesis was designated as at least three demonstrations of effect relative to the SART to demonstrate inter-subject replication as described in Gast (2014). In keeping with guidelines described in Gast and Spriggs (2014), as well as Lane and Gast (2014), demonstrations of effect were determined by analyzing SART data trend and level within- and across-phases to ascertain (1) the extent to which baseline levels were maintained until introduction of the independent variable; and (2) the extent to which level and trend were immediately affected by the introduction of the independent variable). Accordingly, visual analyses of graphed data and calculations of data path properties were conducted relative to stability of data level within-phase; change in data level between phases; trend direction within-phase; change in trend direction between phases; and percentage of data overlap between phases (Gast & Spriggs, 2014). Further in keeping with SCED guidelines, stability envelope parameters were designated *a priori* as 80% of the data points of a phase falling within a $\pm$25% range of the median level of all data point values of the baseline phase (Lane & Gast, 2014). Finally, because the SART was administered prior to meditation on each day of Phase B, and because Day 3 was the first day that meditation took place, Day 3 SART data was not included in analysis because it was impossible for that day's SART to reflect influence of meditation.

4.1.9.2 Secondary Data Analysis

As an exploratory outcome, pre-post score change in CFQ distractibility scores was computed for each subject. Subjects' anecdotal evidence about meditation was also examined.

4.1.10 Procedural Fidelity

A member of the research staff not involved with data collection or analysis was assigned to audit SART scores and delivery of SART instructions for three SARTs in Phase A and two SARTs in Phase B (i.e., in at least 20% of the sessions in each phase, per SCED guidelines (Lane & Gast, 2014). The staff member was also assigned to verify that at least two sessions of mantra meditation took place per protocol, meaning that the subject came to the appointment and stayed with the PI behind the privacy screen within the scheduled time frame, without any observed or heard deviations from behaviors summarized in Table 9. The acceptable rate of interobserver agreement (IOA) was set *a priori* at 80% or greater.

4.2 Results

Table 10 summarizes demographics of the sample. Figure 1 depicts SART data for all subjects and a therapeutic effect for Subject 2 only.

Table 10. Demographics of the Sample

Subject number	Race	Time since stroke at enrollment (months)	Sex	Age at enrollment (years)
1	White	119	Male	62
2	White	47	Male	62
3	White	75	Male	65

Table 10 Note. The final sample size was n=3. Subjects were numbered according to order of enrollment.

Primary Results

Graph of SART Data

Figure 1. Graph of Sustained Attention to Response Test (SART) Data for All Subjects

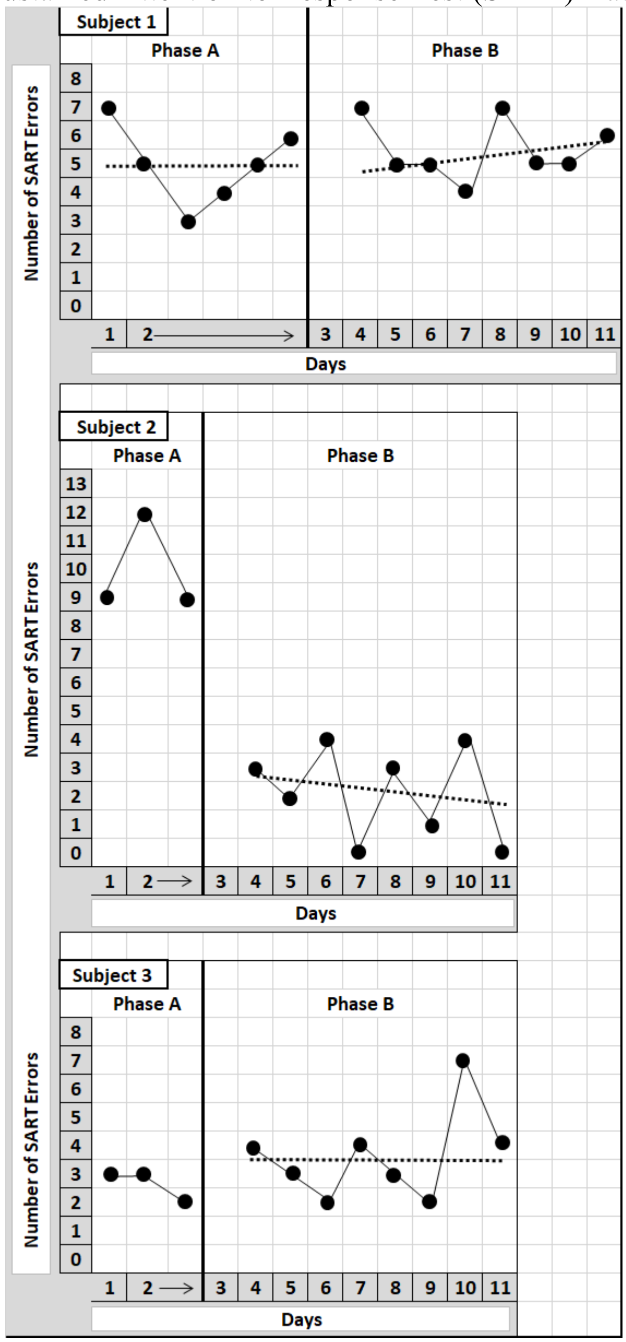

Figure 1 Note. Better attention is indicated by fewer errors on the SART (y-axis). The x-axes show the number of days in the study for each subject. The SART was administered once per day except on Day 2, which had two or more SARTs until the subject achieved baseline stability. Meditation took place in Phase B only, after SART testing each day. Thus, Day 3 SART data was not included in analysis because it could not reflect influence of meditation. A dotted line shows direction of data trend, where calculable. A therapeutic effect was evident for Subject 2 only, including no overlapping data between phases and a decelerating trend within Phase B.

All subjects completed the procedures per protocol with no adverse events. IOA rate was 100%. Evidence of a therapeutic effect for Subject 2 included a pronounced change in data level between phases. The magnitude of this change was quantified with a metric called percentage of non-overlapping data (PND), with higher PND more indicative of a demonstrated effect (Lane & Gast, 2014). PND for subject 1 was 0%. PND for subject 2 was 100%. PND for Subject 3 was 50%. Additional selected properties of the data are available in Appendix 1

4.2.1.1 Tabular SART Data

4.2.1.1.1 Stability of Data Level Within-Phase (Table 11).

Subject 1 achieved stable SART data in Phase A with six SARTs; and Subjects 2 and 3, with three SARTs. This stability was a precondition for initiating Phase B. In Phase B, Subject 1 was the only subject to show a stable level of SART data, which is a metric indicating the strength of the intervention effect (Gast & Spriggs, 2014).

Table 11. Stability of Data Level Within-Phase

	Subject 1		Subject 2		Subject 3	
Phase:	A	B	A	B	A	B
Stability of data level:	stable	stable	stable	variable	stable	variable

Table 11 Note. In Phase A, all subjects demonstrated a stable data level on the Sustained Attention to Response Test (SART). This stability was a precondition for initiation of Phase B (i.e., introduction of mantra meditation). Only Subject 1 had stable Phase B data, which is a metric of intervention strength.

4.2.1.1.2 Change in Data Level Between Phases.

Another indicator of intervention strength is immediacy or abruptness of change in data level when Phase B is introduced (Lane & Gast, 2014). Subject 2 showed the strongest effect in this regard (Table 12).

Table 12. Change in Data Level Between Phases

		Subject 1	Subject 2	Subject 3
Change in data level from Phase A to B:	Absolute:	6 – 7 → +1 (deteriorating)	9 – 3 → -6 (improving)	2 – 4 → +2 (deteriorating)
	Relative:	5 – 5 → 0 (no change)	9 – 2.5 → -6.5 (improving)	2 – 3.5 → +1.5 (deteriorating)

Table 12 Note. Absolute change, which compares the final Phase A datapoint with the first Phase B datapoint, was both largest and therapeutic for Subject 2, as lower scores indicate better attention on the Sustained Attention to Response Test (SART). Subject 2 was also the only subject to improve via relative level change (compares median of latter half of Phase A to median of initial half of Phase B).

4.2.2 Secondary Results

4.2.2.1 Tabular CFQ Data

Table 13 summarizes each subject's distractibility score on the CFQ.

Table 13. Cognitive Failures Questionnaire (CFQ) Distractibility

	Subject 1			Subject 2			Subject 3		
	Pre	Post	Pre – post	Pre	Post	Pre – post	Pre	Post	Pre – post
Distractibility score:	12	12	0	13	13	0	9	14	+5

Table 13 Note. On this subjective test, higher scores indicate more distractibility. Subjects 1 and 2 showed no change. Subject 3 reported worsened distractibility after intervention.

4.2.2.2 Anecdotal Evidence

Subjects conveyed anecdotal data about meditation (Table 14). This anecdotal evidence pertained to meditation generally as well as meditation in the study.

4.3 Discussion

Attention is commonly impaired after stroke (Winstein et. al., 2016). This impairment can have significant negative impact on daily function (Loetscher et. al., 2019), particularly when sustained attention is impaired (Robertson et. al., 1997a; Sturm et. al., 2004). The present study helped to address the evidence gap on effective

Table 14. Anecdotal Evidence

	Subject 1	Subject 2	Subject 3
Prior meditation experience (per subject report):	• None	• Two-year history of daily listening to meditation recordings (various styles; not mantra)	• None
Investigator observations:	• During the intervention period, the subject stated that he needed something more than the mantra to focus on, in order to pay attention. He also stated that as a general principle, meditation with transcendent meaning is preferable to meditation focused on self. • Throughout the study, he required minimal-to-moderate cuing during meditation to disengage from looking around, compulsive counting, attempted socializing, and more-than-occasional lapses into protracted silences.	• During and post-intervention, the subject requested to be included in future studies of mantra meditation. • During initial two days of meditation, he occasionally demonstrated overly lengthy individual intonations, prompting the PI to instruct him after these sessions to increase attention to silence.	• During the intervention period, the subject joked about "this hippie study" and "still waiting for the big mental pleasure" of meditation. • Throughout the study, he required minimal cuing with the chime during meditation (had occasional lapses into protracted silence).

Table 14 Note. Anecdotal data on the experience or evaluation of meditation was recorded.

interventions for this problem. The central hypothesis was that mantra meditation would have a therapeutic effect on chronically impaired attention after stroke, as measured with attention test scores. Primary results showed strong evidence in favor of a therapeutic effect for Subject 2, whose SART impairment data was stable in Phase A, then immediately and abruptly improved when meditation was introduced in Phase B.

Additionally, Subject 2 showed a trend towards continued improvement throughout Phase B. Other strong evidence of a demonstrated effect for Subject 2 included the highest-possible PND between phases. In contrast, for Subjects 1 and 3, there was no strong evidence in support of the central hypothesis—their SART impairment data was stable in Phase A yet remained unchanged (or worsened) in Phase B. As their SART scores indicated less severe baseline impairment than Subject 2, Subjects 1 and 3 may have been more subject to ceiling effects of intervention. Finally, no subject improved (and Subject 3 worsened) relative to the CFQ distractibility score. In sum: while this study showed strong evidence of effect for one subject, there was not replication of effect across all subjects. Thus, further evidence is needed to substantiate the likelihood of a functional relationship between mantra meditation and attention in cases of chronically impaired attention after stroke.

In this study, mantra meditation was chosen as the intervention for several reasons. First, unlike other forms of meditation that are sheer mentation (Lutz et. al., 2008), mantra meditation can be easily seen, heard, and standardized for research purposes. Second, given its simplicity, mantra meditation was presumed to be an optimal attentional challenge (or at least a feasible entry point) for subjects with impaired attention. This simplicity may also enhance the translational potential of mantra meditation compared with other protocols such as standard MBSR, which is not only more complex in terms of attentional demand but also requires specially trained personnel as well as a more protracted dosage (U-Mass., 2014). Third, mantra meditation has been shown to improve attention in healthy volunteers (Menezes et. al., 2013;

Menezes et. al., 2015). as well as subjects with impaired attention related to Alzheimer's disease (Newberg et. al., 2015).

Nevertheless, it remains conceivable that other types of meditation besides mantra may carry more therapeutic efficacy for subjects with impaired attention, possibly depending on subjective engagement. Engagement is a mechanism that can play an important role in attention and neuroplastic change in the context of rehabilitation (Danzl et. al., 2012; Kleim & Jones, 2008). Anecdotal evidence from the present study suggested that engagement may have been comparatively robust for the subject who demonstrated a therapeutic effect (i.e., Subject 2). For example, Subject 2 was the only subject who requested during and after the study to be included in future mantra meditation studies. He was also the only subject who did not require ongoing cuing to stay engaged with the task; rather, he initially showed a need for instruction on how to disengage from overly long intonation. In contrast, Subjects 1 and 3 appeared to indicate that the syllable *um* or other aspects of the meditation might not have been complex and/or meaningful enough to engage their attention. To elucidate how engagement or other subjective mechanisms might impact objective outcomes, future studies of mantra meditation to improve impaired attention should systematically assess engagement with the meditation as well as use of a more complex and/or meaningful mantra than the syllable *um*.

Limitations in the present study arose due to clinical feasibility. While clinical feasibility has been cited as a comparative strength of the non-concurrent multiple-baseline across-subjects SCED, control of threats to history and maturation has been cited as a limitation (Gast et. al., 2014) (although this type of assertion has not gone unchallenged (e.g., Christ, 2007). The present study incorporated some design features specifically recommended to help safeguard against these and other potentially significant threats (Christ, 2007). For example, the study was designed to have multiple SARTs on Day 2 in order to compress the study duration and thus help guard against insufficient enrollment and the significant threat of mortality (Christ, 2007). However, all other days had only one SART and thus did not achieve uniform spacing of stimuli, which can serve as a safeguard against history and instrumentation threats (Christ, 2007). In line with other recommended safeguards against these threats (Christ, 2007), the present study relied on IOA data as well as formative assessment in a manner shown to preclude practice effects when testing cognitive function over a short interval (Collie et. al., 2003), including with the SART (McAvinue et. al., 2005). A formative assessment schedule with more equivalent spacing, as well as an equal number of measurements across subjects throughout the study and random assignment of baseline lengths, would potentially provide more robust control relative to history threats (Christ et. al., 2007). Yet these strategies would result in differential dosing of meditation days across subjects and/or protracted duration (i.e., other potential limitations).

A related feasibility consideration in the present study included designing Phase A to comprise three to 11 datapoints. This design was in keeping with SCED standards that dictate each phase should contain no less than three datapoints to meet design standards with reservations and at least five datapoints to meet design standards without reservations (Kratochwill et. al., 2010). The cap of 11 datapoints was designed to prevent the burden of testing and time commitment per day. Because the study results showed that Phase A comprised only three datapoints for Subject 2, as well as for Subject 3, the present study met SCED standards with reservations; and there was not sufficient data to calculate either within-phase A trend direction or change in trend direction between phases for these subjects. Future studies using uniform spacing of SARTs with five or more datapoints in each phase could potentially strengthen experimental control as well as meet SCED standards without reservations. Other recommendations for future studies would include research to establish what SART score constitutes minimal clinically important difference. Likewise, future research is needed to establish the SART threshold for clinically significant impairment.

In conclusion, this study yielded some preliminary evidence to support the notion that mantra meditation may improve impaired attention after stroke. Such evidence should be considered in light of the limitations mentioned above as well as the outcomes indicating no therapeutic change for two subjects. More research in the target population is needed to establish characteristics that may predict or drive response to mantra meditation, such as severity of baseline impairment as well as engagement or other mechanisms of meditation that may harness attention. While the protocol described in this study may confer clinical benefit for some members of the target population, clinicians should monitor attention and related functional status during treatment as well as consider modifying the mantra or other aspects of the meditation as needed in order to optimize engagement and the attentional challenge.

CHAPTER 5. STUDY 3. A RANDOMIZED CONTROLLED TRIAL OF THE EFFECTS OF MANTRA MEDITATION ON ATTENTION FOR ADULTS WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER

5.1 Introduction

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder that is usually first diagnosed in childhood (American Psychiatric Association [APA], 2013). ADHD can persist into adulthood, with prevalence in the general adult population estimated at 8.2% (Ustun et al., 2017). Impairment of sustained attention can be a particular problem in such cases (Bálint et al., 2009; Gmehlin et al., 2016). This impairment manifests as diminishment of the endogenous capacity to maintain attention over time without alarms, warning signals, or other external cues (Spaccavento et al., 2019). The neurological etiology of adult ADHD can include abnormalities in or between the dorsolateral prefrontal cortex (DLPFC; Ulke et al., 2017) and the default mode network (DMN; Sudre et al., 2017). The DMN is normally active during mind-wandering and normally deactivated during tasks requiring sustained attention (Norman et al., 2017). Routine clinical treatment for ADHD includes methylphenidate (Cortese et al., 2020), a drug with dopaminergic effects on the DLPFC that correlate with self-reported improved attention in adults with ADHD (Volkow et al., 2012). Yet a recent systematic review did not support the comparative tolerability of methylphenidate in adult ADHD (Cortese et al., 2020). Transcranial direct current stimulation (tDCS) applied to the DLPFC has also been shown to improve attention in cases of pediatric through adult ADHD (Salehinejad et al., 2020). However, systematic reviewers have indicated there is not sufficient research to support recommendation of tDCS as routine clinical treatment for ADHD (Salehinejad et al., 2020). In short, there is a need for further research on interventions to improve attention in adult ADHD. Because there is some evidence that meditation could serve as this type of intervention, the purpose of the present study was to evaluate the effects of mantra meditation on sustained attention for adults with ADHD.

5.1.1 Meditation as a Therapeutic Training of Attention

The term *meditation* has historically referred to a type of activity in diverse religious and secular contexts entailing regulation of attention and/or emotion in for the purpose of attaining well-being, balance, or various other ends (Lutz et al., 2008). A broad, contemporary definition identifies meditation as a neurocognitive task (Newberg et al., 2010) in which an enhanced mental state is a generally intended outcome (Nash et al., 2013) and volitional self-regulation of attention is a defining aim or activity (Dorjee, 2016; Lutz et al., 2008; Nash et al., 2013). In other words, meditation may be conceptualized as a "mental training of attention" (Kosaza et al., 2012, p. 745). Training a function can improve that function via neuroplastic change (Kleim & Jones, 2008). Neuroplastic change is widely regarded as an underpinning of adaptive change in behavior even in cases of adult neurological impairment (Alia et al., 2017). Therefore, neuroplastic change may be a therapeutic mechanism by which meditation may improve attention in cases of adult ADHD.

A style of meditation called *focused-attention meditation* has been shown to modulate DMN and/or DLPFC activity in healthy volunteers (Fox et al., 2016). Focused-attention meditation impels sustaining attention on a chosen object and, when the attention wanders, recognizing that the wandering has occurred and bringing the attention back to the chosen object (Lutz et al., 2008). One example of a chosen object for focused-attention meditation is a *mantra*. A mantra is a repeated sound or syllable in meditation—

i.e., a “single salient percept” (Fox et al., 2016, p. 220)—by which “attention is more easily sustained and distractors more easily ignored than without the mantra…” (Fox et al., 2016, p. 220). Insofar as a mantra is a “voluntary verbal-motor production…spoken aloud or silently in one’s head” (Fox et al., 2016, p. 211), mantra meditation differs from typical focused-attention meditation that uses non-verbal objects of focus, such as sensations of breathing (Fox et al., 2016). The syllable *om* (Kalyani et al., 2011) and the syllables *sa ta na ma* (Newberg et al., 2010) are examples of mantras used in historical settings and contemporary research.

There is evidence associating mantra meditation with changes in neurophysiological and/or behavioral indices of attention. Menezes et al. (2013) randomized 26 healthy adult student volunteers to a meditation condition involving mental counting of breaths (one per exhalation) in six once-weekly sessions ranging from 15 – 30 minutes per session. The investigators avoided using the term *mantra* when describing the study “in order to avoid any direct links to a specific philosophical or religious tradition” (Menezes et al., 2013, p. 4). Additional subjects were randomized to a non-meditation relaxation control condition (n = 26) or waitlist control (n = 24). Outcome measures included the pencil-and-paper *Concentrated Attention Test* (Cambraia, 2003, as cited in Menezes et al., 2013), which the investigators characterized as a test of “focused attention” (p. 3). Significant pre-post improvement was evident relative to the meditation condition only ($p < 0.05$). Menezes and Bizarro (2015) also randomized healthy adult student volunteers to this type of mental-counting meditation (n = 14) versus waitlist control (n = 19) for five consecutive weekdays and found significant between-groups differences in attention favoring the meditation condition ($p < 0.05$).

In adults with mild-to-moderate cognitive impairment or dementia, Newberg et al. (2010) compared the effects of mantra meditation ($n = 14$) versus a music-listening, non-meditation control condition ($n = 5$). Mantra meditation was operationalized as repeated intonation of four syllables (i.e., *sa ta na ma*) aloud while touching the thumb to each finger, one finger per syllable, in 12-minute sessions once per day for eight weeks. Outcome measures at pre- and post-intervention included both resting-state and during-meditation cerebral blood flow to the DLPFC as well as pencil-and-paper testing with the *Trailmaking Test Part B,* which has been described as a test of divided attention (Johansson et al., 2012); working memory and task-switching (Sanchez-Cubillo et al., 2009); and cognition/executive function (Newberg et al., 2010). Results on the Trails B were reported to trend towards significance within the mantra group ($p = .05$), but not the comparison group ($p = .19$). Mantra also resulted in significantly higher resting-state cerebral blood flow to the right DLPFC ($p = .007$); significantly decreased right DLPFC activity during meditation ($p = .001$); and significant correlation of these results with the Trailmaking Test (R = -0.61, $p = .02$).

5.1.2 Mantra Meditation in Adults with ADHD

There is an evidence gap on mantra meditation to improve sustained attention for adults with ADHD, as shown by Krisanaprakornkit et al.'s (2010) systematic review of randomized controlled trials of meditation (broadly defined) in pediatric through adult ADHD. Results incorporated only two studies of mantra meditation, neither of which enrolled adults or measured sustained attention but did indicate some preliminary support for improved selective attention (Kratter, 1983, as cited in Krisanaprakornkit et al., 2010; Moretti-Altuna, 1987, as cited in Krisanaprakornkit et al., 2010).

To address the limited evidence on mantra meditation to improve sustained attention for adults with ADHD, the present study evaluated the effects of mantra meditation versus a comparison condition on sustained attention for adults with impaired attention due to ADHD. Sustained attention was measured with an objective, computerized neuropsychological test called the *Sustained Attention to Response Test (SART;* Robertson et al., 1997b; as cited in Manly et al., 2003). The SART is a continuous performance test (CPT), which is a class of tests that have a long history of use to measure sustained attention (Shalev et al., 2011). This type of test requires sustaining attention throughout a continuous stream of serially presented stimuli so that an appropriate response (e.g., pressing a button) can be made when a pre-specified target is seen during the stream. The primary hypothesis was that there would be significantly more mean pre-post change in the number of SART errors of commission associated with active mantra meditation versus comparison mantra meditation. The secondary hypotheses were that there would be significantly more mean pre-post change in the number of SART errors of omission, as well as significantly less mean pre-post change in SART reaction time (RT) variability, associated with the active versus the comparison condition; that within-group changes in SART errors of omission and commission would be significant only for the active condition; and that within-group changes in SART RT variability would be significant only for the comparison condition.

5.2 Methods

This phase II, single blind, randomized controlled superiority trial consisted of two arms: 1) active mantra meditation, and 2) comparison mantra meditation. The setting was a regional public university in the East Central United States, where the principal investigator (PI) was employed as an Assistant Professor of Occupational Science and Occupational Therapy.

5.2.1 Sampling

Convenience sampling was used via self-referral in response to flyers placed around campus, snowball sampling, and advertisement in a database of research opportunities for credit in a general psychology course at the university where the study was located. To pre-determine sample size, a power analysis was performed based upon previous research on non-meditation attentional training in adult ADHD that reported an intervention-related mean change in SART error commission score of -2.01 versus a mean change of 0.4 in the placebo group (O'Connell et al., 2008). The SD of the change with an assumed 0.50 correlation between baseline and post-intervention was 2.066. With alpha level in the present study set at .05 and power at .80, the total sample size required to show a significant difference between groups if a difference exists was determined to be $n = 34$ (17 per group). To account for an anticipated 10% dropout rate, recruitment was set at $n = 38$. Guidelines for stopping and interim analyses were not pre-specified.

5.2.2 Eligibility Screening

Screening was conducted within 1 – 3 days prior to enrollment. Main eligibility criteria are shown in Table 15.

Table 15. Main Eligibility Criteria

Inclusion criteria	Exclusion criteria
• University student age 18 or older	• Conditions that could confound the measurement or effects of intervention: o Uncontrolled depression as indicated by a score of >13 on the *BDI-SF* o Subject report of: ▪ Ongoing or significant history of substance abuse ▪ Change in medications that impact ADHD in the 3 months preceding enrollment as well as during the study ▪ Ongoing participation in any other research study, cognitive rehabilitation, meditation, or mental training program, including commercial brain-training programs ▪ Neurological impairment other than ADHD (e.g., Parkinson's disorder; stroke; traumatic brain injury) ▪ Uncontrolled or severe mental or cognitive disorder with low psychosocial functioning, such as untreated schizophrenia, bipolar disorder, or autism
• Impaired attention at screening: o Self-report of attention problems and/or ADHD diagnosis o Attention problems and/or risk for ADHD as indicated by a score of ≥14 on the *ASRS* o ≥ 4 errors of commission on the *SART*	• Enrollment as a student in the department where the PI was Assistant Professor during the study period

Table 15 Note. Abbreviations: ADHD = attention deficit hyperactivity disorder; *ASRS* = World Health Organization Adult Attention-Deficit/Hyperactivity Disorder Self-Report Screening Scale; *BDI-SF* = Beck Depression Inventory, Short Form; PI = principal investigator; *SART* = Sustained Attention to Response Test

5.2.3 Screening and Testing Instruments

5.2.3.1 World Health Organization Adult Attention-Deficit/Hyperactivity Disorder Self-Report Screening Scale (ASRS)

The *ASRS* (Ustun et al., 2017) is a pencil-and-paper test has six questions on which the subject rates how often symptoms of ADHD have occurred over the past six months. It carries a maximum possible score of 25, with a score of ≥14 as the threshold indicative of risk for ADHD diagnosis. Ustun et al. (2017) validated its screening sensitivity (91.4%) and specificity (96.0%) to distinguish ADHD cases from non-cases in the general adult population. Results were predicated on a sample of 637 adult subjects.

5.2.3.2 Beck Depression Inventory, Short Form (BDI-SF)

The *BDI-SF* (Beck et al., 1961; as cited in Furlanetto et al., 2005) is a pencil-and-paper test has 13 multiple-choice questions on which the potential subject rates depressive symptoms on a scale of 0 – 4, with a score of ≥13 as the threshold indicative of depression. This protocol for BDI-SF has been shown to have high sensitivity (93.5%) and specificity (96%) in general medical inpatients with heterogenous medical conditions, as predicated on a sample of 155 adult subjects (Furlanetto et al., 2005).

5.2.3.3 Sustained Attention to Response Test (SART)

The *SART* (Robertson et al., 1997b; as cited in Manly et al., 2003) is a CPT that uses a go/no-go paradigm to measure sustained attention (Manly et al., 2003; O'Connell et al., 2009). In addition to being used as a screening instrument, the SART also served as the instrument for all pre- and post-intervention testing.

Several studies have elucidated the utility of the SART (with digits in random order or in fixed sequential order) in clinical and non-clinical populations. In 72 healthy adults, Malegiannaki et al., (2012) found that commission-error rate on the SART with randomly ordered digits correlated significantly ($r = -.723$, $p < .01$) with sustained attention scores on the *Test of Everyday Attention (TEA*; Robertson 1994; as cited in Malegiannaki et al., 2012). These investigators found 1) no significant correlation between RT scores and TEA subtests of other, non-sustained types of attention; and 2) significant correlation between scores on a test of sustained attention called the *Attention Related Cognitive Errors Scale (ARCES)* and RTs before ($r = -.327$, $p < .01$) and after (r = -.322, $p < .01$) correct SART responses. Robertson et al. (1997b) demonstrated a significant correlation ($r = -0.27$, $p < .05$) between 75 healthy volunteers' self-report of everyday attentional failures on the *Cognitive Failures Questionnaire (CFQ*; Broadbent et al., 1982, as cited in Robertson et al., 1997b) and commission-error rate on the SART with randomly ordered digits; likewise, they found a significant SART-CFQ correlation ($r = .44$; $p <.05$) in a sample of 34 subjects with right-hemisphere acquired brain lesions. SART with digits in fixed sequential order was shown to be significantly more sensitive to neuroimaging-based indices of DLPFC activity than random SART in a sample of seven healthy volunteers (Manly et al., 2003). Errors of commission in the fixed SART were also shown to discriminate cases of frontal lobe impairment due to traumatic brain injury ($n = 19$) from 16 controls (OR = 2.02, $p = 0.019$; Manly et al., 2003). O'Connell et al.'s (2009) research in a sample of 13 healthy adults demonstrated that the fixed SART preferentially elicited electrocortical signatures of sustained attention (as opposed to response inhibition) when errors of commission were successfully avoided. Fixed SART was also used to elucidate ADHD autonomic biomarkers in a sample of 15 children with ADHD versus 15 healthy controls (O'Connell et al., 2004) and genetic variation related to DLPFC activity in a sample of 52 children with ADHD versus 21 healthy controls (Bellgrove et al., 2006). Finally, O'Connell et al. (2008) demonstrated that significant increase (i.e., worsening) of fixed SART RT variability was associated with placebo training as opposed to an attentional training intervention for 18 adults with ADHD; while significant decrease (i.e., improvement) in commission errors was associated with attentional training but not placebo.

In line with prior research in ADHD and non-clinical populations (e.g., Manly et al., 2003; McAvinue et al., 2005; McAvinue et al., 2012; O'Connell et al., 2008; O'Connell et al., 2009), a fixed SART score of ≥4 errors of commission was designated as the screening threshold for impaired attention. No changes were made to trial outcomes after the trial commenced.

5.2.4 Randomization and Blinding

A computer-generated randomizer program (www.randomizer.org) was used by the PI to generate a simple block random allocation sequence (1:1) for randomizing subjects into equal-sized treatment groups. Block size was 4. After the PI generated the sequence, two staff assistants not involved with testing or intervention accessed the sequence. One assistant placed a printout of each numeral in the sequence into individual envelopes (one numeral per envelope) and sealed each envelope after labeling it with a unique, corresponding subject number; and the other assistant retained a backup printout of the sequence in a locked drawer in her office. The PI did not access the sequence at any time and stored the sealed envelopes in her private faculty office. Envelopes were labeled sequentially 1 – 38; and the PI opened them according to this order, one envelope per subject, immediately after baseline assessment for that subject. The PI was not blinded in that she pre-specified a record of what each numeral in the random allocation sequence would signify (i.e., assignment to either active or comparison). Subjects were blinded to intervention, meaning that they were not informed whether the condition they had been assigned to constituted either active or comparison—only that the probability of being assigned to one condition as opposed to the other was 50:50. After randomization, no subject received further instructions about the condition to which s/he had not been assigned.

5.2.5 Procedures

The PI administered all testing on a 1:1 basis in her private faculty office. Testing included eligibility screening as well as administration of pre- and post-intervention outcome measures. Potential subjects were informed during consent 1) that regardless of condition, the meditation intervention would be characterized by a mantra repeated aloud while holding the hands in a prescribed position; 2) that the PI had not ascribed semantic meaning to the mantras in the study although these types of meanings may have characterized them throughout history; and 3) that the PI would provide further instructions about how to execute the assigned meditation after randomization. The only changes to methods after trial commencement were made after enrollment of the eighth subject. These changes enabled 1) posting of recruitment materials on the university's database for recruiting general psychology students; and 2) issuance of a debriefing form to each subject after post-intervention testing (see Appendix 2).

5.2.5.1 Pre- and Post-Intervention Testing

Each subject completed the SART once within 1-3 days before the intervention period and once within 1-3 days after the intervention period. Using Manly et al.'s (2003) specifications programmed into Matlab R2018 software on an HP Latitude 5490 laptop computer, one administration of the SART lasted about five minutes. During this time, the tested individual viewed a regularly repeating run of digits *1* through *9* on the monitor, one digit at a time, in fixed sequential (not random) order for a total of 25 scored runs. Each digit was presented for 250ms in the center of the laptop screen as a black numeral against a white background. Digits were presented at a font size of 48, 72, 94, 100, or 120 points at each digit onset, with size randomly selected according to the computer program. The interval between the onset of each digit was 1150ms. A black cross on a white background appeared for 900ms between presentation of each digit. Three practice runs were administered prior to the scored 25 runs. Prior to test onset, the tested individual received instructions to press the keyboard's spacebar upon the appearance of any digit except for the digit *3*. Scoring included the count of errors of commission (i.e., the number of times that *3* was pressed) and the count of errors of omission (i.e., the number of failures to press for digits other than *3*). A higher score indicated worse attention, as did increase in variability of reaction time (RT) to digits other than *3*. RT variability was calculated as the coefficient of variation (i.e., the ratio between mean RT and mean standard deviation (SD) of RT (O'Connell et al., 2004; Bellgrove et al., 2006)).

5.2.5.2 Intervention

Intervention was performed by each subject at home, alone. Subjects were instructed that during meditation, they should restrict their attention to carrying out the meditation instructions in a private area free from distractions. The assigned dose was 15 minutes, once per day, for six consecutive days (Figure 2).

Figure 2. Sample Schedule for Testing and Intervention

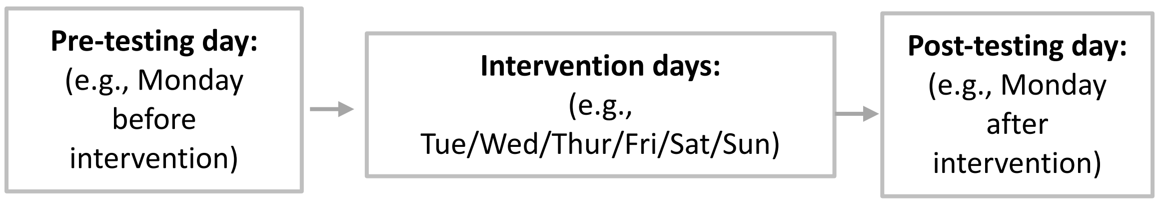

Figure 2 Note. While actual days of the week could vary from subject to subject, the total duration (number of days) was designed to span approximately one week.

5.2.5.2.1 ACTIVE MANTRA MEDITATION.

Similar to the protocol described in Newberg et al. (2010), active mantra meditation was operationalized as having the subject say the syllables *sa ta ma na* out loud at a comfortable pace and volume while touching the thumb to each successive fingertip in time with the syllable's intonation. This sequence of syllables differed from the sequence of syllables in Newberg et al. (2010) so that no associations with any specific religious tradition were either connoted or mandated. The PI monitored compliance via daily videos recorded by the subject and shared with the PI via a private, secure connection. Subjects were instructed that the videos needed to convey audio and show only the finger movement, not faces.

5.2.5.2.2 COMPARISON MANTRA MEDITATION.

Comparison mantra meditation was designed to be more motorically passive than active mantra meditation. Specifically, subjects in the comparison condition were instructed to sit quietly with thumb touching index fingertip while attentively listening to an audio recording that the PI provided via an emailed link to a publicly available YouTube video. The audio recording consisted of the continual sound of an anonymous male individual repetitively intoning the syllable *om* over ambient background sound for 15 minutes. In this way, comparison meditation was designed to use meditation-related practices to entrain attention, similar to a sham meditation protocol that was shown to improve negative mood, state anxiety, and tension in healthy volunteers (Zeidan et. al, 2010). Because both conditions in the present study therefore presumably carried the potential for possible benefit, no waitlist control was used. To monitor compliance for the comparison condition, each subject was asked to email the PI a daily notification of whether the session had been carried out per protocol that day. Video or other methods for supervision of comparison subjects was not used.

5.2.6 Statistical Plan

The statistical analysis plan for primary and secondary outcomes included data tests for normality; two-tailed independent *t*-tests to evaluate between-groups differences in pre-post mean change; paired *t*-tests to evaluate within-group mean changes; and computation of effect sizes for significant findings.

5.3 Results

Figure 3 shows the study flow with denominators for primary analysis. Results are presented for data from subjects enrolled and followed between inception of recruitment (July 9, 2018) through March 6, 2020. Recruitment and enrollment was halted on March 6, 2020, due to institutional constraints associated with the COVID-19 pandemic. There were no harms or unintended effects in either group.

Figure 3. Study Flow

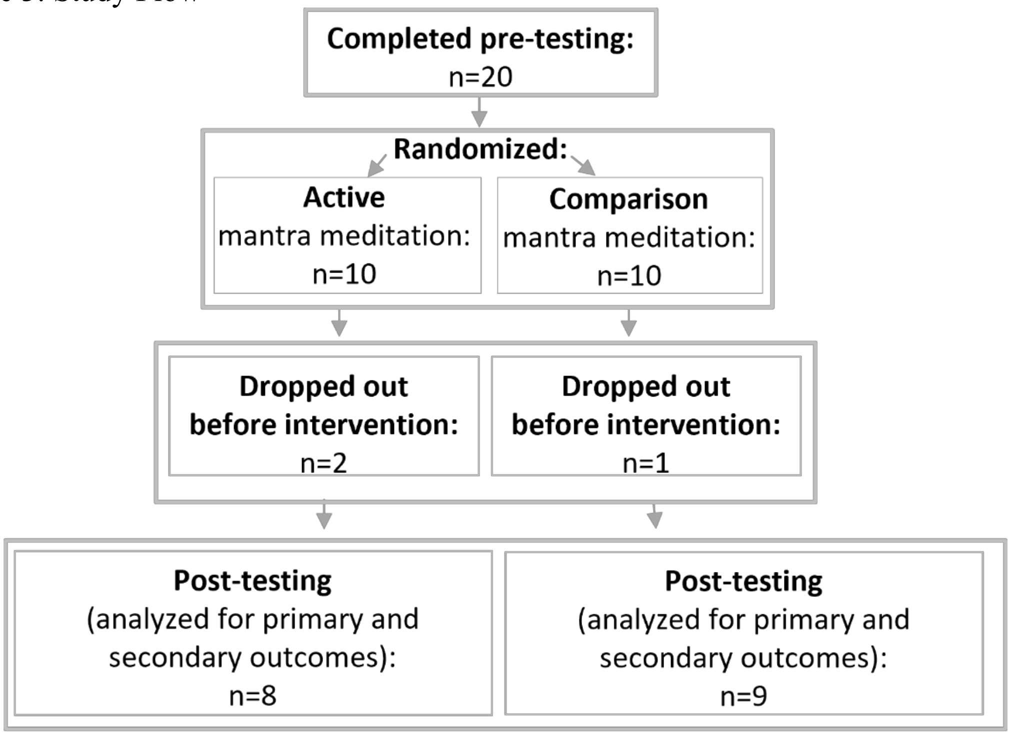

Figure 3 Note. The PI withdrew two subjects from the active condition and one from the comparison condition because of their non-response to all attempts for contact during the intervention period. Thus, 17 subjects received intended treatment and were analyzed for the primary outcome. Analysis was by original assigned groups.

Table 16 shows baseline group characteristics.

Table 16. Baseline Characteristics

Sex	*n*	Mean Age (years)	Active	Comparison
Female	10	19.75	4	6
Male	7	20	4	3

5.3.1 Outcomes and Estimation

Minitab Version 19 was used to verify normal distribution of data and to conduct within- and between-groups analyses. Excel 2008 was used to compute effect sizes for significant findings.

5.3.1.1 Results for Errors of Commission

Analyses of change both within and between groups revealed no outliers (i.e., no observations that were ≥ 1.5 times the interquartile range). Equal variances were assumed and verified for the between-groups analysis (F = 2.10, $p = 0.319$). Intervention was associated with significant within-group changes for both conditions, although the active condition was associated with significantly more improvement than the comparison condition (Table 17).

Table 17. Results for Errors of Commission

Comparison	*n*	Pre	Post	Change	Between-Groups Difference	*P*-Value	CI	Effect Size
Within Group (Active)	8	11.00 (4.24)	4.75 (2.82)	-6.250 (2.659)	-	0.000	95% CI [-8.473, -4.027]; 99.95% CI [-11.968, -0.532]	-1.74
Within Group (Comparison)	9	9.22 (4.35)	5.33 (3.46)	-3.889 (1.833)	-	0.000	95% CI [-5.298, -2.480]; 99.95% CI [-7.322, -0.456]	-0.99
Between Groups	-	-	-	-	2.36 (2.26)	0.048	95% CI [0.02, 4.70]; 95.1% CI [0.01, 4.71]	1.05

Table 17 Note. Pre, post, and change values within groups are reported as the mean error count for the group followed by standard deviation (SD) in parentheses. The between-groups difference is reported as the absolute value for the mean difference in error count change between groups followed by the pooled SD in parentheses. Uncorrected confidence intervals (CIs) are reported first, followed by exploratory Bonferroni corrections for multiple comparisons. Effect size is reported as Hedges' uncorrected *g*. All findings were statistically significant at $p < .05$ and had a large effect size.

5.3.1.2 Results for Errors of Omission

Equal variances were assumed and verified for the between-groups analysis (F = 0.51, *p* = 0.372). No significant within- or between-groups findings were associated with intervention (Table 18).

Table 18. Results for Errors of Omission

Comparison	*n*	Pre	Post	Change	Between-Groups Difference	*P*-Value	CI
Within Group (Active)	8	5.63 (5.83)	3.38 (2.88)	-2.25 (4.56)	-	0.205	95% CI [-6.06, 1.56]
Within Group (Comparison)	9	2.89 (4.28)	1.67 (1.41)	-1.22 (3.27)	-	0.295	95% CI [-3.74, 1.29]
Between Groups	-	-	-	-	1.03 (3.92)	0.598	95% CI [-3.04, 5.09]

Table 18 Note. Within-groups pre, post, and change values are reported as the mean error count for the group followed by standard deviation (SD) in parentheses. The between-groups difference is reported as the absolute value for the mean difference in error count change between groups followed by the pooled SD in parentheses. No significant findings ($p<0.05$) were associated with intervention. Uncorrected confidence intervals (CIs) are reported. Subsequent analyses excluding the only outlier (comparison group; pre = 12; post = 3; change = -9) likewise showed no significant effects of intervention either between groups (*p* = 0.261) or within the comparison group (*p* = 0.668).

5.3.1.3 Results for RT Variability

Analyses of change both within and between groups revealed no outliers. Analysis of between-groups change revealed unequal variances (F = 0.13, *p* = 0.011). Subsequent analyses assuming unequal variances between groups revealed no significant findings associated with intervention; likewise, there were no significant within-group findings (Table 19).

Table 19. Results for Reaction Time (RT) Variability

Comparison	*n*	Pre	Post	Change	Between-Groups Difference	*P*-Value	CI
Within Group (Active)	8	50.74 (17.92)	49.98 (26.03)	-0.76 (24.10)	-	0.932	95% CI [-20.91, 19.39]
Within Group (Comparison)	9	46.08 (18.58)	46.87 (24.47)	0.79 (8.82)	-	0.796	95% CI [-5.99, 7.57]
Table 19 (continued)							
Between Groups	-	-	-	-	1.54	0.868	95% CI [-19.24, 22.33]

Table 19 Note. Within-groups pre, post, and change values are reported as the mean coefficient of variation for the group followed by standard deviation (SD) in parentheses. The between-groups difference is reported as the absolute value for the mean difference in change between groups (pooled SD not reported due to unequal variances). No significant findings ($p<0.05$) were associated with intervention. Uncorrected confidence intervals (CIs) are reported.

5.4 Discussion

Results provide preliminary support for the primary hypothesis of significantly more mean pre-post change in SART errors of commission associated with active versus comparison mantra meditation. The raw magnitude of between-groups difference favoring the active condition was comparable to that of O'Connell et al.'s (2008) non-meditation attentional training program for 9 adults with ADHD, which effected a statistically significant mean SART change of -2.01 ($p<.05$) versus a non-significant mean change of 0.4 ($p = 0.6$) in their placebo group of 9 adults with ADHD. However, the present study builds on these results because unlike O'Connell et al. (2008), the present study showed a significant difference between groups with a large effect size.

While within-group change in commission errors for each group was statistically significant with large effect sizes, these findings did not align with the secondary hypothesis that such changes would be significant only for the active condition. These results may indicate that both conditions effectively entrained attention. This idea is not incompatible with the results of a study by Kalyani et al. (2011), which reported significant impact on limbic structures and attention-related areas (i.e., insula; anterior cingulate cortex) in healthy adult subjects who repeatedly chanted the syllable *om* aloud during neuroimaging. The insula and anterior cingulate cortex are considered nodes of the salience network, which is functionally integrated with attentional networks and structures including the DLPFC (Norman et al., 2017). Kalyani et al. (2011) described the impact as a response pattern similar to that associated with vagal nerve stimulation used in clinical treatment of depression. This evidence suggests that reward and/or other constructs associated with salience/attention may be inherently related to hearing and/or chanting the syllable *om* in meditation. Given this evidence, as well as the significantly greater magnitude of change in commission errors for the present study's active group, it is conceivable that an optimal intervention would combine aspects of both groups, such as the addition of the syllable *om* to the *sa ta ma na* active protocol. Future research is recommended in this regard.

The absence of any other significant findings resulted in failure to reject all other null hypotheses. These results are not incompatible with the mixed evidence base on the utility of SART metrics other than errors of commission for indexing sustained attention in both neurological and non-clinical populations. For example: while Manly et al. (2003) found significantly more fixed SART errors of both commission and omission ($p < 0.001$) for adults with chronic traumatic brain injury (n = 19) versus healthy controls ($n = 16$), errors of commission was the only metric validated as sensitive for discriminating between the groups (OR = 2.02, $p = 0.019$). While these investigators' sub-study of healthy volunteers ($n = 7$) showed significantly more change in DLPFC activity associated with fixed versus random SART ($p < 0.001$), no one metric of the fixed SART was identified as a particular correlate of the change (Manly et al., 2003). On the other hand, avoidance of errors of commission was shown to preferentially elicit electrocortical signatures of sustained attention in a separate study of the fixed SART in 13 healthy adults (O'Connell et al., 2009). With specific regard to ADHD, O'Connell et al. (2004) found significant differences between groups in errors of commission ($p < .03$), omission ($p < .008$), and RT variability ($p < .007$) on the fixed SART for 15 children with ADHD versus 15 healthy controls. Yet for a sample of adults with ADHD ($n = 18$) and healthy controls ($n = 23$), O'Connell et al.'s (2008) placebo-controlled investigation of an attentional training program showed no significant post-intervention change RT variability or in errors of omission, which were reported as rare in the sample to begin with. These findings were similar to those of the present study (Tables 5.4 – 5.5). Further research to validate the psychometric properties and neurological underpinnings of performance associated with errors of omission and RT variability of the fixed SART in cases of adult ADHD would potentially strengthen the utility of this instrument for use in future research on meditation to improve attention in cases of adult ADHD.

The large effect sizes for the primary findings in the present study point towards practical significance. More definitive conclusions would hinge not only on enrollment of the full planned sample size but also further research to establish the fixed SART's minimal clinically important difference (MCID) in errors of commission as well as the threshold score for attention impairment. Because this information is lacking in the literature, the present study operationalized the threshold for impairment in keeping with results from five fixed-SART studies (i.e., Manly et al., 2003; McAvinue et al., 2005; McAvinue et al., 2012; O'Connell et al., 2008; O'Connell et al., 2009) in which neither the mean commission-error score nor the mean commission-error score plus two SD ever reached as high as 4 in healthy adults (combined n = 138). Of note, the mean commission-error score before attentional training in O'Connell et al.'s (2008) sample of 18 adults with ADHD was 6.25—identical to the magnitude of improvement effected by active mantra meditation in the present study.

Carriere et al. (2010) found that in a sample of 638 healthy adults with an age range of 14 – 77, age did not predict performance on the random SART. Age and biological sex have not been examined as predictors of performance on the fixed SART. Given the potential influence of both maturation and biological sex on etiology and/or symptomatology of ADHD, future research examining these potential covariates in a fully powered study is recommended.

Findings may also be considered in light of evidence indicating forms of meditation other than mantra can effect attentional improvement in adult ADHD. For example, a small evidence base indicates that mindfulness meditation may improve performance on pencil-and-paper tests of sustained attention for adults with ADHD (e.g., Bueno et al., 2015; Tarrasch et al., 2016). However, unlike mantra meditation, mindfulness meditation typically entails regulation of not just attention but also emotion; and it can require comparatively protracted, specialized training (UMass, 2014). Thus, mindfulness meditation may be more complex or resource-demanding than mantra meditation—a difference that could conceivably impact translational potential. By the same token, the simpler demand of mantra meditation may render it optimal for cases of more severe impairment and/or non-responders to mindfulness or similarly complex forms of meditation. An additional advantage of mantra meditation for use in clinical and research settings is its comparative ease of measurement—it can be seen and heard, in contrast to silent and/or internally-oriented processes in other types of meditation. Future research is recommended to continue progress towards optimizing the task of meditation for therapeutic use in attentionally impaired populations—including whether differential effects are associated with use of the novel sequence of syllables in Study 3's active condition (i.e., *sa ta ma na*) versus the traditional *sa ta na ma* sequence as described in Newberg et al. (2010).

In sum, the present research indicates preliminary promise that mantra meditation may improve impaired sustained attention in cases of adult ADHD. While the clinical significance of impaired sustained attention has been reported to correlate significantly with everyday difficulties for adults with ADHD—such as inability to concentrate on conversations, overreliance on others to stay organized, and frequent procrastination (Gmehlin et al., 2016)—more serious and morbid functional outcomes associated with ADHD include mood disorders, academic underperformance, accidents, and injuries (Boland et al., 2020). To elucidate the clinical significance of mantra meditation, fully powered studies examining its impact on these types of functional outcomes, in addition to SART or other attentional tests, are recommended.

CHAPTER 6. SUMMARY AND CONCLUSION

This chapter will summarize key findings of the research conducted for this dissertation. Selected limitations, explanatory frameworks, and implications for future research or clinical application will also be described.

6.1 Summary of Key Findings

6.1.1 Study 1

The main objective of this qualitative phenomenological study was to facilitate understanding of the experience of meditation after stroke. This objective was achieved based on data from five community-living adults who self-reported having participated in meditation during the chronic stage of recovery (i.e., >1 year post-stroke). The following five major themes emerged: 1) meditation after stroke can be constituted by non-action as well as action; 2) the experience can manifest via discrete avenues yet also seem synthesized or holistic in character; 3) being oriented to or within meditation after stroke can hinge on contexts of place, time, and direction; 4) meditation after stroke can be valuable relative to numerous aspects of life and function; and 5) although the perceived relationship to stroke may vary, meditation after stroke can be crucial for recovery.

There were limitations related to how meditation was operationalized in Study 1. While the PI's general definition for meditation was provided to potential subjects at screening, there was no further metric for objective validation or homogeneity of participants' definitions. Additionally, Study 1 did not tie the defining bounds for meditation to any specific style, such as focused-attention or mindfulness. At the same time, these limitations were not incompatible with either the purpose of Study 1 or with standard qualitative methodology, in which maximizing differences in the course of sampling makes the study more likely to reflect different perspectives—"an ideal in qualitative research" (Creswell, 2013, p. 157).

An additional limitation in Study 1 is that it did not designate impaired attention as an inclusion criterion. Thus, the extent to which findings may be generalized to individuals with impaired attention remains unknown. At the same time, results were not incompatible with the notion that meditation after stroke involves and/or entrains attention. No participant indicated that attention did not play a role in meditation after stroke. Some even indicated that it improved attention. Thus, the findings from Study 1 were compatible with the stated need and rationale for Study 2.

6.1.2 Study 2

The main objective of this non-concurrent multiple-baseline across-subjects single-case experiment was to test the central hypothesis that mantra meditation (i.e., verbal repetition of the syllable *um*) would have a therapeutic effect on chronically impaired attention after right-hemisphere stroke in adults. The number of errors of commission on the SART was the primary outcome. Results showed strong evidence in favor of a therapeutic effect for one out of a total of three enrolled subjects. Because benchmark was pre-specified as a therapeutic effect for at least three subjects, further evidence is needed to substantiate the likelihood of a functional relationship between mantra meditation and attention in cases of chronically impaired attention after right-hemisphere stroke.

The differential findings across subjects in Study 2 may have differed to the extent that engagement with the meditation may have varied across subjects. More specifically, the non-responders indicated anecdotally that the syllable *um* or other aspects of the meditation might not have been complex and/or meaningful enough to afford an engaging experience (i.e., engage their attention). These findings pointed to a need for research that may elucidate drivers of response to mantra meditation in attentionally impaired populations, such as complexity or other meaning- or salience-related characteristics of the mantra. Along these lines, Study 3 was conducted as described below.

6.1.3 Study 3

The purpose of this phase II, single blind, randomized controlled superiority trial was to evaluate the effects of mantra meditation on sustained attention for adults with ADHD. The primary hypothesis was that there would be significantly more mean pre-post change in SART errors of commission associated with active mantra meditation (i.e., verbal repetition of *sa ta ma na* performed aloud by each subject during successive fingertip-thumb touching) versus comparison mantra meditation (i.e., listening to a standardized recording of verbally repeated *om* during static index-fingertip touching to thumb). Secondarily, it was hypothesized that within-group changes in SART errors of commission would be significant only for the active condition. Preliminary results were predicated on a sample comprised of 17 subjects (active n = 8; comparison n = 9) and indicated support for the primary hypothesis via a significant difference between groups (p<.05) favoring the active condition. Within-group change was also statistically significant (p < .05) for both groups.

These preliminary results should be considered in light of other meditation research. First, the findings of a 2.36 SART difference between groups favoring the active group after intervention were comparable to O'Connell et al.'s (2008) findings, in which an attentional training program in 18 adults with ADHD effected a statistically significant mean change in SART commission errors of -2.01 ($p < .05$) versus a non-significant mean change of 0.4 ($p = 0.6$) in their placebo group. Second, the mean improvement effected by active mantra meditation in Study 3 (i.e., -6.25 SART commission errors) was an amount equivalent to that which would have totally ameliorated the mean baseline SART deficit in O'Connell et al.'s (2008) ADHD sample.

6.2 Explanatory Frameworks and Future Directions

The research conducted for this dissertation yielded some indication of whether and how meditation can be subjectively valuable and/or objectively therapeutic for adults with a history of stroke or ADHD. While mantra meditation was shown to improve SART scores for subjects with impaired attention due to adult ADHD, there was a lesser indication of this benefit relative to impaired attention due to chronic right-hemisphere stroke. The indications that the benefit may have been a function of meaning- (or salience-) related aspects of the meditation are analyzed below in terms of affordance theory and possible neurological mechanisms.

6.2.1 Affordance Theory

In ecological psychology, the term *affordance* refers to an element that affords an opportunity for action relative to an individual's capabilities (Gibson, 1979; as cited in Jorba, 2020). Jorba (2020) postulated how affordances and actions can be wholly cognitive in nature: "The relevant affordance structure in the cognitive domain involves the cognitive element x and the mental action φ….where x is a cognitive element and φ is a certain mental action [and] x affords φ-ing” (pp. 860-861). In Study 2, the cognitive elements included 1) the syllable *um*, which afforded producing speech; 2) silence, which afforded withholding speech; and 3) the interspersion of *um* with silence, which afforded task-switching. These cognitive elements also afforded attention to sensation as well as coordination of neurological activity to control each element.

Study 3’s active condition was similar to mantra meditation in Study 2 but had additional affordances for action and attention. Specifically, Study 3’s active condition added successive fingertip-thumb touching, a number of syllables (*sa ta ma na*), and semantic meaning for the syllables depending on subjects’ preferences. In contrast, comparatively fewer salient elements characterized Study 3’s comparison condition (i.e., listening to a mantra recording of the syllable *om* and maintaining static fingertip-thumb touching). Thus, the Study 3 comparison condition did not afford a cycle of producing and withholding motor action and, in turn, did not afford task-switching and neurological control/coordination of these elements. The comparison condition was, however, operationalized to afford attentional training in the context of meditation because it did impel attending to sensorimotor stimuli that was pre-designated as salient and meditative.

In keeping with Jorba’s (2020) postulates, additional influences on the affordance process in meditation could have included subjects’ abilities, intentions, and action/thinking already taking place. In the present dissertation, these influences could have comprised (but were not necessarily limited to) the severity of neurological impairment; the reasons for enrollment; and symbolic, pre-conceived meanings of meditation (such as those outlined in earlier sections on anecdotal evidence from Study

2). These additional influences were beyond the scope of this dissertation but merit further study.

6.2.2 Potential Neurologic Mechanistic Operations

Direct neurophysiological evidence on regions or networks of the brain was not sought for this dissertation. It is conceivable that DLPFC and/or DMN change may have occurred for responders to meditation. As noted previously, the DMN is normally active during resting-state mind-wandering but not during sustained attention to task (Norman et al., 2017); whereas the DLPFC exerts cognitive control of sustained attention (Spaccavento et al., 2019) and is normally activated by abstract rules and manipulation of information held in working memory (Miller & Wallis, 2013). In this vein, the abstract rules impelling a focused-attention meditator to keep mind-wandering (i.e., the DMN) in check (i.e., recognize mind-wandering and bring the attention back) would normally and presumably be at least partially controlled by the DLPFC. For this reason, and given previously mentioned tenets of neuroplasticity, occupational therapy, and affordance theory—and because there is evidence that normalization of DLPFC-DMN activity underpins attentional recovery after stroke (Park et al., 2014) or adult ADHD (Sudre et al., 2017)—mantra meditation as operationalized in this dissertation may best be understood as an occupation that possibly affords potentially therapeutic brain activity—such as repetitively normalized coordination of DLPFC-DMN connectivity—for adults with attentional impairment due to stroke or ADHD. However, neuroimaging research would be needed to substantiate whether and when the neural signature of meditation associated with improved attention in cases of impaired attention (i.e., therapeutic meditation) 1) mirrors the normal, mantra-related dynamics of DMN-DLPFC coordination; and/or 2) requires coordination of DMN-DLPFC. Future research is recommended in this regard, along with research to determine the effects of meaning- or salience-related variables on the neural signature of therapeutic meditation for the target populations of this dissertation.

6.3 Implications for Clinical and Research Application

Key tenets of the AOTA's *Practice Framework* (2020) provide a relevant context within which findings from this dissertation should be considered (Table 20):

Table 20.How and Why Occupations and/or Activities Can Be Employed for Therapeutic Ends: Key Tenets of the American Occupational Therapy Association's Practice Framework (2020)

Definition of Occupational Therapy	"The therapeutic use of everyday life occupations with persons, groups, or populations (i.e., the client) for the purpose of enhancing or enabling participation" (p. 1).
Domain and Process of Occupational Therapy	" 'Achieving health, well-being, and participation in life through engagement in occupation' … describes the domain and process of occupational therapy in its fullest sense. This statement acknowledges the profession's belief that active engagement in occupation promotes, facilitates, supports, and maintains health and participation" (p.5).
Specialized Knowledge Base for Intervention	"Occupational therapy practitioners use their knowledge of the transactional relationship among the client, the client's engagement in valuable occupations, and the context to design occupation-based intervention plans" (p. 1).
Occupations Versus Activities	"The term occupation denotes personalized and meaningful engagement in daily life events by a specific client. Conversely, the term activity denotes a form of action that is objective and not related to a specific client's engagement or context (Schell et al., 2019) and, therefore, can be selected and designed to enhance occupational engagement by supporting the development of performance skills and performance patterns. Both occupations and activities are used as interventions by practitioners…" (p. 7).

While meditation may logically be considered an occupation (cf. Chapter 1), it is arguable that meditation may also be considered an activity in the vein of Radomski and Giles' (2014) *process-specific training* (cf. Chapter 1), in which case attention would be the cognitive process—or, in the parlance of the *Practice Framework* (AOTA, 2020), a performance skill—trained in isolation. In keeping with Table 20, it is further arguable that whether and when to conceptualize meditation as an occupation versus an activity is within the specialized purview of occupational science and therapy—particularly at the level of the individual occupational therapist, who generally has the most proximal relationship with the client. Irrespective of these arguments, Table 20 and other tenets of the *Practice Framework* (AOTA, 2020) as described in Chapter 1 of this dissertation support the notion that an occupation-based intervention plan can incorporate meditation to enhance occupational engagement supporting health, well-being, and participation in life. In addition, as a platform for understanding potentially salient features of meditation after stroke, Study 1 findings can be used to inform occupation-based intervention in stroke rehabilitation and research. The following examples illustrate this idea.

For example, a major theme in Study 1 conveyed how participants were oriented to and within meditation. This data could be used as a resource not only for meditation-naïve practitioners wondering how to structure meditation intervention after stroke (e.g., use a recording; rely on historic precedents) but also to inform clients/subjects how meditation is (or can be) done after stroke and what it may feel like (e.g., turned away from everything, both mentally and physically). Such information could be of particular use with clients/subjects who are meditation novices because it could ease the learning curve about meditation and thus presumably aid buy-in and/or compliance. Similarly, the generally positive overall value that meditation was ascribed in Study 1 supports its potential usefulness in stroke rehabilitation/research protocols because the likelihood of adherence to the meditation intervention would presumably be enhanced by client belief in its potential benefit—a belief that might conceivably be stronger for clients in stroke rehabilitation than if supporting evidence was sourced from non-stroke populations.

Other examples of specific meaning units with potential value for translation to the clinical or research setting included the major theme that meditation is constituted by either action or non-action. One utility of this theme was to give face validity to meditation's potential feasibility for clients with motor impairment after stroke. In turn, practitioners who serve clients with post-stroke motor impairment need not regard motor impairment as necessarily proscriptive of meditation.

Finer-grained levels of meaning from Study 1, such as significant statements, could likewise inform logistics of intervention design. For example, one significant statement indicated that participation in meditation after stroke was afforded by chair seating as opposed to the tradition of sitting cross-legged on the floor. In turn, practitioners in stroke rehabilitation/research who serve clients with mobility restrictions need not regard non-traditional physical positioning as necessarily proscriptive of meditation. On the other hand, traditions may afford or enhance participation in meditation after stroke, as with the significance of candle-lighting and a consistent time for meditation. Use of these elements in clinical or research settings would be not only practically feasible but also in keeping with tenets of occupational therapy that explicitly designate routines as structures by which life is organized and health may be promoted; and rituals, as meaningful actions that contribute to a client's identity (AOTA, 2020).

While meditation and/or affordances for meditation participation as described in Study 1 might facilitate targeted rehabilitation outcomes such as improved attention, quantitative studies would be needed to substantiate statistical associations between such variables. Accordingly, a main utility of Study 1 findings was to provide groundwork for generation of testable hypotheses (and in turn, objective evidence) about how clinical or research protocols may be tailored to afford targeted outcomes of meditation after stroke. For example, the Study 1 theme indicating variable needs for external guidance (e.g., an audio recording), as well as the overall indications from Study 1 that attention was involved in and/or improved by meditation, could be translated into a randomized controlled trial of the effects of recorded versus self-guided meditation on attentional outcomes for subjects with chronically impaired attention after stroke.

Higher-level evidence such as that derived from a randomized controlled trial would also be needed to establish an inferential-statistics-based likelihood of a functional relationship between the variables of Study 2. Ultimately, overall results of Study 2 did not reach benchmark for concluding that it was likely that attentional status was affected by mantra meditation—even though there was notable improvement for one of the three subjects. Thus, further research is recommended to support more than limited clinical use of Study 2's mantra meditation to target impaired attention after stroke. Practitioners who employ the protocol of Study 2 based on its anecdotal and incidental evidence should monitor attention and related functional status during treatment as well as consider modifying the salience-related aspects of the meditation accordingly and in keeping with clinical judgement and client preferences.

In both Studies 2 and 3, there were indications that a potential contrast in the experience of salience- or meaning-related aspects of meditation across subjects may have differentially influenced subjects' willingness or ability to engage with the intervention. Because Studies 2 and 3 did not designate these aspects as variables for formal investigation, future research specific to mantra meditation associated with improvement of pathologically impaired attention (e.g., SART score change) should use mixed methods to clarify possible relationships between meaning-related variables of the meditation with attentional outcomes. In this vein, it would be appropriate to conduct a mixed-methods version of Study 3 (i.e., randomized controlled trial combined with phenomenology) because both conditions in Study 3 were associated with significantly improved attention and thus may have effectively entrained attention. To address a main limitation of Study 3, such research should also have enrollment sufficient to achieve pre-specified power and thereby minimize risk of Type II error.

While Study 3 did not hypothesize that attention would significantly improve for the comparison group (i.e., *om* condition), the results of Study 3 (and the possible underlying mechanisms for benefit) should be considered in light of Kalyani et al.'s (2011) fMRI study of mantra meditation in healthy volunteers (n = 12). More specifically, Kalyani et al. (2011) substantiated that enunciation of the *om* mantra effects aural vibratory sensation and thereby leads to a neurophysiological response pattern similar to that used in vagal nerve stimulation, which is used as a clinical treatment for depression. Insofar as such a response pattern may be understood to constitute a reward, so may it be conceivable as a mechanism by which *om* meditation may effect reward (i.e., relate to salience mechanisms). This implication becomes even clearer in consideration of

Norman et al.’s (2017) summary of canonical research on attention networks, which identified anterior insula and dorsal anterior cingulate cortex (i.e., affected substrates in Kalyani et al., 2016) as nodes of the salience network. Given this evidence, it is conceivable that adjuvant effects might emerge with addition of the syllable *om* to the *sa ta ma na* active protocol. This point might be arguable given Study 3’s significant between-groups findings favoring the active group; however, the rationale for adjuvancy is strengthened in consideration of the significant within-group findings for each arm of Study 3. In short: while further research would be needed to substantiate the superiority of the active protocol in Study 3, as well as possible adjuvancy between the mantras *om* and *sa ta ma na,* the promising findings of Study 3 would not preclude the judicious application of either the active or the comparison protocol as interventions to remediate impaired attention due to adult ADHD.

6.4 Conclusion

The present dissertation yielded novel evidence about whether and why meditation may have therapeutic potential in cases of stroke or ADHD, particularly in consideration of meditation’s meaningful aspects. The similarities and differences between each mantra condition in this dissertation could be considered interrogative of Fox et al.’s (2016) characterization of mantra in meditation as a “single salient percept” (Fox et al., 2016, p. 220)—by which “attention is more easily sustained and distractors more easily ignored than without the mantra…” (Fox et al., 2016, p. 220). To build on the findings of this dissertation, future research in adults with impaired attention due to stroke or ADHD should include mixed-methods investigation of possible associations between 1) meaning- or salience-related variables of mantra meditation (e.g., ascribed meaning; complexity of enunciation); 2) neurophysiological and behavioral indices of attention; and 3) functional outcomes.

APPENDICES

APPENDIX 1

Study 2 Supplemental Data

		Subject 1		Subject 2		Subject 3	
	Phase:	A	B	A	B	A	B
	Total number of days in phase:	2	9	2	9	2	9
	Total number of in-phase datapoints for analysis:	6	8	3	8	3	8
	Mean:	5	5.5	10	2.1	2.7	3.6
	Median:	5	5	9	2.5	3	3.5
	Range:	3 – 7	4 – 7	9 – 12	0 – 4	2 – 3	2 – 7
Stability envelope (80% of data points within ±25% of median):	Envelope value:	1.25		2.25		0.75	
	Envelope range:	3.75–6.25	3.75–6.25	6.75 – 11.25	0.25–2.75	2.25–3.75	2.75–4.25
	Threshold:	4.8	6.4	2.4	6.4	2.4	6.4

Appendix 1 Note. Phases were sequenced according to the ABC letter notation system, with one baseline phase A and one intervention phase B for each subject. Each subject had an identical number of days in each phase. The number of datapoints in Phase A represented data from Days 1 – 2 and differed across subjects because stability on the Sustained Attention to Response Test (SART) was achieved at different rates. Each subject had an identical number of datapoints in Phase B, which represented data from Days 4 – 11. Mean, median, and range of SART scores per phase are shown for each subject, along with stability envelope parameters. Rounding the stability threshold down to the nearest whole number value yielded the number of in-envelope datapoints required to show stability had been achieved in a given phase.

APPENDIX 2

Study 3 Debriefing Form

MEDITATION TO IMPROVE ATTENTION IN SUBJECTS WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER: A RANDOMIZED CONTROLLED TRIAL

The research you participated in was an experimental design, where the independent variable was meditation condition (active versus control).

Each meditation condition was designed to elicit different attentional engagement (i.e., different than the other condition).

The dependent variable was sustained attention, operationalized as score on computerized tests of sustained attention (i.e., the Sustained Attention to Response Task (SART) and the Conjunctive Continuous Performance Test-Visual (CCPT-V)).

This study used a convenience sampling method. The hypothesis was that active meditation would lead to significantly more change on the SART than the control meditation.

Here are citations for 2 articles that informed the design of this study:

Newberg, A.B., Wintering, N., Khalsa, D.S., Roggenkamp, H., & Waldman, M.R. (2010). Meditation effects on cognitive function and cerebral blood flow in subjects with memory loss: a preliminary study. *Journal of Alzheimer's Disease, 20*, 517–526. DOI 10.3233/JAD-2010-1391

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PEER REVIEWED PUBLICATIONS

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Salmon-Powell, E., Sawaki, L., Carrico, C., Chelette, K.C., Nichols, L., Salyers, E., Reddy, L., & Sawaki, L. (2015, October). *Optimal timing for combined neuromodulation techniques to enhance motor training in chronic stroke with severe motor deficit* [Poster]. American Society for Neurorehabilitation Annual Meeting, Chicago, IL.

Carrico, C., Sawaki, L., Chelette, K.C., Salmon-Powell, E., Nichols, L., Salyers, E., & Sawaki, L. (2015, October). *Sensory-driven motor recovery in poorly recovered subacute stroke patients* [Poster]. American Society for Neurorehabilitation Annual Meeting, Chicago, IL.

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Salyers, E., Sawaki, L., Powell, E., Carrico, C., Korupolu, R., & Sawaki, L. (2015, March). *Modulation of spinal excitability through transvertebral direct current stimulation in subjects with motor incomplete spinal cord injury* [Poster]. 10th Annual CCTS Spring Conference, University of Kentucky Center for Clinical and Translational Science, Lexington, KY.

Carrico, C., Sawaki, L., Powell, E., Chelette, K., Nichols, L., Reddy, L., Salyers, E., & Sawaki, L. (2015, March). *Transcranial direct current stimulation combined with*

peripheral nerve stimulation to aid in upper extremity motor recovery after stroke: Preliminary findings from an ongoing study [Poster]. 10th Annual CCTS Spring Conference, University of Kentucky Center for Clinical and Translational Science, Lexington, KY.

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Salmon, E., Sawaki, L., Nichols, L., Carrico, C., Reddy, L., Salles, S., & Sawaki, L. (2014, May). *Enhancing upper extremity motor recovery with brain stimulation in spinal cord injury: Pilot data* [Poster]. 26th Annual Physical Medicine and Rehabilitation Research Day; University of Kentucky College of Medicine, Lexington, KY.

Salyers, E., Sawaki, L., Chelette, K., Carrico, C., Nichols, L., Henzman, C., & Sawaki, L. (2014, April). *Dose-response relationship between peripheral nerve stimulation and upper extremity motor training in chronic stroke* [Poster]. 2014 National Conference on Undergraduate Research; University of Kentucky, Lexington, KY.

Chelette, K.C., Sawaki, L., Lee, K., Carrico, C., Salles, S., & Sawaki, L. (2013, October). *Transcranial direct current stimulation to aid motor recovery following incomplete spinal cord injury* [Poster]. 2013 American Congress of Rehabilitation Medicine (ACRM) Annual Conference, Orlando, FL.

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Chelette, K., Sawaki, L., Carrico, C., Nichols, L., & Sawaki, L. (2013, May). *Transcranial direct current stimulation for motor recovery from severe post-*

stroke hemiparesis: Early results from an ongoing clinical trial [Poster]. 25th Annual Physical Medicine and Rehabilitation Research Day; University of Kentucky College of Medicine, Lexington, KY.

Carrico, C., Sawaki, L., Chelette, K., Nichols, L., & Sawaki, L. (2013, May). *Peripheral nerve stimulation paired with constraint-induced therapy to enhance post-stroke upper extremity motor performance* [Poster]. 25th Annual Physical Medicine and Rehabilitation Research Day; University of Kentucky College of Medicine, Lexington, KY.

Gundu, G., Sawaki, L., Chelette, K.C., Carrico, C., & Sawaki, L. (2013, May). *Modulating pain in complex regional pain syndrome with transcranial direct current stimulation: Early results from an ongoing study* [Oral Presentation]. 25th Annual Physical Medicine and Rehabilitation Research Day; University of Kentucky College of Medicine, Lexington, KY.

Salyers, E., Sawaki, L., Chelette, K., Carrico, C., Nichols, L., Henzman, C., & Sawaki, L. (2013, April). *Peripheral nerve stimulation dose-response relationship in chronic stroke: Early results from an ongoing trial* [Poster]. 8th Annual CCTS Spring Conference, University of Kentucky Center for Clinical and Translational Science, Lexington, KY.

Carrico, C., Sawaki, L., Chelette, K., Nichols, L., & Sawaki, L. (2013, February). *Peripheral nerve stimulation paired with constraint-induced therapy to enhance post-stroke upper extremity motor performance* [Juried Poster]. American Heart Association International Stroke Conference 2013, Honolulu, HI.

Chelette, K.C., Sawaki, L., Carrico C., Nichols, L., & Sawaki, L. (2012, October). *Optimizing transcranial direct current stimulation for motor recovery from severe post-stroke hemiparesis: Early results from an ongoing clinical trial (Alternate title: Transcranial direct current stimulation for motor recovery from severe post-stroke hemiparesis: Early results from an ongoing clinical trial)* [1st Place Poster]. 2012 American Congress of Rehabilitation Medicine-American Society for Neurorehabilitation (ACRM-ASNR) Annual Conference, Vancouver, British Columbia, Canada.

Carrico, C.L., Sawaki, L., Chelette, K.C., Nichols, L.R., & Sawaki, L. (2012, September). *Nerve stimulation and modified constraint-induced therapy to enhance post-stroke neuroplasticity and motor recovery: A pilot study* [Poster]. Kentucky Appalachian Rural Rehabilitation Network 4th Annual Conference, Richmond, KY.

Gundu, G., Sawaki, L., Carrico, C., Chelette, K., Levay, E., & Sawaki, L. (2012, May). *Modulating pain in complex regional pain syndrome with transcranial direct current stimulation* [Oral Presentation]. University of Kentucky Department of

Physical Medicine and Rehabilitation 24th Annual PM&R Research Day, Lexington KY.

Jamil, T., Sawaki, L., Carrico, C.L., Nichols, L.R., Chelette, K.C., & Sawaki, L. (2012, May). *Improving motor function with peripheral nerve stimulation in severe hemiparesis: Preliminary results* [Poster]. University of Kentucky Department of Physical Medicine and Rehabilitation 24th Annual PM&R Research Day, Lexington KY.

Carrico, C.L., Sawaki, L., Chelette, K.C., Nichols, L.R., & Sawaki, L. (2012, May). *Nerve stimulation and modified constraint-induced therapy to enhance post-stroke neuroplasticity and motor recovery: A pilot study* [Poster]. University of Kentucky Department of Physical Medicine and Rehabilitation 24th Annual PM&R Research Day, Lexington KY.

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Chelette, K.C., Sawaki, L., Carrico, C.L., Nichols, L.R., & Sawaki, L. (2012, March). *Long-term cortical reorganization following stroke in a single subject with severe motor impairment* [Poster]. University of Kentucky's 7th Annual CCTS Spring Conference 2012: Appalachian Health Summit, Lexington, KY.

Carrico, C.L., Sawaki, L., Chelette, K.C., Nichols, L.R., & Sawaki, L. (2012, March). *Nerve stimulation and modified constraint-induced therapy to enhance post-stroke neuroplasticity and motor recovery: A pilot study* [Poster]. University of Kentucky's 7th Annual CCTS Spring Conference 2012: Appalachian Health Summit, Lexington, KY.

Chelette, K.C., Sawaki, L., Henzman, R.C., Carrico, C.L., Nichols, L.R., & Sawaki, L. (2011, May). *Dose-response peripheral nerve stimulation in poorly recovered stroke patients: Ongoing study* [Best Poster]. University of Kentucky Department of Physical Medicine and Rehabilitation 23rd Annual PM&R Research Day, Lexington KY.

Skubik-Peplaski, C., Nichols, L.R., Carrico, C.L., & Sawaki, L. (2011, April). *Creating evidence: Optimal interventions for clients with chronic stroke* [Short Course]. American Occupational Therapy Association 91st Annual Conference and Expo, Philadelphia, PA.

Henzman, R.C., Sawaki, L., Chelette, K.C., Carrico, C.L., Nichols, L.R., & Sawaki, L. (2011, April). *Dose-response peripheral nerve stimulation in poorly recovered stroke patients: Ongoing study* [Grand Rounds Poster]. 2011 Association of Academic Physiatrists Annual Meeting, Phoenix, AZ.

Madumbi, S., Sawaki, L., Chelette, K.C., Nichols, L.R., Henzman, R.C., Carrico, C.L., & Sawaki, L. (2011, April). *Non-invasive brain stimulation for improvement of motor function after severe stroke: Case study* [Poster]. 2011 Association of Academic Physiatrists Annual Meeting, Phoenix, AZ.

Skubik-Peplaski, C., Sawaki, L., Carrico, C.L., Nichols, L.R., & Sawaki, L. (2010, November). *Reaching for neuroplasticity: A tool to improve motor function after stroke* [Keynote Presentation]. Eastern Kentucky University Occupational Therapy and Science Research Day, Richmond, KY.

Skubik-Peplaski C., Nichols, L., & Carrico, C.L. (2010, September). *Creating evidence: Optimal interventions for clients with chronic stroke* [Short Course Presentation]. Kentucky Occupational Therapy Association Annual Conference, Carrolton, KY.

Shordike, A., & Carrico, C.L. (2010, May). *Oral histories of persons with disability: A collaboration of occupational therapists, persons living with disability, and oral historians* [Poster]. 15th Congress of the World Federation of Occupational Therapists, Santiago, Chile.

Nichols, L., & Carrico, C.L. (2009, September). *Current evidence for outpatient neurorehabilitation supporting functional return after stroke* [Short Course Presentation]. Kentucky Occupational Therapy Association Annual Conference, Prestonsburg, KY.

Shordike, A., & Carrico, C.L. (2008, October). *Living with difference: Oral histories of life and disability in Kentucky* [Short Course Presentation]. Society for the Study of Occupation: USA, 7th Annual Research Conference, Fort Lauderdale, FL.

Carrico, C.L. (2007, April). *The use of narrative by individuals with developmental disability to structure subjective experience* [Short Course Presentation]. Eastern Kentucky University Occupational Therapy and Science Research Day, Richmond, KY.

Carrico, C.L. (2007, April). *Living with difference: Oral histories of life and disability in Kentucky* [Short Course Presentation]. Eastern Kentucky University Occupational Therapy and Science Research Day, Richmond KY.