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Mindfulness And Cognitive Aging

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MINDFULNESS AND COGNITIVE AGING

by

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DEDICATION

For my very dear friend and mentor, William "Pat" Bennett, who is no longer with us but will always be cherished in my memory. For my first meditation teacher and most excellent mentor, William Mikulas, whose lessons continue to unfold with time. And for my soul mate and husband, Philip: a constant source of unconditional love!

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ABSTRACT

Mindfulness meditation involves the cultivation of a focused, pre-conceptual consciousness that enables increased present-centered awareness of internal states, cognitive processes, and external stimuli (Mikulas, 2011; Kornfield, 2010). Studies suggest that mindfulness practice affects the brain structures and cognitive processes related to fluid intelligence, and may affect fluid intelligence itself among highly experienced practitioners (e.g., Gard, Taquet, et al., 2014; Lazar et al., 2005; Ritskes et al., 2003). Fluid intelligence includes higher-order reasoning and problem-solving abilities that are independent of cultural and environmental influences. These abilities peak in young adulthood, then begin to decay (Cattell, 1987; Goldberg, 2005).

The current study explored the effect of mindfulness on age-related cognitive decline. In a multiple linear regression analysis and in a series of hierarchical regressions, the relationships of mindfulness experience, trait mindfulness, age and fluid abilities were examined in a group of adults ages 18-75. Findings indicate a significant positive relationship between mindfulness experience and fluid intelligence that was present after key factors known to influence fluid abilities were controlled. Although the effect size of this relationship was modest, it was detectible despite the relatively low experience-level of participants. Because fluid intelligence is related to real-world success, even small improvements may have practical significance. In addition, mindfulness is an accessible, cost-effective intervention with other benefits that amplify its value. However, future longitudinal research will be necessary to establish a causal link.

Although mindfulness experience was related to fluid intelligence, it did not moderate the relationship of age and fluid intelligence. Trait mindfulness had no unique significant relationship to fluid intelligence in this study and played no moderating role.

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List of Abbreviations

ABT .... Acceptance-Based Behavior Therapy

ACC .... Anterior Cingulate Cortex

ADMR .... Average Daily Metabolic Rate

BOLD .... Blood Oxygenation Level-Dependent

BQ .... Baecke Questionnaire for the Evaluation of Habitual Physical Activity

CFIT .... Cattell Test of Fluid Intelligence/Culture Fair Intelligence Test

DBT .... Dialectical Behavior Therapy

DEMEQ .... Demographics, Education, and Mindfulness Experience Questionnaire

DLPFC .... Dorsolateral Prefrontal Cortex

DIPS .... Distributed Intelligent Processing System

DMN .... Default Mode Network

DMPFC .... Dorsomedial Prefrontal Cortex

DTI .... Diffusion Tensor Imaging

EBCT .... Exposure-Based Cognitive Therapy

EEG .... Electroencephalographs

ERN .... Error-Related Negativity

FA .... Focused Attention Meditation

FFMQ .... Five Facet Mindfulness Questionnaire

fMRI .... Functional Magnetic Resonance Imaging

Gc .... Crystallized Intelligence

Gf .... Fluid Intelligence

KIMS .... Kentucky Inventory of Mindfulness Skills

LT MM Hours .... Lifetime Hours of Mindfulness Meditation Experience

MAAS .... Mindful Attention Awareness Scale

MAGT .... Mindfulness and Acceptance-Based Group Therapy

MAPs .... Mindful Awareness Practices

MBAT .... Mindfulness-Based Art Therapy

MBCT .... Mindfulness-Based Cognitive Therapy

MB-EAT .... Mindfulness-Based Eating Awareness

MBRE .... Mindfulness-Based Relationship Enhancement

MBRP .... Mindfulness-Based Relapse Prevention

MBSR .... Mindfulness Based Stress Reduction

MC .... Military Control Group

MiCBT .... Mindfulness-Integrated Cognitive Behavioral Therapy

MMFT .... Mindfulness-Based Mind Fitness Training

MMFT .... Mindfulness-Based Mind Fitness Training

MORE .... Mindfulness Oriented Recovery Enhancement

MRI .... Magnetic Resonance Imaging

MT .... Mindfulness Training Group

OM .... Open Monitoring Meditation

PFC .... Prefrontal Cortex

PSS .... Perceived Stress Scale

TAU .... Treatment As Usual

TMS .... Toronto Mindfulness Scale

VBM .... Voxel-based morphometry

WM .... Working Memory

CHAPTER 1

INTRODUCTION

The psychological literature on mindfulness has burgeoned over the last two decades (Chiesa & Serretti, 2011; 2014; Chiesa, Calati, & Serretti, 2011; Davis & Hayes, 2011; de Vibe, Bjørndal, Tipton, Hammerstrøm, & Kowalski, 2012; Fjorback, Arendt, Ornbol, Fink, & Walach, 2011; Gard, Holzel, & Lazar, 2014; Keng, Smoski, & Robins, 2011; Khoury et al., 2013; Newberg et al., 2014; Sedlmeier et al., 2012; Tang & Posner, 2013). Empirical investigation has primarily centered on the application of methods adopted from Eastern spiritual traditions where they have been practiced for centuries to promote spiritual attainments. These practices have been effectively applied by clinicians to the reduction of stress, the management of pain, and the treatment of psychological disorders (Baer, 2003; Bohlmeijer, Prenger, Taal, & Cuijpers, 2010; Chiesa et al., 2011; 2014). Empirical literature on mindfulness-based methods also indicates their promise for improving parenting, enhancing relationships, fostering the psychological and social development of children and youth, and reducing prejudice (Barnes, Brown, Krusemark, Campbell, & Rogge, 2007; Rutledge & Abell, 2005; Singh et al., 2006; Zoogman, Goldberg, Hoyt, & Miller, 2014). And, perhaps not surprisingly, these Eastern-derived mindfulness practices have been studied as they relate to self-actualization, subjective wellbeing and spiritual growth (Carmody, Reed, Kristeller, & Merriman, 2008; Greeson et al., 2010; Murphy & Donovan, 2004).

Most recently, developments in neuroscientific research have led to the emergence of a new field of inquiry, mindfulness neuroscience (Tang & Posner, 2013). This rapidly growing, interdisciplinary field employs neuroimaging techniques, behavioral tests, and psychological measures to better understand the underlying mechanisms of mindfulness (Dickenson, Berkman, Arch, & Lieberman, 2013; Farb, Segal, & Anderson, 2013; Farb et al., 2007; Gard, Holzel, & Lazar, 2014; Goldin & Gross, 2010; Prakash, De Leon, Klatt, Malarkey, & Patterson, 2013; Teper & Inzlicht, 2013).

The literature on cognitive aging has also enjoyed heightened study, both due to its added relevance as life expectancy increases and the "baby boomer" generation ages, and as a result of increasing technological sophistication in measuring and amending the effects of age-related decline (Daffner, 2010; Drag & Bieliauskas, 2010; Eyler, Sherzai, Kaup, & Jeste, 2010; Meunier, Stamatakis, & Tyler, 2014). Fluid abilities, which include abstract reasoning and the capacity to effectively engage novel situations, are among the earliest and the most profoundly impacted in the process of normal cognitive aging (Nisbett et al., 2012; Perfetti, Tesse, Varanese, Saggino, & Onofrj, 2011; Raz, Gunning-Dixon, Head, Dupuis, & Acker, 1998). With the exception of recent work by Gard, Taquet, et al. (2014), the impact of mindfulness on fluid abilities and age-related change has received little attention. However, findings from a number of cognitive and neurological studies point toward the potential for mindfulness practices to ameliorate aging's detrimental effects (Allen et al., 2012; Gard, Holzel, & Lazar, 2014; Ivanovski & Malhi, 2007; Lazar et al., 2005; Mrazek, Franklin, Phillipe, Baird, & Schooler, 2013; Prakash et al., 2013; Ritskes, Ritkes-Hoitinga, Stodkilde-Jorgensen, Baerentsen, &

Hartman, 2003; Teper & Inzlicht, 2013). The current study sought to further increase our understanding of the relationship of mindfulness and fluid intelligence (Cattell, 1963; 1987) in order to facilitate the development of more effective interventions to prevent or mitigate the detrimental effects of age-related cognitive change.

In the remainder of this introduction, I will do the following: First, I will review the literature on cognitive aging with particular attention to the area of fluid intelligence; second, I will define mindfulness and review the relevant psychological literature; finally, I will offer a summary and propose three research questions based on the literature reviewed.

Cognitive Aging

Normal aging is associated with a variety of cognitive declines, including loss of neural structure, decreased cognitive functioning, and an overall slowing of mental operations and sensory processes (Albinet, Boucard, Bouquet, & Audiffren, 2012; De Chastelaine, Wang, Minton, Muftuler, & Rugg, 2011; Persson et al., 2006). Age-related cognitive deficits emerge due to loss of nerve cells diffusely within the brain, loss of cells in specific regions, and changes in the physiological mechanisms that modulate brain function. Both gray and white matter degenerate, resulting in decreased functional connectivity in a number of brain regions (Drag & Bieliauskas, 2010; Meunier et al., 2013).

In terms of brain regions affected by age-related change, of specific note is the decline in functions relying on the frontal lobes, particularly those functions involving prefrontal cortex circuitry (Braw, Aviram, Bloch, & Levkovitz, 2011; Cabeza, Nyberg, & Parks, 2005; Kane & Engle, 2002; Meunier et al., 2013; van Gerven, van Boxtel, Meijer, Willems, & Jolles, 2007). Most attentional processes are reliant on the prefrontal cortex (PFC), but other key functions depend on this circuitry as well. These include executive functions and working memory capacity, which are widely regarded as underpinnings of the higher order construct of fluid intelligence (Cabeza et al., 2005; Cattell, 1963; 1987; Cornoldi, Bassani, Berto, & Mammerella, 2007; Engle, 2002; Goldberg, 2005; Horn, 1967; Jensen, 1980; Van Gerven et al., 2007).

Attention is a complex construct so foundational to cognitive performance that essentially all cognitive processes depend upon it in some form (McDowd & Shaw, 2000). However, not all forms of attention are equally affected in cognitive aging. When presented with tasks that require selection of relevant stimuli, older adults show relatively preserved performance, although they are slower than young adults. Their performance is also not substantially impaired by distraction (Glisky, 2007). However, significant impairments are demonstrated on tasks that require dividing or switching of attention among multiple inputs or tasks (Verhaeghen, Steitz, Sliwinski, & Cerella, 2003). There is evidence that these deficits may be reduced, however, by extensive training (O'Brien, Edwards, Maxfield, Peronto, Williams, & Lister, 2013) and by aerobic exercise (Williams & Kemper, 2010).

Working memory involves the ability to process information while maintaining access to intermediate information, goals, and strategies (Salthouse, 1994). It has been hypothesized as the primary source of many age-related cognitive deficits. A number of theories of cognitive aging and working memory have been advanced and much of the research on working memory deficits in aging has focused on testing these theories.

Baddeley (2002) proposed an early and still dominant model of working memory composed of *verbal*, *visuospatial*, and *episodic* memory subsystems coordinated by an *executive* or attentional control, the role of which has recently been expanded to cover a broader range of processes. Cognitive aging declines in working memory may arise in any of these subsystems or in the central executive.

A model put forth by Craik and Byrd (1982) posits that working memory impairments arise from reduced attentional resources. Attentional resources are primarily reduced by tasks with high demands (Craik & Byrd, 1982; Craik, 1986). Working memory tasks involve divided attention and are thus more likely to strain the limited attentional resources of older adults. Lack of a clear operational definition has limited empirical support for this theory.

Salthouse (1996) postulated that slowing of the speed with which older adults process information accounts for the majority of deficits in working memory, as well as other processing tasks. Although empirical findings support the broad effects of slowed processing speed on a number of cognitive tasks (Charlton et al., 2008; Finkel, Reynolds, McArdle, & Pedersen, 2007; Levitt, Fugelsang, & Crossley, 2006), other researchers (Park et al., 1996; Poll et al., 2013) have argued that working memory and processing speed contribute independently to higher-level cognition.

Hasher and colleagues (Hasher, Tonev, Lustig, & Zacks, 2001; Hasher & Zacks, 1988; Hasher, Zacks & May, 1999; Lustig, May & Hasher, 2001) have suggested that age-related cognitive deficits can be accounted for by a lack of inhibitory control. Deficits in the ability to inhibit irrelevant information in working memory result in a reduction of its capacity, displacing or impeding the availability of relevant information.

Research support for this theory is mixed, perhaps resulting from different or task-specific forms of inhibition. Van Gerven and colleagues (2007) found, for example, that inhibition plays a minor role in relatively "passive" or simple working memory tasks, but plays a major role in relatively "active" or complex tasks.

Researchers have examined these theories singly and in combination or in contrast to one another. Cornoldi and colleagues (2007) found that older adults produced more errors due to failure to inhibit intrusions of already activated information. However, both young and older adults' visuospatial working memory was impaired by the presence of activated irrelevant information, the reduction of available resources, and task constraints. Verhaeghen and Hoyer (2007) found differential age-related effects in focus-switching, but not in task-switching, indicating that working memory may encompass distinct processes related to each.

As noted, theorists have more recently expanded the role of the central executive construct to cover a range of processes (Burzynska et al., 2012; Banich, 2009; Raz & Rodrigue, 2006). These higher-level functions organize lower-level cognitive processes in order to regulate and verify behavior, thus permitting adaptation to continuous environmental change (Drag & Bieliauskas, 2010). In this new view, working memory and executive functioning operate together to manage cognitive resources (Kray, Eber, & Lindenberger, 2004), a process generally accompanied by conscious awareness.

Recent approaches to the study of executive functions have emphasized their cognitively multifaceted nature. Heyder, Suchan, and Daum (2004) proposed subcomponents thought to represent the most elementary features of executive functioning, *inhibition* and *task management,* and the related functions of *multitasking* and *set shifting.* Multitasking requires the division of attention in order to accomplish the performance and coordination of more than one task at a time. Set shifting requires the flexible shift of attention and response preparation from one set of stimulus-response rules to another.

Using a latent variable approach, Miyake and colleagues (2000) applied confirmatory factor analysis to data collected from 137 college students on a set of tasks frequently used to assess executive functioning. Based on this factor analysis, they postulated three separate but highly correlated executive functions: (a) mental set shifting, (b) information updating and monitoring, and (c) inhibition of prepotent responses (Miyake et al., 2000). Miyake and Friedman (2012) have reported refinements to their theory based on continuing research, largely from their longitudinal study of monozygotic and dizygotic twins (see also Friedman et al., 2008). They draw four conclusions regarding individual differences in executive functions based on their data: (a) they represent a unified construct (i.e., executive functioning) but are also separable, (b) they are largely heritable but not immutable, (c) they have both clinical and societal relevance, and (d) they are fairly stable throughout development.

In a model similar to that of Miyake et al. (2000; 2012), Unsworth et al. (2009) used a latent variable approach to measure four postulated executive functions: (a) the ability to maintain information in an active state (*Working Memory [WM])*, (b) the ability to implement a non-dominant response while suppressing a habitual response (*Response Inhibition)*, (c) the ability to produce unique examples from memory (*Fluency)*, and (d) the ability to sustain attention on a task (*Vigilance)*.

Executive functions have long been regarded as dependent on the frontal lobes, which are the cortical areas last to mature in children and first to be impaired by cognitive aging (Baddeley, 2002). More recently, systems views have been advanced, although the PFC is still considered of primary importance (Drag & Bieliauska, 2010). One systems view has been put forward by Heyder and colleagues (2004). They posit that cortico-subcortical circuits connecting the PFC, the anterior cingulate cortex (ACC), the basal ganglia, and the cerebellum via the thalamus are the neuroanatomical substrates of executive functioning. The authors report evidence for subtle differences between brain regions and related cognitive mechanisms. The PFC is associated with the inhibition of habitual overlearned responses, while the basal ganglia are involved in both the inhibition of habitual and of newly implemented response tendencies. The role of the PFC in task management and multitasking is well established, while the basal ganglia may be related to rapid processing of sensory input and motor demands. The role of the PFC in set shifting is particularly critical under conditions of high working memory load, while the role of the basal ganglia is dependent on task difficulty.

Banich (2009) proposed a theory of neurological mechanisms underlying executive functioning based on functional magnetic resonance imaging (fMRI) studies with the Stroop task. The Stroop task requires participants to name the color in which words are presented whose meaning relates to a color other than the typeface color. For example, they may be asked to name the color of the word RED presented in blue typeface (Stroop, 1935). In Banich's model, a temporal cascade of processes is posited that are executed in discrete "way stations" within the PFC. Posterior regions of the dorsolateral PFC (DLPFC) are invoked when presented with hard to ignore task-irrelevant information. From the information with which it is presented, the mid-DLPFC selects those representations that are identified as task-relevant. Posterior sections of the dorsal ACC are then involved with late-state aspects of selection. Finally, anterior portions of the dorsal ACC are involved in processes associated with response evaluation. The degree to which each of these mechanisms is invoked is contingent upon how successfully control was exercised at earlier way stations. Older adults show less DLPFC activity but increased ACC activity on executive tasks, a finding which is consistent with the cascade-of-control model (Milham et al., 2002).

Over the past two decades, increasing consideration has been given to deficits in executive functioning as a primary contributor to cognitive aging (Drag & Bieliauskas, 2010; Glisky, 2007; Turner & Spreng, 2012). The degree and nature of this association are dependent on the way in which executive functions are modeled. Treitz, Heyder, and Daum (2007), for example, found age-related deficits in response inhibition and the ability to divide attention, which showed sharp declines after age 60. However, verbal fluency, reasoning, and strategic memory processing remained intact.

Changes in prefrontal integrity are associated with decreases in executive functioning, and are a well-recognized accompaniment of cognitive aging. This relationship is the basis for the frontal hypothesis of aging, which ascribes a causal role to prefrontal decline (West, 1996). Increasingly, evidence supports the diversity of executive functions. Most of these show dependence on the PFC, which is itself a diverse structure with far-reaching connectivity to other areas of the brain. For regions associated with executive functioning, Burzynska and colleagues (2012) found that increased PFC thickness was associated with stronger performance on executive functioning tasks, especially for older adults. Turner and Spreng (2012) looked at the performance of younger and older adults on tasks associated with two executive functions: (a) updating and maintaining information in working memory, and (b) inhibiting dominant responses. They found that for the task related to working memory, older adults showed increased bilateral recruitment of the DLPFC relative to younger adults, a finding that may indicate compensatory activity (Eyler et al., 2010). Compared with young participants, older adults also showed greater activity in supplementary motor areas, which the researchers theorize reflects greater monitoring demands. Age-related activation during the response inhibition task was detected in the right inferior frontal gyrus and supplementary motor area.

The degree and nature of the relationships of working memory and executive functioning to fluid intelligence has given rise to an expanding body of research. A number of studies have examined the link between working memory and fluid intelligence. Although more sparse, a body of research has also found executive functioning to be related to fluid intelligence.

Researchers have demonstrated a strong relationship between working memory capacity and psychometric intelligence, most notably fluid abilities (Ashton, Lee, & Vernon 2005; Blair, 2006; Colom, Rebolla, Palacios, Juan-Espinosa, & Kyllonen, 2004; Engle, Tuholski, Laughlin, & Conway, 1999; Fukuda, Vogel, Mayr, & Awh, 2010; Salthouse & Pink, 2008). Belsky (1990) describes fluid intelligence (Cattell, 1963) as "on-the-spot reasoning ability," (p. 125). It comprises a set of skills that are independent of experience. Crystallized intelligence, on the other hand, includes the collection of knowledge a person has acquired through experiences and education (Cattell, 1963; 1987;

VanderZanden, Crandell, & Crandell, 2007). Working memory capacity scores are highly correlated with reasoning abilities, reading comprehension, and scores on the SAT (Nisbett et al., 2012). Nevertheless, different definitions of working memory have resulted in disputes regarding the extent of its relationship to intelligence (Ackerman, Beier, & Boyle, 2005).

Salthouse and Pink (2008) were interested in learning why the relationship between working memory capacity and fluid intelligence has been a consistent research finding. One criticism of research showing links between these processes involves the similarity or overlap in the types of measures employed for each, potentially resulting in spuriously large associations. Salthouse and Pink sought to circumvent this problem by narrowly conceptualizing working memory. The researchers postulated that working memory may be related to fluid intelligence either due to the amount of information that must be kept simultaneously active during measured tasks, or the quality of processing from task demands. To tease apart these two explanations, the researchers subjected nearly 1,000 adults to a battery of cognitive and working memory tests, varying amount and volume of to-be-remembered information randomly across successive trials and tests. The researchers found a significant relationship between working memory and fluid intelligence, results which were consistent with prior findings. Furthermore, they found strong influences of fluid intelligence on the simplest versions and earliest trials of the task, indicating that the relationship is qualitative rather than quantitative.

Fukuda and colleagues (2010) conducted an exploratory factor analysis to examine a model that distinguishes the number of representations that can be maintained in working memory from the resolution precision of those representations. The researchers looked at multiple number-limited and resolution-limited measures of working memory and found support for two orthogonal factors. However, only the number-limited factor reliably contributed to the relationship between working memory and fluid intelligence (r = .66 versus r = -.05). They concluded that this relationship is mediated by the number of discrete representations that can be concurrently sustained in working memory, not by the clarity or precision of those representations.

In the past, efforts to increase intelligence scores have yielded disappointing results (Sternberg, 2008). Research showing that IQ is highly heritable, especially in later years, seemed to support the notion that such efforts were misguided (Plomin, DeFries, Knopik, & Neiderhiser, 2013). In fact, Cattell (1963; 1987) saw fluid intelligence as innate and the aspect of intelligence least amenable to training effects. Nevertheless, a number of recent studies have discovered improvements on measures of fluid intelligence in response to cognitive training. Most studies have employed working memory training, thus strengthening the evidence of a positive relationship between these constructs.

Jaeggi, Buschkuehl, Jonides, & Perrig (2008) were the first to offer evidence that fluid intelligence can be increased by training in working memory. The authors conducted a landmark study finding meaningful gains in fluid intelligence as a result of training on a demanding working memory task that was unrelated to the fluid intelligence measure. Effects occurred across the spectrum of abilities, but were larger at lower levels. In addition, the effects were dosage-dependent, with increased training leading to increased gains in fluid intelligence.

Since that time, a flurry of studies has expanded on this groundbreaking research. (Jaeggi, Buschkuehl, Shah & Jonides, 2014; Melby-Lervåg & Hulme, 2013; Redick et al., 2013; Shipstead, Redick, & Engle, 2012; Stepankova et al., 2014; Zinke et al., 2014). Melby-Lervåg and Hulme (2013) conducted a meta-analysis of 23 studies with 30 group comparisons selected for experimental rigor. The authors concluded that training programs produce short term improvements in working memory, with some evidence these effects may be maintained for visuospatial, but not for verbal, working memory. Transfer of training to other cognitive skills was not found. Sixteen group comparisons employed a measure of fluid intelligence in their outcomes. Of these 16 group comparisons, only four sampled healthy older adults (Borella, Carretti, Riboldi, & DeBeni, 2010; Dahlin, Nyberg, Backman, & Neely, 2008; Richmond, Morrison, Chein, & Olson, 2011; Schmiedek, Lovden, & Lindenberger, 2010). Three of these four achieved statistical significance post-training, with respective effect sizes of $d = 1.14$, $d = 0.06$, $d = 0.67$, and $d = 0.54$. Two studies including older adults collected follow-up data (Borella et al., 2010; Dahlin et al., 2008), but gains were nonsignificant.

In a recent study, Zinke and colleagues (2014) employed working memory training with a sample of older adults. Research participants were given three weeks of *visuospatial*, *verbal*, and *executive* working memory training and compared post-training to a no-treatment control group. Results were significant for all three training tasks on measures of fluid intelligence, and stable at 9-month follow-up. Largest gains on fluid intelligence measures were shown for the oldest participants, but these gains were not stable at follow-up. In general, lower performance prior to training predicted larger post-training gains. In another recent study, Stepankova and colleagues (2014) examined the effects of working memory training with older adults, finding significant results on nontrained measures and visuospatial skills. A dose-response effect was also evident such that frequency of training predicted greater skill gain. These studies support evidence of neuroplasticity of cognitive substrates in older adults.

Jaeggi and colleagues (2014) recently sought to address inconsistent findings regarding generalization of training gains to measures of fluid intelligence and other cognitive skills by considering the potential explanatory role of individual differences. The researchers assessed participants on need for cognition and implicit theories of intelligence prior to training in one of two working memory interventions. Participants' improvements were assessed by a battery of fluid intelligence measures. Both interventions improved fluid intelligence. The authors also found that motivation, pre-existing ability, need for cognition, and implicit theories about intelligence contributed to training success.

Evidence differs regarding the nature and degree of the relationship between executive functions and fluid intelligence (Friedman et al., 2006; Roca et al., 2014; Roca et al., 2012; Roca et al., 2010; Salthouse & Davis, 2006; Unsworth et al., 2009). Salthouse and Davis (2006), for example, analyzed data of 3,400 individuals, ages 5-95, with regard to cognitive abilities and neuropsychological variables. They found that, for variables assumed to reflect executive functioning, the individual differences in what these variables had in common showed nearly perfect overlap with the construct of fluid intelligence. In contrast, Friedman and colleagues (2006) found *information updating and monitoring* to be the only executive function in their model significantly related to fluid intelligence. Neither *shifting mental set* nor *inhibiting prepotent responses* was significantly related to fluid intelligence. Unsworth and colleagues (2009), however, found that the four executive functions in their multidimensional model, *WM, response* *inhibition, fluency,* and *vigilance,* were separate but related to one another; and each was significantly related to fluid intelligence.

A number of neuroimaging and EEG studies have provided support for the proposal that the neural basis of intelligence is a distributed brain network, or Distributed Intelligent Processing System (DIPS; de Rocha, Rocha, & Massad, 2011; Neubauer & Fink, 2009a). The neural efficiency hypothesis, a property of DIPS, posits that individuals with higher intelligence evidence more focused cortical activation during cognitive performance than individuals with lower intelligence (Neubauer & Fink, 2009b). This results in lower, more efficient total brain activation during processing among those with higher intelligence. Langer and colleagues (2012) implemented an investigation exploring the neurological correlates of fluid intelligence from a DIPS perspective. The researchers examined functional connectivity and fluid intelligence using graph theoretical methods. Specifically, they were interested in whether the brain functional network showed small-world characteristics, and whether these features were linked to performance on measures of fluid intelligence. A small-world network describes a graph in which most nodes are not neighbors of one another, but can be reached from every other node by a small number of steps. High clusters and short paths are characteristics of such a network. Langer and colleagues (2012) found that these small-world characteristics were strongly related to fluid intelligence such that the more intelligent the participant, the more their functional brain network resembled a small-world network. Furthermore, they identified the parietal cortex as the main network hub (Langer, Pedroni, Gianotti, Hanggi, Knoch, & Jancke, 2012). These findings lend support to the neural efficiency hypothesis of intelligence.

Cognitive aging summary. Normal aging is associated with a variety of cognitive declines, particularly in functions relying on PFC circuitry. Most attentional processes are reliant on the PFC, but other key functions depend on this circuitry as well. These include executive functions and working memory capacity, which are widely regarded as underpinnings of the higher order construct of fluid intelligence.

All cognitive processes depend upon attention in some form. Stimulus selection and distraction are not significantly impaired in older adults, although their performance is slower than that of younger adults. However, significant impairments are found on tasks that require dividing or switching attention among multiple inputs. These deficits may be reduced by extensive training on such tasks and by aerobic exercise.

Working memory involves the ability to process information while maintaining access to intermediate information, goals, and strategies. It is considered by some to be the primary source of many age-related cognitive deficits. A number of theories of cognitive aging and working memory have been advanced. Baddeley (2002) proposed that working memory is composed of verbal, visuospatial, and episodic memory subsystems coordinated by an executive control. Age-related declines may arise in any of these subsystems or in the central executive. Craik and Byrd (1982) posited that working memory impairments arise from reduced attentional resources. Salthouse (1996) postulated that slowing of processing speed accounts for the majority of deficits. Hasher and colleagues (2001) have suggested that age-related decline can be accounted for by a lack of inhibitory control.

The role of the central executive, which Baddeley considered an aspect of working memory, has been expanded to cover a range of processes that are in collaboration with working memory. In this new view, executive functions are higher-level processes that organize lower-level processes in order to permit adaptation to environmental change. Evidence suggests that executive functioning is a multifaceted construct. Depending on the way in which the construct is modeled, these facets may include: (a) inhibition; (b) task management; (c) multitasking; (d) mental set shifting; (e) maintaining, updating, and monitoring of information in working memory; (f) the ability to produce unique examples from memory (fluency); and (g) the ability to sustain attention on a task (vigilance).

Executive functions have long been thought to be dependent on the frontal lobes. Although the PFC is still considered primary, systems views have more recently been advanced. Heyder and colleagues (2004) posited that cortico-subcortical circuits connecting the PFC, the anterior cingulate cortex (ACC), the basal ganglia, and the cerebellum via the thalamus are the substrates of executive functioning. Banich (2009) proposed that executive functioning involves a temporal cascade of processes that are executed in discrete "way stations" within the PFC. The degree to which each mechanism is invoked is contingent upon how successfully control was exercised at earlier way stations.

Recent attention has focused on deficits in executive functioning as a primary contributor to cognitive aging. In the literature, the degree and nature of the association between executive decline and cognitive functioning is contingent on the way in which executive functions are modeled. Evidence suggests response inhibition and the ability to divide attention decline sharply after age 60, but verbal fluency, reasoning, and strategic memory processing remain intact. Changes in prefrontal integrity are associated with decreases in executive functioning, and are a well-recognized accompaniment of cognitive aging. Furthermore, increased cortical thickness has been associated with stronger performance on executive functioning tasks, especially for older adults.

Although both working memory and executive functioning are considered underpinnings of fluid intelligence, most of the research has focused on working memory. A positive relationship has been established between working memory capacity and fluid abilities, although differences in modeling of working memory have resulted in disputes regarding the extent of this relationship. Recent studies finding improvements on measures of fluid intelligence following working memory training have bolstered the evidence of their link. A few recent studies of working memory training in older adults have also found significant improvements in fluid intelligence.

Depending on how executive functions are modeled, evidence differs regarding the nature and degree of their relationship to fluid intelligence. Salthouse and Davis (2006) and Unsworth and colleagues (2009) each found a high degree of overlap, whereas Friedman and colleagues (2006) found only information updating and monitoring to be significantly related to fluid intelligence.

Recent research has examined the relationship between fluid intelligence and neural functional connectivity using graph theoretical methods. Small-world characteristics were strongly related to fluid intelligence such that the more intelligent the participant, the more their functional brain network resembled a small-world network characterized by high clusters and short paths. The parietal cortex was identified as the main network hub.

Mindfulness

Despite the recent popularity of mindfulness in the research literature, defining the construct continues to be a topic of debate (Awasthi, 2013; Davidson, 2010; Grossman, 2008; 2010; 2011). In the Buddhist tradition, mindfulness teacher Larry Rosenberg (2004) calls mindfulness a mirror that reflects what comes before it. Mikulas (2004) defines mindfulness as an expanded consciousness that is pre-conceptual. It includes awareness of mental and sensory contents and processes as they occur moment-to-moment. Brown and Ryan (2003), developers of the first self-report mindfulness scale, describe mindfulness as "the state of being attentive to and aware of what is taking place in the present." (p. 822).

Lutz, Slagter, Dunne, and Davidson (2008) have characterized meditation practices as primarily cultivating either *focused attention* (FA) or *open monitoring* (OM). These categories have traditionally been called *concentration* and *mindfulness* (Mikulas, 2011). Many mindfulness training centers initially emphasize the development of focused attention by attending to the sensations of breathing. However, this is not the "one-pointed" focus of strict concentration practices (Kornfield, 2010; Satchidananda, 1990). Because the sensations of breathing shift and change, mindfulness is already being cultivated during this initial phase (Goldstein. 2003). Once the mind can remain steady on the breath, training shifts its emphasis to the more refined cultivation of mindfulness, or open monitoring of the broader and more subtle contents of consciousness by observing them and allowing them to enter and exit awareness without judgment or reactiveness (Kabat-Zinn, 2005; Mikulas, 2004). In other mindfulness training centers, OM practices are taught from the beginning and concentration develops gradually along with mindfulness (Mikulas, 2011).

Mindfulness and psychological health. The majority of studies published in the scientific literature on mindfulness have looked at the clinical applications of mindfulness practices. One of the most widely researched and applied clinical programs is Mindfulness Based Stress Reduction (MBSR). MBSR is taught in an 8-week course developed by Jon Kabat-Zinn (1990). This program has been reported to reduce mood disturbance, alleviate a number of stress-related symptoms, and increase quality of life in patients with a diverse array of medical and psychological complaints (Bohlmeijer et al., 2010; Fjorback et al., 2011; Piet & Hougaard, 2011). MBSR has served as the foundation for several other clinical interventions. These include Mindfulness-Based Cognitive Therapy (MBCT; Ma & Teasdale, 2004) for prevention of depressive relapse, Mindfulness-Based Art Therapy (MBAT; Monti & Peterson, 2004) for stress management among cancer patients, Mindfulness-Based Eating Awareness (MB-EAT; Kristeller & Hallett, 1999) for treatment of binge eating disorder, Mindful Awareness Practices (MAPs; Zylowska et al., 2008) for ADHD, Exposure-Based Cognitive Therapy (EBCT; Kumar, Feldman, & Hayes, 2008) for depression, Mindfulness-Integrated Cognitive Behavioral Therapy (MiCBT; Cayoun, 2011) for mood and anxiety disorders, Mindfulness-Based Mind Fitness Training (MMFT; Stanley, Schaldach, Kiyonaga, & Jha, 2011) for deploying military personnel, and Mindfulness-Based Relationship Enhancement (MBRE; Carson, Carson, Gil, & Baucom, 2004) for relationship improvement among functional couples. Although not the sole or primary component, mindfulness has also been incorporated into other psychotherapy approaches with evidence of effectiveness: Dialectical Behavior Therapy (DBT) for borderline personality disorder (DBT; Linehan, 1993), Modified DBT for ADHD (Philipsen et al., 2007), Acceptance and Commitment Therapy (ACT; Hayes, 2002), Acceptance-Based Behavior Therapy (ABT; Roemer & Orsillo, 2007) for anxiety disorders, Mindfulness and Acceptance-Based Group Therapy (MAGT; Kocovski, Fleming, & Rector, 2009) for social anxiety disorder, and Mindfulness-Based Relapse Prevention (MBRP; Marlatt & Gordon, 1985) for substance-use disorders.

Over the past five years alone, 9 reviews and 11 meta-analyses have focused on the effectiveness of mindfulness-based interventions for psychological symptoms and clinical disorders in adults (Bohlmeijer et al., 2010; Chiesa & Serretti, 2010; 2011; 2014; Davis & Hayes, 2011; Cramer, Lauche, Paul & Dobos, 2012; deVibe et al., 2012; Eberth & Sedlmeier, 2012; Fjorback et al., 2011; Goyal et al., 2014; Greenberg & Harris, 2012; Hofmann, Sawyer, Witt, & Oh, 2010; Keng et al., 2011; Khanna & Greeson, 2013; Khoury et al., 2013; Klainin-Yobos, Cho, & Creedy, 2012; Piet & Hougaard, 2011; Sedlmeier et al., 2012; Shennan, Payne, & Fenlon, 2011; Wanden-Berghe, Sanz-Valero, & Wanden-Berghe, 2011). These will be reviewed briefly in the paragraphs that follow.

In a recent meta-analysis, Goyal et al. (2014) examined 47 randomized clinical trials of meditation programs designed to address psychological symptoms, stress, and well-being. Mindfulness meditation showed moderate effectiveness for anxiety, depression, and pain, with effect sizes ranging from 0.30 to 0.33 at 8 weeks and 0.22 to 0.33 at 3-6 month follow-up. The authors found low or insufficient evidence of effectiveness for stress/distress, mental health-related quality of life, positive mood, attention, substance abuse, eating habits, sleep, and weight issues. Mindfulness meditation was not found to be more effective than other active treatments (i.e., medication, exercise, or behavioral therapies).

A comprehensive meta-analysis of mindfulness-based intervention studies was conducted by Khoury and colleagues (2013). A total of 209 studies from published journals and dissertations were included in the analysis. The authors included all studies examining the pre-post or controlled effects of mindfulness-based therapy. Participant samples included individuals with psychological disorders, physical or medical conditions, and individuals with no clinical diagnosis. Analyses included meta-regression and clinical significance analysis. Follow-up data were included when available. Effect sizes were medium for both pre-post studies and wait-list controlled studies, with respective Hedges $g = 0.55$ and $g = 0.53$. When compared with other active treatments, including other active psychological treatments, effect sizes were more modest, with Hedges $g = 0.33$ and $g = 0.22$ respectively. In studies including follow-up, results were maintained. No differences were found between mindfulness-based therapies and traditional cognitive or behavioral therapies. Meta-regression results indicated the effect size of mindfulness-based interventions was positively moderated by mindfulness outcomes, treatment duration, and the mindfulness training of the therapist. Clinical outcomes for depression and anxiety indicated reductions to moderate, mild, or non-clinical levels at post-treatment, depending on the initial severity of symptoms.

The efficacy of mindfulness-based interventions for treatment of depressive symptoms in adults with psychiatric disorders was examined in a meta-analysis by Klainin-Yobas et al. (2012). Thirty-nine studies were included in the analysis. Both quasiexperimental and experimental studies were included. While most studies tested the efficacy of MBSR or MBCT, a number of other mindfulness-based interventions, or interventions with mindfulness as a major component, were also included. Effect sizes for between-group comparisons were calculated using 19 of the 39 studies. The average effect size across these 19 comparisons was $d = 0.53$. Within group comparisons produced effect sizes ranging from $d = 0.56$-2.09, with average $d = 0.60$. Effect sizes were not significantly associated with methodological quality of studies, but were related to length of intervention, with longer interventions yielding larger effects.

DeVibe et al. (2012) conducted a meta-analytic review of 31 randomized clinical trials using the protocols for MBSR only. Populations studied were both clinical and non-clinical and outcomes included psychological symptoms, health, quality of life, and social functioning. Hedges *g*-values were moderate and consistent, with $g = 0.53$ for mental health outcomes, $g = 0.50$ for personal development, and $g = 0.57$ for quality of life. Somatic health values were somewhat smaller, with $g = 0.31$. Outcomes were positively correlated with course attendance.

A meta-analysis looking at the use of mindfulness meditation and MBSR in nonclinical settings was performed by Eberth and Sedlmeier (2012). Criteria for the review included use of an inactive control group, inclusion of nonclinical adult participants, the use of psychological measures, and assessments taken some temporal distance from a meditation session. Variables assessed included cognitive performance, psychological symptoms, stress, emotion regulation, personality traits, self-concept, self-realization, and subjective well-being. Thirty-nine studies were included in the analysis. Averaged across all studies and dependent variables, the authors found an overall effect size of $r = .27$, or a medium effect. MBSR produced larger effects on psychological symptoms whereas studies of mindfulness meditation reported larger effects on variables associated with the concept of mindfulness. The authors note that MBSR effect sizes may be inflated by elements other than the mindfulness meditation component. In a related but broader meta-analytic review, Sedlmeier and colleagues (2012) looked at the effects of all forms of meditation on psychological variables in nonclinical groups. The meta-analysis included 163 studies. The overall effect size was $r = .28$, with larger effects for psychological variables and medium to small effects for cognitive measures.

Chiesa and Serretti (2011) conducted a systematic review and meta-analysis of MBCT for adults with psychiatric disorders. Sixteen controlled studies were included in the analysis. All but two employed a randomized controlled design. The authors found that MBCT in addition to usual care was significantly more effective than usual care alone in reducing depressive relapses in individuals with major depressive disorder with three or more prior depressive episodes. In addition, MBCT plus gradual withdrawal of maintenance antidepressant medication was as effective at reducing relapse at 1-year follow-up as continuation of maintenance antidepressants. They conclude that MBCT shows potential for the reduction of residual depressive symptoms in patients with major depression and for reducing anxiety symptoms in individuals with bipolar disorder, in remission, and in some anxiety disorders.

A meta-analytic review of MBCT by Piet and Hougaard (2011) used more restrictive selection criteria. Studies included in the analysis were randomized controlled trials of MBCT for prevention of relapse in adults with major depressive disorder, in remission, conducted according to the manual developed by Segal, Teasdale, Williams, and Gemar, (2002). Six studies were included in the analysis. Findings included a relative relapse/recurrence risk reduction of 34% compared to treatment as usual (TAU) or placebo controls. Risk reduction was 43% for individuals with three or more previous episodes.

Mindfulness practices have been used to treat the psychological distress that often accompanies serious or chronic medical conditions. Bohlmeijer and colleagues (2010) carried out a meta-analysis of eight randomized controlled studies of the effectiveness of MBSR on depression, anxiety, and psychological distress in adults with a variety of chronic medical diseases. Where data were available, they looked at both pre- to post-intervention change and follow-up effects. Statistically significant effects were found for all outcomes, with effect sizes ranging from small to medium.

Cramer et al. (2012) performed a systematic review and meta-analysis of three randomized controlled trials consisting of 327 participants with breast cancer. Interventions included MBSR and MBCT, and the primary outcome measures were psychological health and health-related quality of life. Compared with usual care, mindfulness-based interventions were more effective in reducing anxiety and depression.

Hofmann and colleagues (2010) conducted a meta-analysis of the effect of mindfulness based therapy on anxiety and depression in adults with a variety of medical and psychological disorders. Thirty-nine studies were included in the analysis. Most studies used MBSR, MBCT, or interventions modeled on these approaches. Both experimental and quasiexperimental studies were included in the analysis. Effect sizes for the overall sample were moderate, with Hedge's $g = 0.59$ for mood symptoms and Hedge's $g = 0.63$ for anxiety symptoms.

In addition to meta-analyses, a number of recent systematic reviews of mindfulness interventions have been conducted. Chiesa and Serretti (2010) systematically reviewed the controlled research on the effects of mindfulness, in both clinical and non-clinical populations, on psychological and physiological variables. They conclude that the evidence suggests the potential effectiveness of mindfulness in the treatment of depressive relapse in major depression, inter-episode anxiety in bipolar disorders, social phobia, substance abuse, chronic pain, and hypertension. In four lower-quality studies, mindfulness showed promise for persons with psoriasis, multiple sclerosis, and HIV. Eleven studies reviewed by Chiesa and Serretti (2010) looked at the effects of mindfulness, primarily MBSR, with healthy subjects. Most of these were non-randomized and included wait-list controls. Studies found significant reductions in stress levels, depression, anxiety, and rumination. Increases were found in interpersonal sensitivity, healthy coping, self-compassion, and spirituality.

Two systematic reviews examined the psychological effects of mindfulness in varied populations. Keng and colleagues (2011) reviewed empirical research investigating the effects of mindfulness on multiple indicators of psychological health. Studies of trait mindfulness and mindfulness meditation were included in the review. Both trait mindfulness, currently measured by self-report questionnaires, and mindfulness meditation were associated with a variety of indicators of psychological health. Increased trait mindfulness was also associated with increased sustained attention and persistence. Mindfulness meditation was negatively associated with reactivity to emotional stimuli.

Fjorback and colleagues (2011) performed a systematic review of randomized controlled trials using the standard protocols for MBSR and MBCT. Twenty-one articles were included in the review. In 18 studies, these interventions were more effective in improving mental health outcomes compared to TAU or a wait list control, and as effective as an active control condition in three studies. These 18 studies reported overall medium effect sizes.

Four systematic mindfulness reviews looked at mindfulness interventions applied for specific disorders or conditions. Wanden-Berghe and colleagues (2011) examined eight studies applying mindfulness interventions in the treatment of eating disorders. All studies reported statistically significant positive results. Quality varied across studies reviewed. Shennan and colleagues (2011) reviewed the empirical evidence for the use of mindfulness-based interventions in cancer care. Seventeen studies met criteria for the review. Studies reported statistically significant improvements in stress, depression, anxiety, sexual difficulties, immune function, and physiological arousal. Quality of studies varied.

Two reviews looked at the use of mindfulness practices in the treatment of substance use disorders. Chiesa and Serretti (2014) reviewed a total of 24 studies using mindfulness-based interventions. They conclude that available evidence suggests such interventions can reduce substance use to a significantly greater extent than wait-list controls, education support groups, and some specific control groups. They note the need for more experimental rigor and larger sample sizes. Khanna and Greeson (2013) conducted a narrative review of the use of mindfulness and yoga as complementary addiction therapies. Specific treatments included MBRE (Marlatt & Gordon, 1985), Mindfulness Oriented Recovery Enhancement (MORE; Garland, 2013), Mindfulness

Training for Smoking Cessation (Brewer et al., 2011), and Astanga Yoga. They conclude that these methods show promise, but additional research is needed.

Davis and Hayes (2011) performed a conceptual review of psychotherapy-related mindfulness research in order to clarify the benefits to the psychotherapy practitioner. The authors looked at both evidence for the application of mindfulness as a therapeutic intervention and research supporting its use as a tool for practitioner development. They conclude that mindfulness shows promise for increasing behaviors related to successful psychotherapy outcomes, both for practitioners and for clients. Mindfulness meditation practice was a stronger predictor of positive outcomes than was trait mindfulness.

Keng and colleagues (2011) also reviewed randomized controlled trials of four leading interventions with mindfulness as an important component. Decreased depression and anxiety were common outcomes reported for all four of these interventions. Additional outcomes included reductions in anger, decreased distress, increased life satisfaction, increased global functioning, improved social functioning, reductions in inpatient hospitalization, and improvements in quality of life. Some outcomes were more intervention-specific, generally as a function of the symptom or behavior targeted. MBSR decreased stress, mood disturbance, daily hassles, medical symptoms, fatigue, and rumination. It also decreased burnout, distraction, and the avoidance symptoms associated with PTSD. The authors note that for all four of these mindfulness-based interventions, dismantling and other controlled research is needed in order to determine the specific contribution of mindfulness to the outcomes reported.

Mindfulness and cognition. Although still in its infancy, the scientific investigation of the neurological and cognitive effects and constituents of mindfulness is growing rapidly (Tang & Posner, 2013). The majority of this review will focus on this mindfulness neuroscience research since it is of most relevance to the current study.

Although still poorly understood, the neurological correlates of mindfulness have increasingly been the subject of investigation. (Barnhofer et al., 2007; Davidson et al., 2003; Dickenson et al., 2013; Grant, Courtemanche, Duerden, Duncan, & Rainville, 2010; Holzel et al., 2010; Holzel et al., 2008; Holzel, Ott, Hempel, Hackl, Wolf, Stark, & Vaitl, 2007; Kang et al., 2013; Kasamatsu & Hirai, 1966; Lazar et al., 2005; Pagnoni, Cekic, & Guo, 2008; Prakash et al., 2013; Ritskes et al., 2003; Short et al., 2010; Taylor et al., 2013). This line of research has been facilitated by advancements in neuroimaging technology (Sedlmeier et al., 2012).

The development of electroencephalographs (EEG) enabled early meditation researchers to observe neural activity taking place in the living brain (Collura, 1993). In a classic and very early study of meditators, Kasamatsu and Hirai (1966) analyzed EEG wave patterns among 48 Zen teachers and their disciples in Japan, and compared them to a group of 22 subjects who had never studied meditation. Recordings were taken during a weeklong meditation retreat. Teachers and their most advanced students made a typical progression through four phases of brain-wave activity. The wave pattern correlated with the student's length of training and the Zen teacher's independent assessment of their proficiency. An interesting finding occurred when the brain wave activity of four Zen masters was compared to that of four controls in response to a series of repetitive click stimuli. When the clicks first occurred, both groups exhibited a blocking of alpha wave activity. The control subjects gradually habituated to the stimuli so that the alpha blocking no longer occurred. The Zen masters, however, showed no habituation to the clicks, and continued to exhibit blocking as long as the stimuli continued. The authors conclude this meditation practice appears to promote a serene, alert awareness that is consistently responsive to both external and internal stimuli.

Davidson et al., (2003) looked at brain and immune function in 41 participants who had completed an 8-week MBSR program in their workplace and compared their responses to those of a wait-list control group. EEG recordings were taken from 27 sites distributed across the scalp at baseline (pre-training) and upon completion of the course. Brain wave activity was recorded in response to a positive and a negative emotion induction. Participants also completed self-report measures of anxiety and positive affect. Significant left side frontal activation was recorded on EEGs of meditators compared with controls. Left side activation has been previously associated with positive affect. To investigate the effect of mindfulness training on immune function, participants were vaccinated with influenza vaccine at the completion of the 8-week program and antibody titers were examined at 3-5 and 8-9 weeks post intervention. Significant increases in antibody titers were found among meditators, and the level of left-side activation predicted the magnitude of antibody response to the vaccine. Self-report measures showed decreased anxiety, but significant increases in self-reported positive affect were not found. This study was the first to suggest that prefrontal asymmetries are modifiable by training. Left-side activation occurred among meditators in response to both positive and negative affect induction. This supports other research indicating this pattern is associated with more adaptive responses to negative events. Unlike the study by Kasamatsu and Hirai (1966) reported above, the subjects in this experiment were not engaged in meditation when EEG recordings were taken. This indicates that measures were reflecting more enduring, trait-like influences of mindfulness training rather than correlates of a meditative state.

In another study linking mindfulness and frontal asymmetry, Barnhofer et al. (2007) examined resting EEG activity before and after participation in an 8-week MBCT course. Individuals who had at least one prior episode of depression with suicidality were randomly assigned to receive MBCT or TAU. The TAU group displayed decreased relative left-frontal activation, while no such change was observed in the MBCT group. This suggests decreases in positive affective style among the group receiving TAU, whereas a more balanced pattern of activation was retained among those receiving the mindfulness intervention.

The development of fMRI, which uses blood flow to detect neural activity, has made it possible to measure quick and tiny metabolic changes that take place in the active brain. This more sophisticated technology provides both an anatomical view of the brain and a minute-to-minute recording of brain activity (Huettel, Song, & McCarthy, 2009). In a study using fMRI to scan the brains of 11 Zen practitioners engaged in meditation, Ritskes et al., (2003) found increased activity in the PFC. They found increased activity in the basal ganglia as well, which have also been implicated in higher cognition and executive functions (Brown, Schneider, & Lidsky, 1997; Ell, Helie, & Hutchinson, 2012). Simultaneously, the gyrus occipitalis superior (visual orientation) and the ACC (conscious activities directed by will or volition) became significantly less active.

Holzel et al. (2007) compared 15 vipassana meditators with 15 non-meditators, matched for age, sex, education, and handedness, using fMRI. Vipassana, sometimes also called *Insight* meditation, is a mindfulness practice derived from traditional Buddhist teachings. Meditators' mean practice history was 7.9 years for an average of 2 hours per day. In a block design, participants engaged in three tasks during neuroimaging: (a) a mindfulness of breathing condition in which breath sensations in the area below the nostrils were noticed; (b) a mental arithmetic condition; (c) and a mindfulness condition in which participants pushed a button each time they noticed a sensation when inhaling. For the mindfulness of breathing condition, meditators showed greater activation in the rostral ACC and the dorsomedial PFC (DMPFC) bilaterally in contrast to the arithmetic condition. Post-scanning self-report data indicated that meditators kept more continuous attention on the task, felt less bored, and encountered fewer difficulties with the task than control participants. The authors speculate that activation in the ACC may correspond to successful resolution of conflict in meditation. With regard to the DMPFC, which is commonly activated in emotional processing (Phan, Wager, Taylor, & Liberzon, 2002), Holzel and colleagues (2007) speculate that its activation may correspond to aspects of emotional processing, such as paying attention to and identifying emotions.

In another study employing fMRI, Short et al. (2010) also found activation in the ACC and PFC in meditators. Participants were 13 meditation practitioners from a variety of meditation traditions. All meditators showed activation in the DLPFC and the ACC. Long-term meditators showed significantly more consistent and sustained activation in these regions during meditation compared to short-term meditators. These regions are associated with sustained attention and attentional error monitoring. No corroborating self-report data were collected.

Dickenson et al. (2013) investigated the neural correlates of a brief mindfulness induction that emphasized the FA/breathing focused phase of training in novice meditators. During fMRI scans, meditators were compared to a group of control participants who attended to their thoughts in an unfocused way. Researchers hypothesized the meditators would show increased blood oxygenation level-dependent (BOLD) signals in regions associated with attention, such as frontal-parietal areas. Control participants were expected to show greater activation in the *default mode network* (DMN). The DMN is a set of brain regions active during the stream of spontaneous thoughts, memories, and cognitive processing that occurs in the waking restful state. Both hypotheses were confirmed. Relative to the control participants, meditators recruited an attention network consisting of the ACC, insula, and frontal-parietal regions, and showed decreased activation of the DMN. Neural activation in attention-related regions during meditation correlated with trait mindfulness as measured by the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2004), suggesting that trait mindfulness positively moderates this activation. As expected, DMN activity was greater in the unfocused, mind-wandering condition.

The DMN includes cortical regions of the medial prefrontal cortex (MPFC), posterior cingulate, angular gyrus, and left superior and middle frontal gyri, in addition to the subcortical hippocampus and parahippocampal gyrus (Raichle et al., 2001). Although its function is still poorly understood, the DMN is involved in the automatic flow of cognitive processing that is generally active during a resting state. It appears to be central to our sense of self (Buckner & Carroll, 2007). Decreased connectivity in these regions in older adults is a common finding (Mevel et al., 2013). Pagnoni and colleagues (2008) employed fMRI to look at neural activity in Zen awareness practitioners and control subjects engaged in a simplified meditation condition. The meditation period was interspersed with a lexical decision task. Zen practitioners, compared to matched controls, showed decreased duration of the neural response linked to conceptual processing in regions of the DMN. There was no difference in the behavioral performance of mindfulness practitioners and control subjects on the lexical decision task. This would suggest that awareness meditation may facilitate the ability to control or regulate the automatic flow of spontaneous cognitive processing.

Using fMRI and independent component analysis techniques, Taylor and colleagues (2013) looked at resting-state functional connectivity within the DMN in 13 experienced meditators and 11 beginner meditators. Experienced meditators had over 1,000 hours of Zen meditation. Beginners were novices given one week of meditation instruction and practice. Relative to beginners, experienced meditators had weaker functional connectivity in regions associated with self-referential emotional processing. This may also reflect reduced emotional autobiographical memory retrieval during rest. Experienced meditators also had increased connectivity between DMPFC and right inferior parietal lobule regions, possibly reflective of enhanced emotional resources and greater present-moment awareness. Prakash et al. (2013) also found increased DMN connectivity between the DMPFC and the precuneus in older adults that was positively related to trait mindfulness as measured by the MAAS (Brown & Ryan, 2004). These results suggest that both mindfulness experience and trait mindfulness may play neuroprotective roles.

A number of recent studies have observed structural changes in the brains of mindfulness practitioners. Grant et al. (2010) employed structural MRI to investigate the responses of 17 meditators and 18 controls participants to moderate pain. Meditators had significantly lower pain sensitivity than controls, and this reduced sensitivity was associated with thicker cortex in brain regions related to affect. These included the ACC, bilateral para-hippocampal gyrus, and anterior insula. Greater mindfulness experience was related to increased gray matter, suggesting a possible causal link.

Voxel-based morphometry (VBM) uses MRI data to extract gray matter volume information (Ashburner & Friston, 2000). Holzel and colleagues (2008) used VBM to investigate regional gray matter concentration in 20 mindfulness meditators and compared this data to that of 20 non-meditators matched for age, sex, education, and handedness (Holzel et al., 2008). Meditators had practiced an average of 8.6 years for 2 hours per day. Results indicated meditators had increased gray matter concentration in the left inferior temporal gyrus and the right hippocampus, regions involved in visceral awareness and the modulation of cortical arousal, responsiveness, and emotional processing. In the left inferior temporal gyrus, gray matter concentration was predicted by the amount of meditation training, suggesting a causal role of meditation training in gray matter concentration in that region.

Holzel et al. (2010) conducted a longitudinal MRI study to look at changes in amygdala gray matter density following an 8-week MBSR class. The amygdala has been implicated as an important brain structure in the stress response. Twenty-six healthy but stressed individuals reported their stress levels via the Perceived Stress Scale (PSS) following the mindfulness course. Reductions in perceived stress were positively correlated with decreases in gray matter density in the right basolateral amygdala. In addition to the effects of mindfulness practice, these findings suggest a link between psychological state variables and neuroplastic brain changes.

Lazar and colleagues found increased cortical thickness in the brains of experienced mindfulness meditators (Lazar et al., 2005). In 20 experienced Insight Meditation (i.e., mindfulness) practitioners, cortical thickness was measured using MRI. Participants had an average of 9.1 years of experience and practiced an average of 6.2 hours per week. Fifteen control participants with no meditation experience were also assessed. Meditation and control participants were matched for sex, age, and years of education. Results indicated significant increases in cortical thickness in the meditation practitioners in a sizeable region of the right anterior insula and the right middle and superior sulci of the PFC. A trend toward significance was observed in the left superior temporal gyrus and in the fundus of the central sulcus. A significant age by group interaction was observed for the right frontal region. Typical age-related thinning was observed in the control group, but not in the meditation group. In addition, thickness in these regions was associated with meditation experience. These findings suggest that mindfulness meditation may offset age-related cortical thinning.

Diffusion tensor imaging (DTI) also uses MRI data, assessing the integrity of anatomical connectivity in white rather than gray matter. Kang and colleagues (2013) mapped the cortical thickness of 46 experienced meditators and compared this to 46 matched meditation-naïve controls. Meditators were trained in an awareness meditation method called Brain Wave Vibration. This form of meditation emphasizes performing natural rhythmic physical movements while focusing attention on bodily sensations, emotions, and the movement of energy within the body (Bowden, Gaudry, An & Gruzelier, 2012). Compared to controls, meditators displayed significantly greater cortical thickness in anterior regions of the brain and significantly thinner cortex in the posterior regions of the brain. The relatively thicker regions seen in the brains of meditators are located in frontal and temporal areas and include the PFC, superior frontal cortex, temporal pole and the middle and inferior temporal cortices. Significantly thinner posterior areas include parietal and occipital regions, including the postcentral cortex, inferior parietal cortex, middle occipital cortex and posterior cingulate cortex. The inferior parietal cortex and the postcentral cortex are regions involved in self-referential processing. In addition, greater cortical thickness and higher fractional anisotrophy values were observed in the region adjacent to the MPFC. The authors note these findings may indicate enhanced executive control in meditators.

A rapidly growing body of research concerns the relationship of mindfulness practices and cognitive abilities. (Anderson, Lau, Segal, & Bishop, 2007; Chambers, Lo, & Allen, 2008; Chan & Woollacott, 2007; Gard, Holzel, & Lazar, 2014; Gard, Taquet, et al., 2014; Hodgins & Adair, 2010; Jha, Krompinger, & Baime, 2007; Jha, Kiyonaga, Wong, Gelfand, & Stanley, 2010; Josefsson & Broberg, 2011; Lutz et al., 2008; McHugh, Simpson, & Reed, 2010; Moore & Malinowski, 2009; Moynihan et al., 2013; Mrazek et al., 2013; Ortner, Kilner, & Zelazo, 2007; Slagter et al., 2007; Tang et al., 2007; van den Hurk, Giommi, Gielen, Speckens, & Barendregt, 2010; van Leeuwen, Muller, & Melloni, 2009; Wenk-Sormaz, 2005; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Because mindfulness practice involves training attention in order to stabilize and expand awareness, most researchers working in this domain have investigated the performance of mindfulness meditators on tasks of attention. Other factors that have been studied include sensory acuity, working memory, executive functioning, and cognitive flexibility. Some research has examined behavioral performance data concomitantly with neurological correlates (Allen, Dietz et al., 2012; Pagnoni & Cekic, 2007; Slagter et al., 2007; Teper & Inzlicht, 2013).

In a series of early studies, Brown, Forte, and Dysart (1984a; 1984b) assessed visual sensitivity thresholds in mindfulness meditators. The ability of mindfulness practitioners to detect light flashes of short durations was compared before and following a 3-month intensive meditation retreat. Retreat participants showed significantly greater perceptual sensitivity following the retreat than prior to the retreat as well as when compared to a group of practitioners who did not participate in the retreat. Their post-retreat acuity was also superior to their pre-retreat acuity and to that of the non-retreat participants. A related study comparing three groups of mindfulness meditators to non-meditating controls also found decreased perceptual sensitivity thresholds in all three meditation practitioner groups as compared to controls, but no differences in their acuity. This suggests the increased acuity found in the prior study resulted from the intensity of practice during the 3-month retreat.

Valentine and Sweet (1999) studied differences in the practice of mindfulness and concentration meditation on a measure of sustained attention. Sustained attention is the capacity to detect unpredictable stimuli over longer periods of time (Sarter, Givens, & Bruno, 2001). Impairment in this domain has been implicated in a number of cognitive problems, including learning and memory deficits (Posner, 1994). Problems with sustained attention have also been linked to psychological disorders (Lawrence, Rossy, Hoffmann, Garavan, & Steiny, 2003). In this study, Valentine and Sweet incorporated type of meditation practice (mindfulness vs. concentration), length of meditation practice (long-term 25 months or more vs. short-term 24 months or less) and expectancy (expected vs. unexpected stimuli). Nineteen Buddhist meditators, self-identified as mindfulness or concentration practitioners, were compared to 24 non-meditator controls. Meditation conditions included 4 short-term mindfulness meditators, 5 short-term concentration meditators, 4 long-term mindfulness meditators, and 6 long-term concentration meditators. Sustained attention was measured on Wilkins' Counting Test, in which the task was to count bleeps presented at slower or faster rates. Meditators were tested following their usual meditation practice. Findings demonstrated that meditators' attention and accuracy were greater than that of controls, and long-term meditators performed better than short-term meditators. In addition, although both groups were equally effective when the presentation of bleeps was slow, mindfulness meditators performed significantly better than concentration meditators when the stimulus was fast. These findings were explained in terms of expectancy theory (Posner & Snyder, 1975), which posits that the slow bleeps are expected while faster ones are not. Results suggest that mindfulness meditators are better able to shift between stimuli that are unexpected. This may be attributed to the specific form of attentional training provided by mindfulness meditation.

In another study comparing concentration and mindfulness meditators on tasks of attention, Chan and Woollacott (2007) looked at specific attentional networks involved in meditation. Fifty meditators (20 concentration practitioners and 30 mindfulness practitioners) and 10 control participants were given the Stroop task, which measures the inhibition facet of executive control (Miyake et al., 2000). Participants were also administered the Global-Local Letters task, which measures orientational attention. Meditation experience was associated with performance on the Stroop task, while no such association was present on the Global-Local Letters task. The authors conclude that meditation practice appears to be related to increased effectiveness of the executive attention network, but not the orientation network. The ACC and PFC are implicated in the executive attention network while the parietal systems are implicated in the orientation network. No differences were found between concentration and mindfulness meditators.

Jha et al. (2007) investigated the effect of mindfulness on three attention subsystems. Using the Attention Network Test, three distinct but overlapping attentional subsystems were measured: alerting, orienting, and conflict monitoring. Two mindfulness groups and one control group were included in the design. The MBSR group consisted of 17 recruits with no prior meditation experience. The Retreat group consisted of 17 participants, with prior experience exclusively in concentration meditation, who attended a 1-month mindfulness retreat. The control group consisted of 17 participants with no meditation training or experience. Results showed differential effects for the groups. Whereas the MBSR group showed significantly improved orienting attention as compared to the Retreat and control groups following training, the Retreat group demonstrated improved attentional alerting. In other words, the meditation-naïve participants in the MBSR group showed an increased ability to orient attention inward as a result of their training. Participants in the intensive retreat, who were presumably already practiced in orienting attention inward as a result of their concentration practice, developed an increased ability to open up to external phenomena as they increased their awareness through mindfulness practice. No differences were found in conflict monitoring performance.

Anderson and colleagues (2007) looked at the relationship of mindfulness and aspects of attention in 72 healthy adults, randomly assigned to a MBSR course or a wait-list control group. Both groups were tested on measures of sustained attention, attention switching, inhibition of elaborative processing, and non-directed attention. Participants also completed measures of emotional well-being and self-reported state mindfulness. State mindfulness invoked during meditation was measured by the Toronto Mindfulness Scale (TMS; Lau et al., 2006). MBSR participants showed significantly greater improvements in emotional well-being and mindfulness, but no improvements in attention relative to the control group. However, for participants in the MBSR course, improvements in state mindfulness were associated with improvements in non-directed attention, indexed by the detection of objects in consistent and inconsistent scenes. These findings suggest that it is increased state mindfulness as a result of training and practice that lead to improved attention.

Another study examining the effects of meditation on sustained and executive attention was conducted by Josefsson and Broberg (2011). Fifteen experienced meditators (2 or more years experience) who practiced often (a mean practice frequency of 8 times per week) were compared with 15 non-meditators (no meditation experience) on tasks of sustained and executive attention. Contrary to findings by Chan and Woollacott (2007) and Valentine and Sweet (1999), no significant differences were found between meditators and non-meditators on either attention task, after controlling for the effects of age. Type of meditation was not controlled or reported in this study. Participants were recruited from among university students, Buddhist centers, and secular meditation groups. While most Buddhist forms of meditation include mindfulness to some degree, it is unclear to what degree mindfulness practice was represented in this study. No self-report measures of mindfulness were included.

In support of earlier findings, Chambers et al. (2008) reported increased performance for mindfulness meditators on a task of sustained attention. Twenty participants attending their first 10-day intensive meditation retreat were compared with 10 wait-list controls. Participants were tested twice; once before commencement of the retreat, and again 7-10 days after its conclusion. The post-retreat waiting period was decided upon in order to allow participants to readjust to their daily routine. The researchers were interested in the more enduring effects of the meditation course rather that its immediate effects. Participants were administered five self-report measures assessing mindfulness, rumination, and affect. They also completed performance tests assessing sustained attention, attention switching, and working memory. Retreat participants showed improvements in self-reported mindfulness, rumination, and depression relative to the comparison group. Furthermore, those attending the retreat demonstrated increased performance on measures of working memory and sustained attention in comparison to participants not attending the retreat.

Evidence suggests that mindfulness practice of shorter duration is also related to improvements in cognition. For example, Wenk-Sormaz (2005) randomly assigned 120 undergraduate students to one of three groups: the Meditation group practiced a Zen breath awareness meditation for 20 minutes, the Learning group used a mnemonic device to learn a list of items, and the Rest group was told to rest and allow their minds to wander for 20 minutes. Participants were tested before and after these 20-minute sessions. Meditation group participants performed significantly better on a task of executive, or flexible, attention than did the Learning or Rest group members. Randomization, an active control group, and the pre-post design suggest a specific causal effect of the mindfulness intervention.

Zeidan et al. (2010) also looked at the effects of meditation experience of a shorter duration on cognitive performance. Forty-nine university student volunteers with an interest in meditation, but no experience, were randomly assigned to a mindfulness meditation training group or to a group who listened to a book for the same duration of time. Each group met for four 1-hour sessions. Meditation was taught by an instructor with 10 years experience teaching mindfulness meditation. Measures were administered before session 1 and again following session 4. Mindfulness training, but not book listening, significantly improved executive attention, working memory, and visuospatial processing. Mindfulness training also increased trait mindfulness as measured by the Freiburg Mindfulness Inventory (FMI; Buchheld, Grossman, & Walach, 2001), and reduced fatigue and anxiety. Both interventions improved mood.

A study by Tang et al. (2007) also demonstrated the potential effectiveness of brief mindfulness training. The authors randomly assigned 80 healthy undergraduate students either to receive 5 days of meditation training or to receive 5 days of information about relaxation. Days were consecutive and intervention sessions were each 20 minutes long. The meditation training method was drawn from traditional Chinese medicine and incorporated meditation and mindfulness training. Compared to control participants, meditation participants showed greater improvement in executive attention, higher vigor, and lower depression, anxiety, anger, and fatigue. They also showed decreased cortisol and increased immunoreactivity when compared to the control group. Gains in fluid intelligence showed a trend toward significant.

Van den Hurk et al. (2010) compared the performance of 20 expert mindfulness meditators (mean meditation experience 14.5 years) to that of 20 non-meditator control participants, matched for age and gender, on the attention network test. Mindfulness meditators demonstrated better orienting as well as executive attention compared to matched controls. Meditation practitioners also showed a reduction in the fraction of errors, with reaction times comparable to those of the control group.

Visual attention processing in mindfulness practitioners was investigated by Hodgins and Adair (2010). Data were collected from 96 participants recruited from meditation centers, MBSR classes, and a local community. A group of mindfulness meditators was compared with a group of age-matched non-meditators on performance measures of change blindness, perspective-shifting, concentration, sustained inattentional blindness, and selective attention. Results indicated that meditators performed better than comparison subjects in all areas, with the exception of inattentional blindness. The investigators conclude their findings show that mindfulness meditation is associated with more flexible, efficient, and accurate visual attentional processing.

Moore and Mallinowski (2009) looked at the relationship of mindfulness and cognitive flexibility. Twenty-five Buddhist mindfulness practitioners, all of whom had completed at least one 6-week meditation course, were compared with 25 meditation naïve individuals on measures of attention, attentional flexibility, and the ability to suppress interfering information and focus and direct attention. Groups also completed a self-report mindfulness questionnaire, the Kentucky Inventory of Mindfulness Skills

(KIMS; Baer, Smith, & Allen, 2004). Meditators had greater trait mindfulness scores and scored better on all performance measures than control participants. In addition, the correlations of trait mindfulness and all attention measures were moderate to high. The authors conclude these results suggest mindfulness is associated with improvements in attentional functions and cognitive flexibility.

In order to investigate the effect of mindfulness in an emotional context, Ortner and colleagues (Ortner et al., 2007) conducted two studies. In Study 1, twenty-eight mindfulness practitioners were instructed to categorize tones presented 1 or 4 seconds following the onset of scenes with either neutral or emotionally arousing content. Participants ranged in age from 19 to 71 years, with meditation experience varying from 1 month to 29 years. Reaction times were recorded for tone categorization. Participants also completed self-report measures of mindfulness, positive and negative affect, satisfaction with life, self-compassion, and personality. In addition, they rated a different group of 12 pictures as neutral, pleasant, or unpleasant. Participants with more mindfulness meditation experience demonstrated less interference from the affective pictures. They also reported more psychological well-being. Meditators with more experience scored higher on one of the mindfulness measures (the TMS), but not the other (the MAAS). State mindfulness scores on the TMS did not correlate with performance or self-report measures. Trait mindfulness scores on the MAAS, however, were positively correlated with psychological well-being, self-compassion, vitality, and satisfaction with life.

In Study 2, eighty-two paid participants from a university student body were randomly assigned to a 7-week mindfulness meditation group, a body awareness and relaxation meditation group, or a wait-list control group. Measures were the same as in Study 1, with the addition of physiological measures (skin conductance responses) to emotional pictures. A baseline battery was collected prior to the interventions, and the same measures were completed following the 7-week period. Both mindfulness meditation and relaxation meditation resulted in smaller physiological responses to unpleasant pictures and increased well-being. However, only mindfulness meditators experienced less emotional interference from unpleasant pictures in the performance task.

In an investigation of the relationship of mindfulness and working memory capacity, Jha et al. (2010) recruited two military cohorts during the stressful pre-deployment phase, all of whom had no experience with mindfulness techniques. Military personnel were divided into a group of 37 male participants who attended a mindfulness training group (MT) and a military control (MC) group of 17 male participants who did not receive mindfulness training. A second control group consisted of 12 civilians who also received no intervention. The MT group received a program that was similar to MBSR, but blended mindfulness skills with concrete applications for the military environment. These additional components included information and skills for dealing with the stress and trauma encountered in combat, plus training in bodily resilience. Working memory capacity was measured via the operation span task at two points corresponding to before and after mindfulness training. Positive and negative affect were also assessed via a self-report measure. MT group members recorded the amount of time spent practicing mindfulness outside of training. While working memory capacity remained steady for civilians, it degraded over time for MC group and for the MT group who recorded low mindfulness practice time. However, for those with higher practice time, working memory capacity increased. In addition, high practice time correlated with lower levels of negative affect and higher levels of positive affect. Moreover, the relationship between negative affect and practice time was mediated by working memory capacity. Such a mediating effect was not found for positive affect. The authors conclude that improvements in working memory capacity as a result of mindfulness training may account for some of its positive effects.

Mrazek and colleagues (2013) also looked at the effects of mindfulness training on working memory, GRE performance, and mind wandering. Undergraduate students were randomly assigned to either a mindfulness class or a nutrition class. Each class met for 45 minutes four times per week for a 2-week period. Classes were taught by professionals with extensive expertise in their respective fields. Mindfulness training significantly improved both GRE reading comprehension scores and working memory capacity while reducing the occurrence of distracting thoughts. Among mindfulness students more prone to distraction at pretest, reduced mind wandering mediated performance improvements.

A few studies have looked at both behavioral measures and neurological correlates of mindfulness. Allen and colleagues (2012) employed a randomized design with an active control condition to examine neuroplasticity in regard to attentional control and affective processing. The researchers used fMRI to examine whole-brain BOLD signals during a Stroop task performed pre- and post-intervention. Behavioral metacognition and Stroop errors were also measured. Those assigned to the meditation condition were given 6 weeks of training in the development of FA, OM, and fullness of feeling/empathy (Lutz, Dunne, & Davidson 2007; Risom, 2010). Control participants were given 6 weeks of shared group reading and listening. Both were told these courses were designed to improve attention and emotional well-being, and were invited to participate in the alternate treatment at no charge at the end of the course. Both groups improved significantly on a response inhibition task following treatment, but only the mindfulness training group showed decreased affective Stroop conflict. In addition, the mindfulness training group exhibited greater DLPFC responses during executive processing. This pattern indicates recruitment of top-down, executive responses to resolve conflict. Improvement in response inhibition and greater recruitment of dorsal ACC, MPFC, and right anterior insula during negative valence processing were only evident in participants with the most mindfulness practice, indicating that there may be specific neural mechanisms for graduated stages of mindfulness training and practice.

Teper and Inzlicht (2013) also looked at the neural correlates of executive functioning by measuring error-related negativity (ERN) in meditators and controls via EEG during a Stroop task. ERN was measured to assess the performance monitoring aspect of executive control, wherein current behavior is compared to a desired outcome. Neurologically, this process is undergirded by the ACC, which feeds the monitoring result to the DLPFC (Kerns et al., 2004). Meditators and control participants were recruited via Craigslist.com and various meditation centers. The meditators had an average of 3.19 years experience and came from various meditation backgrounds, which differed in the degree to which concentration and mindfulness are emphasized. In this study, meditators exhibited greater executive control as indicated by fewer errors. This was accompanied by a higher ERN and more emotional acceptance in meditators than in control participants. Furthermore, pathway models indicated that meditators' greater executive control could be accounted for by emotional acceptance and, though to a lesser degree, by performance monitoring.

Slagter et al. (2007) used behavioral data and EEG to investigate attentional blink in mindfulness meditators. When two stimuli, or "targets", are presented in close proximity within a rapid stream of events, the second target is often not seen. This so-called "attentional-blink" deficit is considered an illustration of the limited information processing capacity of the human brain (Marois & Ivanoff, 2005). Longitudinal data were collected from 17 participants in a 3-month mindfulness meditation retreat in which they meditated for 10 to 12 hours per day. Retreat participants had data collection sessions at the beginning and at the end of the retreat. Data were also collected from 23 control participants who were interested in meditation but had no meditation experience. Control participants received a 1-hour meditation class and were asked to meditate for 10 minutes daily for 1 week prior to each session. Each data collection session consisted of an attentional-blink task and the recording of brain-potentials via scalp electrodes during the task. Of particular interest was the P3b brain potential, which is an index of brain attentional resource allocation. As hypothesized, retreat participants showed a smaller attentional blink deficit following the retreat. Electrode recordings also showed reduced allocation of brain resources to the first target compared with controls. Furthermore, retreat participants who showed the smallest attentional blink also showed the most reduction in allocation of resources to the first target. The authors conclude that the ability to accurately identify the second target among retreat participants was facilitated by reduced allocation of brain resources to the first target. Intensive mindfulness practice seems to result in increased control over the distribution of limited brain resources.

There remains a paucity of research exploring mindfulness and cognitive aging. Interest is building, however, as the need to counteract cognitive decline in an aging population increases in salience (Gard, Holzel, & Lazar, 2014). Van Leeuwen et al. (2009) compared performance on an attentional blink task among three groups of participants: (a) a group consisting of 17 long-term Zen meditations from an older population; (b) a group of 17 age, sex, and education matched controls who had never practiced meditation; and (c) a group of 17 meditation-naïve controls from a younger population. As expected, long-term meditators showed a reduced attentional blink when compared to controls. Moreover, the older meditation practitioners showed a reduction in attentional blink as compared to the control group taken from the younger population. The older age-matched control group displayed an attentional blink that was larger and broader by comparison. These findings not only replicate the behavioral findings of Slagter et al. (2007), they further suggest that mindfulness meditation practice may protect against the age-related decline in allocation of attentional resources.

McHugh and colleagues (2010) applied a brief mindfulness induction to assess its effect on stimulus over-selectivity in older adults. Over-selectivity, or the control of behavior by a limited number of stimuli in the environment, emerges with aging. Over-selectivity is closely linked with attention. Twenty-four non-demented older adults (mean age 78.58), with memory recall at least below average, were randomly assigned to either a mindfulness or unfocused attention group. All were given a battery of cognitive tests prior to commencement of the study to assure group equivalence in pre-training cognition and affect. The mindfulness group was given instructions in mindfulness and told to practice for 10 minutes; the unfocused attention group was told to allow their mind to wander freely without trying to focus on anything in particularly. All were then administered the over-selectivity protocol. The mindfulness group showed a significant reduction in the level of over-selectivity relative to the unfocused attention group. These findings suggest that mindfulness training may provide a means of ameliorating over-selectivity in older adults.

The effects of mindfulness on left frontal alpha asymmetry have been shown in prior research (e.g., Davidson et al., 2003). Moynihan and colleagues (2013), building on earlier studies, examined the effects of MBSR training on frontal asymmetry, executive functioning, and immune function in a population of older adults. A total of 201 participants were randomly assigned to MBSR training or to a wait-list control group. Executive functioning was measured by the Trail Making Test part B/A ratio, frontal asymmetry was assessed via EEG, and immune function was measured by immunoglobulin G antibody response to a challenge with the antigen keyhold limpet hemocyanin. Trait mindfulness was measured via the MAAS (Brown & Ryan, 2004). Behavioral and EEG data were assessed prior to training, following completion of MBSR, 3 weeks post-training, and 24 weeks post-training. Immune response was measured at the latter three timepoints. Increased executive functioning, left frontal asymmetry, and higher baseline antibodies were shown post intervention. Improved trait mindfulness was shown after intervention and at 21-week follow-up. All improvements were small but significant. Unexpectedly, although immune response was greater post-intervention, it was lower 24 weeks after the antigen challenge. Authors suggest future research look at changes in antibody response compared to T-cell-mediated effector functions, which are known to decrease with age.

A neuroprotective effect of mindfulness practice was also suggested in a VBM study conducted by Pagnoni and Cekic (2007). Thirteen regular practitioners of Zen awareness meditation were compared with 13 matched control participants on gray matter volume and performance on a task of sustained attention. Groups were matched on age, sex, and education level. As in the study by Lazar and colleagues (2005), meditators, but not control subjects, showed no age-related decline in gray matter volume. This effect was most pronounced in the putamen, an area once thought to be primarily involved in motor functions but is now implicated in attentional processing and cognitive flexibility (Ell et al., 2012). A difference in the relationship of age and gray matter volume of meditators and controls was also observed in the PFC when the statistical threshold for the VBM analysis was lowered. The same pattern occurred in attentional performance, with meditators showing no age-related decline.

Recent research with direct applicability to the current study was conducted by Gard and colleagues (Gard, Taquet, et al., 2014). The researchers employed graph theoretical methods to investigate the relationship of meditation and yoga to fluid intelligence and brain functional organization in aging practitioners. Such methods have been effectively used in prior research to demonstrate a relationship between brain network efficiency and fluid intelligence (e.g., Langer et al., 2012). Participants included 16 highly experienced Kripalu yoga practitioners (*m* = 13,534 lifetime hours of experience), 16 highly experienced vipassana meditation practitioners (*m* = 7,458 lifetime hours of experience), and 15 practice-naïve age-matched controls. Although the yoga and meditation techniques included in this study entail different practice methods, the authors note that both incorporate the cultivation of mindfulness. Findings from this study support the hypothesized slower decline in fluid intelligence in yoga practitioners and meditators combined, and demonstrate more efficient and resilient functional brain networks in practitioners compared with controls. While most group differences were driven by the yoga practitioners and only partially by the meditation practitioners, the authors point out that differences between yoga and meditation practitioners were not significant. Results also showed that trait mindfulness, as measured by the Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006), positively correlated with fluid intelligence and global brain network efficiency and resilience. Because this research is cross sectional, no causal inferences between mindfulness and these cognitive factors can be drawn.

Three recent reviews have examined the effect of a variety of meditation practices on cognitive aging and neurodegenerative diseases (Gard, Holzel, & Lazar, 2014; Marciniak et al., 2014; Newberg et al., 2014). While most of the research included in each of these reviews involves meditation methods other than mindfulness (e.g., mantra and other yogic techniques), the conclusions of the reviewers are broadly consistent with the mindfulness literature and are thus worth noting in the context of the current study. Individual studies involving the relationships of neurological correlates, cognition and mindfulness practices have been outlined in the paragraphs above.

Gard, Holzel, and Lazar (2014) examined 12 studies involving a wide range of meditation techniques. Only three of these studies involve mindfulness practices. Most of the studies reviewed involved small sample sizes and had a high risk of bias. Despite these limitations, the authors reported that meditation studies show preliminary positive effects on memory, attention, executive functioning, processing speed and general cognition. They conclude that evidence suggests these interventions have the potential to offset age-related cognitive decline.

Newberg et al. (2014) reviewed the literature on meditation, memory, and attention in adult populations with the aim of exploring its potential applications in patients with neurodegenerative disease. They conclude that meditation shows promise for improving various attentional networks and working memory capacity. They also note that these effects are generally moderated by the length and intensity of practice.

A review by Marciniak and colleagues (2014) looked at the effect of meditation on cognitive aging and neurodegenerative diseases. Only seven studies were identified, three of which examined meditators employing mindfulness practices. They concluded that meditation shows positive effects on attention, memory, verbal fluency, and cognitive flexibility in older adults and adults with neurodegenerative disorders, indicating its potential for the prevention of age-related cognitive decline. These findings are limited by methodological flaws.

Mindfulness summary. Many mindfulness training practices initially emphasize the development of FA and steadiness of mind by attending to the sensations of breathing. Once some steadiness of attention has been developed, training shifts its emphasis to the more refined cultivation of mindfulness, or OM of the broader and more subtle contents of consciousness. Other mindfulness centers teach OM practices from the beginning, allowing concentration to develop gradually along with mindfulness.

Mindfulness-based interventions have been effectively applied with a number of psychological and medical conditions. In 11 recent meta-analytic reviews, effect sizes have consistently been in the medium range. Some evidence exists for specific and dose-response effects for mindfulness practices. Outcomes most often reported include reductions in depression, anxiety, and psychological distress. In addition to these outcomes, studies point to the effectiveness of mindfulness-based interventions in reducing substance abuse, fatigue, stress, and medical symptoms. Mindfulness-based interventions show promise in the treatment of a number of other psychological and medical conditions. These include eating disorders, ADHD, bipolar disorder, social phobia, panic disorder, and PTSD. Physiological disorders where mindfulness has been applied include cancer, hypertension, human immunodeficiency virus (HIV), fibromyalgia, rheumatoid arthritis, and other chronic pain conditions. Physiological mechanisms positively affected by mindfulness include pain, hypertension, psoriasis, and immune function. Behaviorally, mindfulness has been found to decrease emergency room visits and psychiatric hospitalizations.

In terms of psychological processes, mindfulness has been linked to decreased impulsivity, anger, rumination, reactivity, boredom, burnout, and daily hassles. Mindfulness has been shown to increase global functioning, healthy coping, mood and emotion regulation, self-efficacy, persistence, insight, quality of life, social and relationship effectiveness, response flexibility, self-concept, personal development, positive emotions, life satisfaction, and subjective well-being. Effects of a higher, or more spiritual, order include increased awareness, compassion, empathy, intuition, self-realization, and spiritual experiences.

Neurologically, evidence links mindfulness to activation of the PFC and neuroplastic changes in this region. More specifically, mindfulness appears to activate the DLPFC and DMPFC, the ACC, and the basal ganglia. These structures are implicated in executive functioning, attention, working memory capacity, and emotional processing. Enhanced connectivity was found in experienced meditators between the DMPFC and the right inferior parietal lobule regions, possibly reflecting enhanced emotional resources, greater present-moment awareness, and increased fluid intelligence.

Mindfulness is also associated with decreased activation of the DMN, which is the neural system operational during an unfocused resting state. The stream of automatic processing that takes place in the DMN is implicated in the phenomenological sense of self. More specifically, researchers found decreased duration of the neural response associated with conceptual processing and weaker functional connectivity in regions associated with self-referential processing. This finding accords with Buddhist teaching regarding the insight that mindfulness provides into the illusory nature of a permanent phenomenological self. Longer-term neurological activation effects of mindfulness practices include increased left frontal cortical activation (associated with positive affect and adaptive coping) and more balanced bi-lateral frontal activation in patients with recurrent depression.

Structural brain changes associated with mindfulness practice include increased gray matter in the PFC, superior frontal cortex, temporal pole, middle and inferior temporal cortices, and basal ganglia. These anterior portions of the brain are active in executive control. Mindfulness also appears to mitigate age-related loss of gray matter and cortical thinning in the PFC and basal ganglia. Other structural differences in meditators include reduced cortical thinning in affective areas (associated with enhanced emotional processing) and decreased gray matter in the amygdala (associated with negative affect).

A growing body of evidence points to the positive impact of mindfulness on cognition. Because attention is the cognitive process most obviously exercised and trained by mindfulness, this domain has been the most widely researched. Mindfulness has been linked to enhanced perceptual sensitivity and acuity, more facile ability to shift perspective, improved sustained and non-directed attention, and enhanced executive, orienting, and alerting attention. Research suggests that mindfulness also reduces errors in attention, improves the ability to inhibit distracting stimuli, diminishes change blindness, and decreases the attentional blink through a more uniform allocation of brain resources. Mindfulness has also been found to aid visuo-spatial processing, enhance the ability to shift between unexpected stimuli, decrease emotional interference on a cognitive task, increase working memory capacity, and enhanced executive functioning.

Evidence suggests mindfulness may also protect against age-related cognitive changes. Older practitioners did not exhibit the increased stimulus over-selectivity and attentional blink that normally occur with advancing age. Mindfulness also enhanced executive functions, increased left frontal asymmetry, and boosted immune response in older adults. Finally, older mindfulness meditation and yoga practitioners exhibited a reduced decline in fluid intelligence when compared to age-matched controls, and their functional brain networks were more efficient and resilient.

Literature Review Summary

Declines accompanying normal cognitive aging primarily involve functions relying on prefrontal cortex circuitry. These include attention, working memory, and executive functions. Working memory and executive functions are regarded as the underpinnings of fluid intelligence, which is also subject to decay in the process of normal cognitive aging. Executive functions are thought to depend on cortico-subcortical circuits connecting the PFC, the ACC, the basil ganglia, and the cerebellum via the thalamus. A more efficient and resilient functional brain network is strongly related to increased fluid intelligence.

Mindfulness has been shown to activate the PFC, the ACC and the basil ganglia. It is associated with increased gray matter in these regions, and has been shown to mitigate age-related cortical thinning in these structures as well. In terms of health and clinical issues, mindfulness and mindfulness-based interventions have been found to be helpful with a plethora of conditions and concerns. These include depression, anxiety, substance abuse, eating disorders, ADHD, bipolar disorder, panic disorder, social phobia, PTSD, chronic pain conditions, immune function, hypertension, psoriasis, cancer, stress, fatigue, anger, impulsivity, rumination, psychological distress, boredom, burnout, coping, self-efficacy, persistence, insight, relationship effectiveness, life satisfaction, personal development, compassion, empathy, intuition, and self-realization.

In terms of cognition, evidence suggests that mindfulness training is related to improved attention, working memory, and executive functioning, and it has been shown to mitigate age-related declines in these domains. Decreased gray matter in the amygdala, more even allocation of cognitive resources, and a more equanimous reaction to negative stimuli have also been found in mindfulness practitioners. Finally, mindfulness has been linked to increased fluid intelligence and a more efficient and resilient functional neural network in older practitioners.

Study Purpose

The aim of the current research is to further investigate the links between mindfulness and fluid abilities, which are the first and most profoundly affected cognitive functions in normal aging. This study will build on the findings on other research suggesting a relationship between these two constructs. A better understanding of this relationship should lay the foundation for more effective interventions to prevent or ameliorate the effects of age-related cognitive decline.

Research Questions

Based on a review of the literature, I have developed the following research questions:

(a) Is mindfulness positively related to fluid abilities? (b) Does mindfulness moderate the effects of age on fluid abilities?

More specifically, I will address the following questions:

1. Is mindfulness positively related to fluid intelligence in healthy adults?

    a. Is degree of mindfulness experience associated with fluid intelligence in healthy adults?

    b. Is trait mindfulness (i.e., the propensity to experience mindful states) associated with fluid intelligence in healthy adults?

    c. Does trait mindfulness moderate the relationship of mindfulness experience and fluid intelligence in healthy adults?

2. Does mindfulness moderate the relationship of age and fluid intelligence in healthy adults?

a. Does degree of mindfulness experience moderate the relationship of age and fluid intelligence in healthy adults?

b. Does trait mindfulness moderate the relationship of age and fluid intelligence in healthy adults?

CHAPTER 2

METHOD

In the cognitive aging literature, age, educational history, physical activity, and health have been the most consistent predictors of age-related cognitive performance (Albert et al., 1995; Colcombe & Kramer, 2003; Colcombe et al., 2003; Colsher & Wallace, 1991; Dixon & deFrias, 2004; Etnier & Berry, 2001; Farmer, Kittner, Rae, Bartko, & Regier, 1995; Gatz et al., 2001; Singh-Manoux, Hillsdon, Brunner, & Marmot, 2005; Stern, 2009; van Hooren et al., 2007; Wahlin, deFrias, MacDonald, & Nilsson, 2006). Therefore, except when they are the variables of interest, these factors were controlled.

This study employed a cross-sectional correlational design. Because health, education, and exercise were not of primary interest in this study, these variables were controlled in order to reduce error variability (Maxwell & Delaney, 2000). To control for health, participants were pre-screened and only those individuals who reported themselves to be in good-to-excellent general health and free from conditions adversely affecting cognitive functioning were included in the study. Education and exercise were statistically controlled. The procedure for controlling these variables differed depending on the research question under consideration. For Research Questions 1a and 1b, education, activity level, and age of each participant were entered separately into the regression equation in order to partial out their effects and arrive at the unique contribution of mindfulness to the variability in fluid abilities. For Research Question 1c, the variability due to age, education, and activity level was controlled by entering these variables as a group in Block 1 of a hierarchical regression analysis. For Research Questions 2a and 2b, where age was a variable of interest, only education and exercise were controlled and were entered in the first block of the hierarchical regression analysis. (Cohen & Cohen, 1983; Miles & Shevlin, 2001).

The study was approved by the Institutional Review Board of the University of South Carolina on October 15, 2009, upon expedited review. Approval was also granted by the East Tennessee State University Institutional Review Board on December 11, 2009, following expedited review. Yearly extensions have been granted by both Boards during the data collection and analysis process. All relevant ethical standards for the treatment of human participants were followed.

Participants

An *a priori* power analysis was computed in order to determine the number of participants required to detect a medium-sized effect for each of the hypothesized relationships. The power analysis was performed with G*Power 3 (Erdfelder, Buchner, Faul, & Brandt, 2004; Keppel & Wickens, 2004). For a standard multiple regression analysis with four predictors (Questions 1a and 1b), 70 participants were required in order to detect a medium effect (0.2), with power set to .80 and alpha set to .05. For a hierarchical multiple regression ($R^2\Delta$) with six predictors (Question 1c), a total of 55 participants were required in order to detect a medium effect with power set to .80 and alpha set to .05. For a hierarchical multiple regression ($R^2\Delta$) with five predictors

(Questions 2a and 2b), the number of participants required to detect a medium effect size was 49.

In order to fully satisfy the recommendations of the power analyses, the sample consisted of 75 healthy, non-demented community-dwelling adults, ages 18-75. Table 2.1 lists demographics for the sample.

Participants were drawn from the communities of Johnson City, Elizabethton, Grey, Bristol, and Kingsport, TN; Tallahassee and Quincy, FL; and Dothan, AL. Twenty-seven of those who participated in the study were male and 48 were female; 59 participants were white, 8 were African American, 1 was Hispanic, 3 were Asian, 2 identified themselves as bi-racial, and 2 designated themselves Other. Recruitment took place via advertisement, public fliers and postings, the East Tennessee State University participant pool, email list-serves, churches, meditation centers, senior centers and announcements to community groups.

Data were collected in 2010 and 2011. Collection sites included Johnson City Mindfulness Meditation Center, East Tennessee State University, Johnson City Senior Center, Elizabethton First Presbyterian Church, Tallahassee Buddhist Community Center, and the Spiritual Enrichment Center of Dothan, AL (see Table 1 for numbers and percentages). A recruitment aim was to obtain a varied and relatively random sample that was representative of the population of interest.

Individuals expressing an interest in the study were contacted, briefed about the study, administered the health and meditation screening, and scheduled for assessment. The screening instrument consisted of a checklist of conditions and a table of prescription medications that have been found to adversely affect cognitive functioning (Albert et al., 1995; Christensen et al., 1994; van Hooren et al., 2007). These conditions included neuromuscular and central nervous system disorders (e.g., Alzheimer's disease and other dementias), vascular disorders, and major mental illness (e.g., schizophrenia and depression). Also included was a self-rating of overall general health and a question regarding experience with concentration forms of meditation (see Appendix A and *Measures* section below). Individuals who reported fair or poor current health or health conditions and medications that have detrimental effects on cognition were excluded from the study. Because the effects of strictly FA, or concentration, forms of meditation have been found to differ significantly from OM, or awareness, forms of meditation in both their neurological correlates and their effects (Dunn, Hartigan, & Mikulas, 1999; Valentine & Sweet, 1999), individuals who reported themselves to be intermediate or advanced practitioners of a concentration form of meditation were excluded from the study.

Prior to beginning the study, all participants were fully apprised of parameters relevant to their participation and signed a form acknowledging their informed consent to participate. The Informed Consent Form outlined the study purpose, duration, and procedures, and included a brief outline of the measures. The form also detailed possible risks or discomfort involving study participation. These included the risk of slight frustration while working to solve the problems included in the dependent variable measure and a minor risk that a violation of confidentiality could occur in spite of steps taken to prevent it. Potential benefits and financial costs and compensation related to participation were summarized. Potential benefits included enjoyment from working to solve the problems in the dependent measure, the possibility of a temporary increase in mental clarity following completion of the measures, an increased sense of social involvement from volunteering, and the potential satisfaction from playing a role to create a better understanding of mental functioning and aging. Participants were told they would be entered in a drawing to win a cash prize of $200.00 and were offered a one hour workshop in mindfulness meditation as compensation for their participation. There were no associated financial costs.

Also as part of the informed consent process, participants were assured that their participation was voluntary and that they had the right to withdraw or refuse to participate at any point in the study. They were informed of the confidential nature of their participation and the measures taken to protect their confidentiality. These measures included the removal of personally identifying information from response packets following completion of the measures, which were then identified by number only and kept in a separate secure location. Following data analysis, personally identifying information was destroyed. Participants were informed that de-identified study records would be accessible to the Principal Investigator and project team, and the University of South Carolina and East Tennessee State University Institutional Review Boards. They were told that results of the study might be published in aggregate form without naming participants.

The Informed Consent Form included contact information for the Principal Investigator, Dissertation Director, and both Institutional Review Boards. The participants were invited to contact any of these parties at any time with pertinent questions or complaints. Participants initialed each page of the form to indicate their understanding of its contents and signed the last page to indicate their understanding of the document and consent to participate in the study. Following completion of all study measures, participants were verbally debriefed and encouraged to ask questions.

Procedure

To address Research Questions 1 and 2, participants were assessed individually or in small groups during sessions of 30 to 45 minutes in length. Measures of the predictor variables (i.e., age, mindfulness experience, and trait mindfulness), along with measures of control variables and demographics, were administered first. Mindfulness experience was based on self-reported number of lifetime hours of formal sitting practice (Lazar et al., 2005). Trait mindfulness was measured by the Mindful Attention Awareness Scale (Brown & Ryan, 2003). The control variable of physical activity was measured by the Baecke Questionnaire (Baecke, Burema, & Frijters, 1982), while age and education were recorded on the demographics questionnaire. Following completion of predictor measures, participants took a 5 minute break during which they were asked to place themselves into a relaxed and focused state before administration of the dependent measure. The Cattell Test of Fluid Intelligence/Culture Fair Intelligence Test (CFIT) was employed as the dependent measure (Cattell 1940; 1951).

Measures

Demographics, Education, and Mindfulness Experience Questionnaire (DEMEQ). The DEMEQ was created for this study to record demographics, assess education, and determine extent of mindfulness meditation experience (See Appendix B for a copy of the DEMEQ). Demographic variables included age/date of birth, gender, and race/ethnicity. Education was indexed on a seven-point scale, ranging from "Less than 6th grade" to "Advanced degree".

The measure of meditation experience was derived from Lazar et al. (2005). Many meditation studies categorize meditators according to self-reported years of meditation practice (Easterlin & Cardena, 1999; Haimerl & Valentine, 2001; Shapiro, 1992; Valentine & Sweet, 1999). However, Lazar and her colleagues (2005) sought a more sensitive metric for measuring meditation experience than total years of practice, since daily practice varies between meditation practitioners. One effect of regular meditation practice is a drop in respiration rate during formal practice. Respiration continues to slow as meditative state deepens (Goldstein, 2003). Lazar and colleagues (2005) tested to determine if changes in respiration rate between rest and meditation could provide an objective measure for level of meditation experience. They found a strong correlation between respiration rate change and self-reported total lifetime hours of formal sitting meditation practice ($r = -0.75$, $p < .001$). I have, therefore, used the more sensitive metric of total lifetime hours of formal sitting practice, collected from a single question, to answer Research Questions 1 and 2. No additional psychometric data are available on this metric.

Baecke Questionnaire for the Evaluation of Habitual Physical Activity (BQ). The BQ was used in this study to assess physical activity level. It includes a total of 16 questions classified into three domains: *Work*, *Sports*, and non-sports *Leisure* activity. Each domain has several questions scored on a five-point Likert scale, ranging from never to always or very often. Work activity level is the mean score of eight occupational questions, sports activity level consists of the mean score of four sports-related questions, and non-sports leisure activity level is the mean score of four habitual physical activities performed during leisure time. Each domain can receive a score from one to five points.

For the two most frequently reported sports activities, questions regarding the number of months per year and hours per week of participation were computed to calculate the value of the first sports-related question. The total score was calculated as the mean of the three activity level scale scores.

The BQ has been extensively used in a number of countries, including the United States, the Netherlands, Belgium, Finland, France, Japan, and Brazil. It has also been validated and used with a variety of populations, including healthy adults, older adults, adults with a variety of medical conditions, and certified athletic trainers (Baecke et al., 1982; Cauley, LaPorte, Sandler, Schramm, & Kriska, 1987; Conn, Tripp-Reimer, & Maas, 2003; Florindo & Latorre, 2003; Florindo, Latorre, Jaime, Tanaka, & Zerbini, 2004; Florindo et al., 2006; Jacobs, Ainsworth, Hartman, & Leon, 1993; Naugle, Behar-Horenstein, Dodd, Tillman, & Borsa, 2013; Ono et al., 2007; Philippaerts, Westerterp, & Lefevre, 1999; Pols, Peeters, Kemper, & Collette, 1996; Richardson, Ainsworth, Wu, Jacobs, & Leon, 1995; Tehard et al., 2005).

Principal Component Analysis of the BQ with the original Dutch sample of young male and female adults ($N = 167$, age range 20 – 32 years) distinguished three conceptually meaningful factors corresponding to work, sports, and leisure physical activities. In the original sample, test-retest reliability after a 3-month interval was computed for the Sports Index as .90, the Work Index as .80 and for the Leisure Index as .74. In other adult samples, test-retest reliability coefficients for the total score have ranged from .73 for 11 months between testings to .93 for a three-week testing interval (Pols et al., 1996; Naugle et al., 2013). Interclass correlations have generally been .70 or greater (Florindo & Latorre., 2003; Florindo et al., 2006; Jacobs et al., 1993; Ono et al., 2007). Assessment of internal consistency in a mixed adult sample in the United States (*N* = 390) resulted in an alpha coefficient of .62 for the total score (Naugle et al., 2013).

Regarding validity, the BQ has been found to correlate significantly to concurrent activity diaries and physical activities indices (Florindo & Latorre 2003; Pols et al., 1996), and has been shown to be significantly related to a number of physical activity criteria. These have included peak and maximum oxygen consumption (Jacobs et al., 1993; Richardson et al., 1995), body fat percentage (Jacobs et al., 1993; Richardson et al., 1995), cardiorespiratory capacity (Florindo & Latorre 2003), obesity indices (Tehard et al., 2005), step count (Ono et al., 2007), and average daily metabolic rate as measured by the doubly-labeled water method (Philippaerts et al., 1999).

The method of doubly-labeled water is considered the gold standard criterion for the measurement of physical activity (Anastasopoulou et al., 2014; Black, Coward, Cole, & Prentice, 1996). This somewhat costly procedure for measuring energy expenditure involves the ingestion of water labeled with a known concentration of naturally occurring, stable isotopes of hydrogen and oxygen. As the body expends energy, carbon dioxide and water are produced. The differences between the isotope elimination rates are then used to calculate the individual's total energy expenditure, or the average daily metabolic rate (ADMR; Schoeller & van Santen, 1982). Using doubly-labeled water to derive ADMR in a sample of Flemish males (*N* = 19), Philippaerts and colleagues (1999) found a significant correlation with the BQ of .69 ($p < .001$).

Mindfulness Attention Awareness Scale (MAAS). The MAAS (Brown & Ryan, 2003) is a 15-item questionnaire that assesses individual differences in trait mindfulness as reflected in the frequency of mindful states over time. Brown and Ryan (2003) postulate that although mindfulness may be actively cultivated, people differ in their propensity to be mindful. The items are presented on a six-point Likert scale ranging from 1 (almost always) to 6 (almost never). High scorers indicate more mindfulness. To reduce social desirability, respondents are asked to rate the items in terms of what "really reflects" their experience rather than what they think their experience ought to be. Factor analysis confirmed a single-factor structure, with a sample alpha of .87, and test-retest reliability of .81 ($p<.0001$). Temporal stability has been assessed with a sample of 60 undergraduates over a four-week period ($ICC = .81$, $p< .0001$). Coefficient alpha has ranged from .82 in an undergraduate sample ($N = 327$) to .87 in a general adult sample ($N = 239$). Convergent and discriminant validity analysis revealed a pattern of correlations that suggests individuals scoring highly on the MAAS tend to be more mindful of external behavior and aware of and receptive to inner experience, more in tune with emotional states and able to modify them, less likely to be socially anxious or self-conscious, less likely to be ruminative, and slightly less likely to enter states of absorption. The MAAS also correlated with a number of measures of well-being. In a study looking at group differences in trait mindfulness, mindfulness practitioners were compared to controls and demonstrated elevated scores. Further studies assessed the measure's relationship to positive affect, day-to-day self-regulation, and subjective well-being in both clinical and nonclinical populations. An experience-sampling study found that both trait and state mindfulness predict positive emotional states and self-regulated behavior. The authors conclude that the MAAS measures a quality of consciousness and self-awareness that identifies more mindful individuals and differentiates mindfulness practitioners from non-practitioners. (See Appendix D for a copy of MAAS)

The Cattell Test of Fluid Intelligence/Culture-Fair Intelligence Test (CFIT). The CFIT was developed to measure intelligence in children and adults in a manner that minimizes the influences of verbal fluency, cultural climate, and educational level. To this end, the test focuses on fluid intelligence (Gf). Fluid intelligence may be conceptualized as one's reasoning and problem solving abilities, independent from the culture and environment. This is in contrast to crystallized intelligence (Gc), which is defined as the collection of skilled judgments a person has acquired by application of fluid intelligence to his or her experiences and education (Cattell, 1963; 1987; Cattell & Horn, 1978).

The CFIT employs a series of nonverbal tasks that draw on fluid abilities. Cattell (1963; 1987) and Jensen (1980) maintain that the CFIT is a fine-grained measure of fluid intelligence because, unlike some other measures of Gf (e.g. the Raven's Progressive Matrices), it employs subtests in diverse formats to measure the same underlying construct. They contend that by use of these subtests, the CFIT mitigates against contamination of the measure due to test specificity. Four subtests comprise the CFIT, each of which taps a different nonverbal ability: Series, Classifications, Matrices, and Conditions. Raw scores are converted to normalized standard scores expressed by age group, and scoring is done using score key overlays on response forms. Cattell developed three versions of the CFIT. Scale 1 is for children ages 4-8 while Scale 2 is most appropriate for children age 8 and above, as well for the majority of adults. Higher ranges of intelligence are best measured with Scale 3 because of its increased difficulty level. The test takes two forms (A and B). Form A of Scale 2 was used in the current study. Each form takes 12.5 minutes to complete.

Several studies have assessed the reliability and validity of the CFIT. In samples of male and female junior high and high school students, job corps groups, and adults through age 60 (*N* = 3999 and *N* = 832), Scale 2 of the CFIT was found to have a test-retest reliability coefficient of .84 and split half reliability correlation coefficients ranging from .74 to .87 (Cattell 1940; 1951; Cattell, Krug, & Barton, 1973; Crampton & Jerabek, 2000). When administered as a power test as opposed to a speed test in adult samples, test-retest stability has ranged from .71 to .92 (Colom & Garcia-Lopez, 2003; Knapp, 1960). Researchers have found Cronbach's alpha coefficients of .72 (Crampton & Jerabek, 2000) and .80 (Krug, 1973). In terms of validity, factor analyses have shown heavy loading of the CFIT on the fluid intelligence factor (Cattell 1940; 1951; Horn, 1965; Masunaga & Horn, 2001). When the "general ability" (intelligence) factor is correlated with the concepts featured in the subtests, factor analyses have found coefficients in the .70s and .80s (Cattell, 1951; Horn & Cattell, 1966). The CFIT also correlates significantly with other tests of general intelligence, including the WISC , WAIS, Stanford-Binet, and General Aptitude Test Battery, with coefficients ranging from .60 to .77 (Barton, 1973; Cattell & Horn, 1978; Crampton & Jerabek, 2000; Krug, 1973). Cross-validation with Raven's Progressive Matrices, a measure frequently used to assess fluid abilities (Kline, 2013), has yielded coefficients ranging from .55 to .85 (Cattell & Horn, 1978; Crampton & Jerabek, 2000).

Table 2.1

Sample Demographics

	Count	Percent	Cum Percent
Gender			
Male	27	36	36
Female	48	64	100
Race/Ethnicity			
White	59	78.7	78.7
African	8	10.7	89.3
American			
Hispanic	1	1.3	90.7
Asian	3	4	94.7
Bi-racial	2	2.7	97.3
Other	2	2.7	100
Health			
Excellent	20	26.7	26.7
Very Good	43	57.3	84
Good	12	16	100
Recruitment Source*			
University	33	44	44
Senior Center	5	6.7	50.7
Community Grp	5	6.7	57.3
Church	9	12	69.3
Meditation Ctr.	23	30.7	100

* Participants drawn from Dothan, AL, Tallahassee, FL, Quincy, FL, Johnson City, TN, Elizabethton, TN, Grey, TN., Bristol, TN, and Kingsport, TN

CHAPTER 3

RESULTS

Data were analyzed using Statistical Package for the Social Sciences (SPSS), Version 16. Multiple linear regression analysis was performed to answer Research Questions 1 and 2. Prior to analysis, data were examined to assure that assumptions for the statistical tests were met. Linearity was confirmed by inspection of partial regression plots. The assumption of normally distributed residual error was assessed by visual inspection of a histogram of standardized residuals and normal probability plot of residuals. Homoscedasticity was confirmed by observation of simple residual plots. Casewise diagnostics were conducted to identify outliers. Collinearity statistics (Tolerance and VIF) were examined for multicollinearity among independent variables. All assumptions for multiple linear regression were met.

Most participants were young (M = 38.11, SD = 19.66, Mdn = 27, Mod = 22), had some college or technical school (DEMQ M = 4, SD = 1.42), and were moderately physically active (M = 2.92, SD = 0.51). Trait mindfulness scores were moderately high (M = 4.25, SD = 0.74). Hours of meditation experience ranged from 0 to 10,000 (M = 538.36 hours, SD = 1599.26, Mdn = 3 hours, Mod = 0 hours), with 35 of 75 participants having no meditation experience. Average fluid intelligence scores were moderately high (CFIT M = 33.92, SD = 5.92).

Mindfulness Experience and Fluid Intelligence

In order to determine the impact of mindfulness experience on fluid intelligence (Research Question 1a) a standard multiple regression was performed with fluid abilities as the dependent variable and age, education, physical activity, and mindfulness experience as predictor variables. Mindfulness experience, age, education, and exercise are structured such that higher scores represent greater degrees of these factors. Seventy-five participants were included in the analysis. Descriptive statistics are included in Table 3.1. The regression model, including all predictor variables, significantly predicted CFIT fluid intelligence scores, $F(4,70) = 18.19$, $p = .000$, adj. $R^2 = .48$. Forty-eight percent of the variance in fluid intelligence scores can be accounted for by age, education, physical activity, and mindfulness experience.

As expected, age significantly predicted fluid intelligence score, $\beta = -1.02$, $t(70) = -8.32$, $p = .000$, $sr^2 = .48$. As age increased, fluid intelligence scores declined. Forty-eight percent of the variance in fluid intelligence was uniquely accounted for by age. Education also significantly predicted CFIT score, $\beta = 0.56$, $t(70) = 4.80$, $p = .000$, $sr^2 = .16$. As education increased, scores on the CFIT increased. Education uniquely accounted for about 16% of the variance in fluid intelligence scores. The contribution of physical activity scores was nonsignificant, $\beta = -0.14$, $t(70) = -1.16$, $p > .05$).

Although not as strong a contributor as age and education, mindfulness meditation experience significantly predicted fluid intelligence scores, $\beta = 0.21$, $t(70) = 2.24$, $p = .03$, $sr^2 = .04$. Lifetime mindfulness meditation experience uniquely accounted for about 4% of the variance in CFIT fluid intelligence scores when the contributions of age, education, and physical activity were taken into account. Scores on the CFIT increased as mindfulness experience increased. Table 3.2 contains bivariate correlations, unstandardized regression coefficients (B), standardized regression coefficients (β), intercept, and semi-partial correlations (sr^2) for Research Question 1a.

Trait Mindfulness and Fluid Intelligence

To ascertain the effect of trait mindfulness on fluid intelligence (Research Question 1b), a standard multiple regression was performed with fluid abilities as the dependent variable and age, education, physical activity, and trait mindfulness as predictor variables. Scale values are such that higher scores represent greater degrees of trait mindfulness. Seventy-five participants were included in the analysis.

The model, including all predictor variables, significantly predicted CFIT fluid intelligence scores, $F(4,70) = 16.10$, $p = .000$, adj. $R^2 = .45$. Forty-five percent of the variance in fluid intelligence scores can be accounted for by age, education, physical activity, and trait mindfulness.

Once again, age significantly predicted fluid intelligence score, $\beta = -0.94$, $t(70) = -7.91$, $p = .000$, $sr^2 = .45$. As age increased, scores on the measure of fluid intelligence declined. In this model, 45% of the variance in fluid intelligence was uniquely accounted for by age. Education also significantly predicted CFIT score, $\beta = 0.56$, $t(70) = 4.63$, $p = .000$, $sr^2 = .16$. As education increased, scores on the CFIT increased as well. Education uniquely accounted for about 16% of the variance in fluid intelligence scores. Neither physical activity, $\beta = -0.10$, $t(70) = -1.13$, $p > .05$, $sr^2 = .01$, nor trait mindfulness, $\beta = 0.67$, $t(70) = 0.80$, $p > .05$, $sr^2 = .005$, contributed significantly to fluid intelligence scores. Table 3.3 contains bivariate correlations, unstandardized regression coefficients

(B), standardized regression coefficients (β), intercept, and semi-partial correlations (sr^2) for Research Question 1b.

Interactions

To investigate the moderating influence of trait mindfulness on the relationship of mindfulness experience and fluid intelligence (Research Question 1c), a hierarchical multiple regression analysis was performed. The interactions were examined based on recommendations of Cohen and Cohen (1983) and Miles and Shevlin (2001). Predictor variables were standardized and an interaction term constructed from the crossproducts of the standardized predictors. Age, education, and exercise were entered as a group in Block 1 to partial out their influence. Trait mindfulness was entered in Block 2 since it was presumed to precede mindfulness experience in time. Next, mindfulness experience was entered in Block 3. Finally, in Block 4, the trait mindfulness X mindfulness experience interaction term was entered into the regression equation. The interaction was not significant, $\beta = 0.15$, $t(68) = 0.80$, $p > .05$, $sr^2 = .005$.

To look at the moderating effect of mindfulness experience on the relationship of age and fluid intelligence (Question 2a), a similar methodology was followed. Education and exercise were entered as a group in Block 1 of the hierarchical multiple regression analysis. Age was entered separately in Block 2, mindfulness experience was entered in Block 3, and the age X mindfulness experience interaction term was entered in Block 4. This interaction was also nonsignificant, $\beta = -0.05$, $t(69) = -0.13$, $p > .05$, $sr^2 = .0001$. Research Question 2b, which is concerned with the moderating effect of trait mindfulness in the relationship of age and fluid intelligence, was analyzed in a similar manner. This interaction was nonsignificant as well, $\beta = 0.07$, $t\ (69) = 0.70$, $p > .05$, $sr^2 = .004$.

Table 3.1

Descriptive Statistics for Independent and Dependent Variables

Variable	*Mdn*	*Mod*	*M*	*SD*	Min-Max
Age	27	22	38.11	19.66	18-75
Education*	4	4	4.88	1.42	3-7
Baecke	2.92	2.67	2.88	0.51	1.71-4.04
LT MM Hrs	3	0	538.36	1599.26	0-10,000
MAAS	4.27	4	4.25	0.74	2.27-5.33
CFIT	34	39	33.92	5.92	10-44

Baecke = Baecke Questionnaire for the Evaluation of Habitual Physical Activity

LT MM Hrs = Lifetime hours of mindfulness meditation experience

MAAS = Mindfulness Attention Awareness Scale

CFIT = Cattell Test of Fluid Intelligence/Culture-Fair Intelligence Test

* Education values as follows:

1 = less than 6th grade

2 = less than HS graduate

3 = HS diploma or GED

4 = some college or technical school

5 = college degree

6 = some post-college

7 = advanced degree

Table 3.2

Research Question 1a Bivariate Correlations, Collinearity Statistics, and Regression Analysis Results

	CFIT (dv)	Age	Education	Baecke	LT MM Hours	Tolerance	VIF
Age	- .55					.47	2.15
Education	- .09	.70				.52	1.94
Baecke	- .13	.01	- .03			.97	1.03
LT MM Hours	- .08	.42	.29	.16		.80	1.25

	B	β	Sig	sr^2
Age	- 0.31	- 1.02	$p = .000$	.48
Education	2.33	0.56	$p = .000$	.16
Baecke	- 1.55	- 0.14	$p = .118$	.02
LT MM Hours	0.001	0.21	$p = .029$	.04

Intercept = 38.32 $R^2 = .51$ *adj.* $R^2 = .48$

Baecke = Baecke Questionnaire for the Evaluation of Habitual Physical Activity

LT MM Hours = Lifetime hours of mindfulness meditation experience

MAAS = Mindfulness Attention Awareness Scale

CFIT = Cattell Test of Fluid Intelligence/Culture-Fair Intelligence Test

Table 3.3

Research Question 1b Bivariate Correlations, Collinearity Statistics, and Regression Analysis Results

	CFIT (dv)	Age	Education	Baecke	LT MM Hours	Tolerance	VIF
Age	- .55					.52	1.94
Education	- .09	.70				.51	1.95
Baecke	- .13	.009	- .03			.99	1.01
MAAS	- .04	.10	.10	-.07		.98	1.02

	B	β	Sig	sr^2
Age	- 0.28	- 0.94	p = .000	.45
Education	2.32	0.56	p = .000	.16
Baecke	- 1.13	- 0.10	p = .261	.01
MAAS	0.54	0.067	p = .443	.005

Intercept = 34.36 $R^2 = .48$ *adj.* $R^2 = .45$

Baecke = Baecke Questionnaire for the Evaluation of Habitual Physical Activity

LT MM Hrs = Lifetime hours of mindfulness meditation experience

MAAS = Mindfulness Attention Awareness Scale

CFIT = Cattell Test of Fluid Intelligence/Culture-Fair Intelligence Test

CHAPTER 4

DISCUSSION

In this study, I used survey, self-report and performance data to investigate the link between mindfulness and fluid intelligence, which includes the set of cognitive abilities undergoing the steepest decline during the process of normal cognitive aging. The results show a unique significant positive relationship between mindfulness experience and fluid intelligence. This relationship was demonstrated even after four key factors known to affect fluid intelligence were taken into account. Although mindfulness meditation experience was related to fluid intelligence, it did not moderate the relationship of age and fluid intelligence in the current study. Trait mindfulness, contrary to the findings of Gard, Taquet, et al. (2014), had no unique relationship to fluid intelligence. It also played no moderating role. Contrary to expectation, physical activity showed no unique significant relationship to fluid intelligence (Colcombe, & Kramer, 2003; Colcombe et al., 2003; Etnier & Berry, 2001; Singh-Manoux et al., 2005). As expected based on prior research, both age and education were uniquely and significantly related to fluid intelligence scores (Albert et al., 1995; Colsher & Wallace, 1991; Dixon & de Frias, 2004; Farmer et al., 1995; Schaie, 1990; Schwartzman, Gold, Andres, Arbuckle, & Chaikelson, 1987; van Hooren et al., 2007).

Mindfulness Experience and Fluid Intelligence.

The positive relationship between mindfulness experience and fluid intelligence found in the current study is consistent with research finding better performance on measures of attention, working memory, executive functions, and a number of other cognitive factors among mindfulness practitioners (Allen et al., 2012; Anderson et al., 2007; Chambers et al., 2008; Chan & Woollacott, 2007; Gard, Taquet, et al., 2014; Hodgins & Adair, 2010; Jha et al., 2007; Jha et al., 2010; Josefsson & Broberg, 2011; Lutz et al., 2008; McHugh et al., 2010; Moore & Malinowski, 2009; Moynihan et al., 2013; Mrazek et al., 2013; Ortner et al., 2007; Pagnoni & Cekic, 2007; Slagter et al., 2007; Tang et al., 2007; Teper & Inzlicht, 2013; van den Hurk et al., 2010; van Leeuwen et al., 2009; Wenk-Sormaz, 2005; Zeidan et al., 2010). It is the second study to find a significant relationship between mindfulness-related practices and fluid intelligence, and the third study to examine these variables. Recently, Gard, Taquet, et al. (2014) found greater fluid intelligence, more functional brain network connectedness, and smaller declines in fluid intelligence with age among yoga practitioners and meditators. Tang et al. (2007) found improvements in executive attention and various health indicators in response to a Chinese medicine-derived intervention that included the cultivation of mindfulness. The link between meditation and fluid intelligence did not reach statistical significance in that study, but showed a trend in that direction.

While research indicating an effect of mindfulness practices on cognitive performance is encouraging, findings linking mindfulness to fluid intelligence are of particular interest in that this higher-order construct is predictive of success in many real-world contexts. Individuals with greater fluid intelligence tend to perform better academically (Vock, Preckel, & Holling, 2011), experience more career success (Schmidt & Hunter, 1998), and enjoy greater health and longevity (Deary, Weiss, & Batty, 2010).

The paucity of research investigating a relationship between mindfulness and fluid intelligence may be attributable both to the infancy of the field of mindfulness neuroscience and to the long-held assumption that fluid intelligence was innate and thus not modifiable (Cattell, 1963; 1987). Disappointing efforts to increase intelligence and strong evidence of its heritability seemed to support this assumption (Plomin et al., 2013; Sternberg, 2008). Recently, however, a number of studies have indicated that fluid intelligence scores can be increased by training in working memory (Jaeggi et al., 2014; Melby-Lervåg & Hulme, 2013; Shipstead et al., 2012; Stepankova et al., 2014; Zinke et al., 2014). Although some researchers have raised concerns about transfer of training and persistence of effects, identification of intervening individual difference variables may be a promising approach for addressing these concerns (Jaeggi et al., 2014).

Despite their preliminary nature, findings from the current research, combined with those of Gard, Taquet, et al., (2014), suggest that fluid intelligence may also be modifiable by mindfulness practices. However, it must be noted that both of these studies are correlational. Short-term longitudinal studies have shown that some lower-level cognitive abilities are enhanced by mindfulness practice. This supports the suggestion that mindfulness practices are causal in their relationship to cognitive factors related to fluid intelligence. However, because the research designs in this study and those of Gard and colleagues are correlational, an inference cannot be made that mindfulness causes increases in fluid intelligence. It is also possible that people with greater fluid intelligence may be more likely to engage in mindfulness practices. More intelligent individuals may also be more adept at evoking a focused and mindful state. Indeed, it may be that the relationship between mindfulness and fluid intelligence is iterative, with the focused observation induced through mindfulness practice increasing fluid abilities which then in turn facilitate mindful awareness, and so on. These are empirical questions to be answered in future research.

While significant, the unique contribution of mindfulness experience to fluid intelligence found in the present study is a modest one. Mindfulness experience only accounted for 4% of the variance in fluid intelligence scores. Age, on the other hand accounted for nearly half the variation in fluid intelligence ($sr^2 = .48$), while education uniquely contributed to 16% of the variation. It may be that this small effect size represents the true magnitude of the relationship of mindfulness practices to fluid intelligence. It is worth noting, however, that the mean lifetime practice hours among participants in this study was low ($M = 538.36$) in comparison to the mean practice hours reported in other mindfulness neuroscience research, where it ranged from 3,127.28 (Lazar et al., 2005) to 13,534 lifetime hours (Gard, Taquet, et al., 2014). The true magnitude of the effect may have been attenuated due to this range restriction (Goodwin & Leech, 2006). Additional studies with a broader range of meditation practitioners will be necessary to better understand the magnitude and shape of the relationship of mindfulness practice and fluid intelligence.

Although not measured in this study, speculation based on prior research yields a number of potentially salient variables that may underlie, mediate, or moderate the relationship of mindfulness practices and fluid intelligence. Cognitive factors related to fluid intelligence that are favorably impacted by mindfulness practices include attention (e.g., Chambers et al., 2008), working memory (e.g., Jha et al., 2010), and executive functioning (e.g., Moynihan et al., 2013). Working memory and executive functioning are considered fundamental constituents of fluid intelligence. Other potential intervening cognitive variables include cognitive flexibility (Moore & Mallinowski, 2009), and more efficient allocation of cognitive resources (Slagter et al., 2007).

Attention is such a fundamental mechanism that all cognitive functions rely on it to some degree, including intelligence (McDowd & Shaw, 2000). In a recent study, Unsworth, Fukuda, Awh, and Vogel (2014) found that attention control is an important component of the relationship between working memory and fluid intelligence. Attention control involves focusing attention on the task at hand while not getting swept up by distractions, a function that is fundamental to most meditation practices. The beneficial influence of mindfulness on the cognitive factor of attention is one of the most well-supported findings in mindfulness neuroscience (Chambers et al., 2008; Chan & Woollacott, 2007; Gard, Holzel, & Lazar, 2014; Jha et al., 2007; Valentine & Sweet, 1999).

Working memory is strongly related to fluid intelligence (e.g. Salthouse & Pink, 2008). In a recent meta-analysis, Au and colleagues (2014) concluded that n-back training, a common measure of working memory, is efficacious in improving performance on measures of fluid intelligence (Au et al., 2014). A number of studies indicate that working memory is increased by mindfulness practices (Chambers et al., 2008; Jha et al., 2010; Mrazek et al., 2013; Zeidan et al., 2010).

Executive functioning collaborates with working memory in the management of cognitive resources (Kray et al., 2004). It includes abilities required to direct behavior toward a goal, particularly in non-routine circumstances (Banich, 2009). Executive functioning has also been closely linked to fluid intelligence (Banich, 2009; Friedman et al., 2006; Salthouse & Davis, 2006; Unsworth et al., 2009). Whether looked at more narrowly as executive attention (Tang et al., 2007; Wenk-Sormaz, 2005; Zeidan et al., 2010) or studied as a more broadly-conceived set of functions (Allen et al., 2012; Moynihan et al., 2013; Teper & Inzlicht, 2013), researchers have found this construct to be enhanced by mindfulness training.

Cognitive flexibility is considered an important element of executive functioning (Crowe, 1998). It involves the ability to adapt cognitive strategies to meet unexpected conditions or demands in the environment (Cañas, Quesada, Antolí, & Fajardo, 2003). A number of studies have linked cognitive flexibility to fluid intelligence (Colzato, van Wouwe, Lavender, & Hommel, 2006; Dumontheil, Thompson, & Duncan, 2011; Duncan, 2010; Huepe & Salas, 2013). Researchers have also found increases in cognitive flexibility following mindfulness training (Heeren, Van Broeck, & Philippot, 2009; Moore & Mallinowski, 2009). Increased cognitive flexibility following mindfulness interventions has been demonstrated in older adults as well (Alexander, Langer, Newman, Chandler, & Davies, 1989).

The manner in which individuals with higher levels of fluid intelligence allocate cognitive resources has been found to differ from that of individuals with lower fluid intelligence (Neubauer, Grabner, Freudenthaler, Beckmann, & Guthke, 2004; Rypma et al., 2006; Van Der Meer et al., 2010). The neural efficiency hypothesis suggests that individuals with higher intelligence use cerebral resources more efficiently, resulting in lower total activation when engaged in cognitive tasks (Neubauer & Fink, 2009a). A number of studies lend research support to this hypothesis (Langer et al., 2012; Micheloyannis et al., 2006). Evidence suggests that individuals with higher levels of mindfulness experience allocate cognitive resources in a more efficient manner (Gard, Taquet, et al., 2014; Slagter et al., 2007). These lines of research may be seen as supportive of a causal inference for fluid intelligence on mindfulness experience, or the inferences of an iterative process initiated by the presence of higher fluid intelligence.

Drawing from neurocognitive research, speculation regarding the neurological substrates of the cognitive functions addressed above is also possible. Findings suggest that working memory, executive functions, and fluid intelligence are largely dependent on PFC circuitry (Miller & Cohen, 2001). Of particular significance is the role of the DLPFC and the ACC (Kane & Engle, 2002). Evidence consists of increased activation in these regions during cognitive performance (Pochon et al., 2001), correlating gray matter density in these areas (Johnson, Jung, Colom, & Haier, 2008), and increased interconnection of these areas with other key brain regions (Colom et al., 2009; Madden et al., 2012). Cortical interconnectedness related to fluid intelligence has been looked at in terms of white matter integrity (Grieve, Williams, Paul, Clark, & Gordon, 2007), thickness of the corpus callosum (Luders et al., 2007), and the functional connectivity of neural networks and network small-world characteristics (Langer et al., 2012; van den Heuvel, Stam, Kahn, & Hulshoff Pol, 2009).

Correspondingly, mindfulness practitioners have been found to have increased activation in PFC, DLPFC, ACC, frontal-parietal areas, and other anterior structures (Allen et al., 2012; Davidson et al., 2003; Dickenson et al., 2013; Holzel et al., 2007; Short et al., 2010), increased cortical thickness of gray matter in the PFC, ACC, and insula (Grant et al., 2010; Lazar et al., 2005), increased white matter integrity and thickness in PFC and other anterior regions of the brain (Kang et al., 2013), and increased connectivity in neural networks and network small-world characteristics (Gard, Taquet, et al., 2014). Neurocognitive studies looking at long-term meditators from a variety of traditions have found less gray matter atrophy among aging meditators in multiple brain regions compared with controls. Regions particularly salient to fluid intelligence include ACC, frontal regions, and parietal lobes (Luders, 2014; Luders, Cherbuin, & Kurth, 2015). Other cortical characteristics of long-term meditators from varied traditions include increased thickness of the corpus callosum (Luders, Phillips, et al., 2012) and larger gyrification within a number of regions, including the insula, a structure involved in the regulation of distractions (Luders, Kurth, et al., 2012). Cortical gyrification has been found to be positively correlated with intelligence (Luders et al., 2008).

Although some research suggests mindfulness experience may protect against or ameliorate cognitive and neurological declines in aging (Gard, Taquet, et al., 2014; Lazar et al., 2005; Luders et al., 2015; McHugh et al., 2010; Pagnoni & Cekic, 2007; van Leeuwen et al., 2009), mindfulness was not found to moderate the relationship of age and fluid intelligence in the current study. The studies noted above looked at lower-level constructs, with the exception of Gard, Taquet, et al. (2014) who found slower age-related declines in fluid intelligence among meditation and yoga practitioners.

The explanation for the inconsistency of my findings with those of Gard, Taquet, et al. (2014) may reside in the relative brevity of lifetime practice among my participants. The mean mindfulness meditation practice level in the current study was 538.36 lifetime hours. Gard and colleagues (2014), on the other hand, reported a mean of 7,458 lifetime practice hours for vipassana meditators and 13,534 lifetime hours for Kripalu yoga practitioners. Justifying their decision by the contention that Kripalu yoga has a strong mindfulness component, they compared yoga and meditation practitioners combined with control participants. The authors noted, however, that the slower age-related decline in fluid intelligence in their study was driven primarily by yoga practitioners and only partly by meditation practitioners. Looked at separately, the fluid intelligence decline for yoga practitioners was significant (p =0.032), while the decline for meditation practitioners showed a trend toward significance (p = 0.07). The authors attribute this finding to the substantial differences in lifetime practice hours between yoga and vipassana meditators in their study. If this attribution is correct, it lends strength to the argument that participants in the current study had insufficient mindfulness experience to demonstrate a moderating effect on age.

It must be noted, however, that in Gard, Taquet, et al. (2014), the practice method cannot be uncoupled from differences in the experience level of practitioners. If one categorizes meditation styles broadly as FA or OM as advocated by Lutz and colleagues (2008), the combination of vipassana and Kripalu practitioner data for analysis purposes can be justified. It should be pointed out, however, that these practices originated in different cultural and spiritual traditions: vipassana from Buddhism and Kripalu yoga from Hinduism. Vipassana is primarily based on the *Satipatthana Sutta*, the canonical Buddhist text with the fullest instructions on mindfulness practice (Thera, 2013). More than 50 different practices for the cultivation of mindfulness are included in this text (Goldstein, 2003). Kripalu is derived from *kundalini* yoga, one of the eight yoga varieties outlined in the *Yoga Sutras* by Patanjali (Bryant, 2009). Kundalini yoga emphasizes facilitating the movement of *prana*, or life-force energy, through the chakras, or energy centers, from the base of the spine to the crown of the head. In addition to the development of witness consciousness (an OM practice) Kripalu students attend to the flow of *prana*, practice yoga poses, and study *pranayama*, or yogic breathwork (Faulds, 2005). Because Kripalu has components in addition to those practiced by vipassana students, the findings of Gard, Taquet, et al. (2014) may be due to the effects of one or more of these. However, the researchers report finding no significant differences between vipassana and Kripalu practitioners.

Trait Mindfulness and Fluid Intelligence

Gard and colleagues (2014) found a positive correlation between trait mindfulness and fluid intelligence, a finding not present in the current study. Moore and Mallinowski (2009) reported positive relationships between trait mindfulness and attention, a related lower-level cognitive variable. To explain these inconsistent findings, it is important to consider issues and concerns that have been raised regarding self-report measures of trait mindfulness in general, as well as the MAAS specifically.

Grossman (2008; 2011) and others have pointed out a number of validity problems with self-report measures of mindfulness (Awasthi, 2013; Bergomi, Tschacher, & Kupper, 2013; Christopher, Charoensuk, Gilbert, Neary, & Pearce, 2009). Chief among these is the issue of construct validity (i.e., are they measuring mindfulness?). At present, there is no gold standard external referent (Grossman, 2011). Most traditional Buddhist mindfulness teachers assert that mindfulness is complex and subtle, and is inextricably intertwined with other related concepts (Gunaratana, 2001; Mikulas, 2011; Rosenberg, 2004). Whereas some neurological correlates have been identified, there is as yet no replicated set of cortical markers that are known to discriminate the mindful state or to index stages in the development of mindfulness as detailed in the traditional Buddhist literature (Awasthi, 2013).

A second related issue concerns lack of an agreed-upon operational definition of mindfulness (Bergomi et al., 2013; Grossman, 2008; 2011). Eight adult mindfulness scales are currently available (Bergomi et al., 2013). Although there are areas of convergence, each scale defines mindfulness differently and many correlate poorly with others (Grossman, 2011). This makes comparisons across studies difficult. Is mindfulness a single factor, as Brown and Ryan (2003) argue, or are there several aspects to the construct, as other scale developers contend (e.g., Baer et al., 2004; Baer et al., 2006)? Brown, Ryan, and Creswell (2007) have criticized the other scales for conflating mindfulness with mindfulness skills and attitudinal supports, whereas Grossman (2011) has criticized the MAAS as not representing all qualities included in the Buddhist construct. Could these scales be tapping constructs other than mindfulness? Grossman (2011) claims that the MAAS measures not mindfulness or awareness, but rather the propensity to experience lapses of attention (Carriere, Cheyne, & Smilek, 2008), and Rosch (2007) asserts that the FFMQ (Baer et al., 2006) and other trait mindfulness scales may actually measure all-around psychological adjustment rather than mindfulness. Ortner et al. (2007), cited in the Introduction, measured state mindfulness during meditation with the TMS (Lau et al., 2006) and trait mindfulness with the MAAS. While meditators with more mindfulness experience scored higher on the TMS, scores on the TMS did not correlate with self-report well-being measures. Scores on the MAAS, however, were related to well-being measures but did not correlate with meditation experience.

Comparison of conclusions reached in the current research with those of the two studies cited earlier is problematic because each operationalized trait mindfulness differently. Gard and colleagues (2014) employed the FFMQ (Baer et al., 2006), Moore and Malinowski (2009) used the KIMS (Baer et al., 2004), and I measured trait mindfulness with the MAAS (Brown & Ryan, 2003). Whereas the MAAS has a one factor structure, the FFMQ has five factors, and the KIMS has three factors. The MAAS correlates poorly with the KIMS and the FFMQ (Baer et al., 2004; Baer et al., 2006). Although my conclusions diverged from expectations based on findings in these studies, the poor correlation of the MAAS with the measures employed by Gard, Taquet, et al. (2014) and Moore and Malinowski (2009) may account for the contradictory results.

Social desirability bias, a well-recognized issue with self-report measures (Crowne & Marlowe, 1960), may have also influenced results in the current study. Although the MAAS developers made efforts to address the issue of social desirability in their scale, the measure is not immune from this problem (Brown & Ryan, 2003; Grossman, 2011). Social desirability has been found to correlate positively with the MAAS (Brown & Ryan, 2003). Furthermore, Grossman (2008; 2011) has pointed out that items in the currently available self-report mindfulness scales may not be interpreted the same way across populations. In addition to being a problematic feature inherent to current scales, this issue is pertinent to social desirability bias. It is also related to the populations on which the scale has been validated, as further addressed below.

Much of the mindfulness research in the United States is conducted with urban samples from the Northeast and Western regions of the country. Conducting studies in those regions is convenient due to a preponderance of major universities and meditation centers. Recent research has identified regional personality differences in the United States that may color the interpretation of scale questions by study participants (Rentfrow et al., 2013). The authors found three distinct regional personality clusters in the United States. The rural Southeastern region, where the current research was conducted, is part of a cluster Rentfrow and colleagues (2013) termed Friendly and Conventional. Personality factors defining the region include moderately high levels of Extraversion, Agreeableness, and Conscientiousness, moderately low Neuroticism, and very low Openness. They characterize someone with these traits as "sociable, considerate, dutiful, and traditional" (Rentfrow et al., 2013, p. 1006). To the extent that participants in the current study share personality traits representative of the region in which they live, they may have been inclined to interpret and respond to MAAS items in conventional and socially desirable ways. In addition, these personality characteristics may have influenced respondents to interpret scale items in a manner congruent with traditional personal values or aspirations to belong (Bergomi et al., 2013; Christopher et al., 2009; Grossman, 2011; Van Dam, Earleywine, & Borders, 2010; Van Dam, Earleywine, & Danoff-Burg, 2009).

Degree of mindfulness experience may also influence the way scale items are interpreted. Grossman and Van Dam (2011) found that experienced mindfulness meditators and nonmeditators often attach different meanings to scale items. Christopher and colleagues (2009) reported that MAAS scores of Thai Buddhist monks with 15 years experience did not differ from those of a normative convenience sample with no meditation experience (Christopher, Christopher, & Charoensuk, 2009). In light of such findings, Grossman (2011) has speculated that it may require a certain degree of mindfulness to identify one's own mindful states. This inherent scale problem is particularly salient in this study because participants were largely nonmeditators and meditators with little experience.

Although Gard, Taquet, et al. (2014) did not examine interaction effects in their study, they speculate that trait mindfulness may have mediated the effect of meditation and yoga on fluid intelligence. However, I found that trait mindfulness played no intervening role in the relationship of mindfulness experience and fluid intelligence, nor did it moderate the effect of age on fluid intelligence. These findings are not unexpected, given that I found no significant relationship between trait mindfulness and fluid intelligence. In light of the mindfulness measurement issues noted above, it may be more accurate to say that scores on the MAAS did not moderate the effect of mindfulness experience or age on fluid intelligence scores.

Physical Activity and Fluid Intelligence

Contrary to expectation, I found no unique relationship between physical activity and fluid intelligence (Colcombe & Kramer, 2003; Colcombe et al., 2003). Although a great deal of research has pointed to the potential for exercise to boost cognitive performance among people of various ages (Bherer, Erickson, & Lui-Ambrose, 2014; Reed et al., 2010; Singh-Manoux et al., 2005), results of studies in this domain have not been unequivocal, particularly for older adults (Lautenschlager & Cox, 2013; Lochbaum, Karoly, & Landers, 2002; Snowden et al., 2011). Recent studies indicate that relatively high level of aerobic exercise may be required to demonstrate positive results (Kirk-Sanchez & McGough, 2014). The BQ activity measure (Baecke et al., 1982) used in this study includes questions regarding physical activities in the domains of Work, Sports, and Leisure. This measure may not have been adequately sensitive in its measurement of aerobic exercise. Likewise, participants' activity level may not have reached an adequate threshold to demonstrate a relationship to fluid intelligence. Alternately, participants may have misrepresented the level of their activity due to faulty memory, personality factors, or perceived socially desirable levels; factors that could be controlled by the addition of an objective measure of aerobic capacity, such as maximum oxygen uptake (Lochbaum et al., 2002).

Study Limitations

The principal limitation of this study is its correlational nature. For this reason, causality cannot be inferred. It may be the case that mindfulness experience increases fluid intelligence, but it is also possible that individuals with greater fluid intelligence choose to practice mindfulness. A second study was originally planned to partially address this issue. The study design included a mindfulness meditation intervention group and a meditation-naïve comparison group, prescreened for health and matched on age and trait mindfulness. Measures of fluid intelligence were to be obtained pre- and post-intervention. Unfortunately, due to constrained resources, I was unable to obtain a sufficient number of participants for an adequate test of the hypothesis. Although this second study design fell short of the gold-standard, longitudinal randomized controlled study, significant results would have bolstered the case for an inference of causality.

A second limitation of this study concerns issues regarding the study sample. In terms of mindfulness experience, participants were primarily nonmeditators and novice-level mindfulness meditation practitioners. This restriction of range not only limits the generalizability of the results, but also may have attenuated the magnitude of the relationship of mindfulness experience and fluid intelligence (Goodwin & Leech, 2006). It may also have reduced the likelihood of observing a moderating effect for mindfulness on the relationship of age and fluid intelligence were such an effect to be apparent at levels of experience greater than those of the study sample (e.g., Gard, Taquet, et al., 2014).

Another potentially relevant sample feature includes the geographic region from which participants were drawn and the typical values and personality characteristics of that region. Van den Hurk and colleagues found that Openness to Experience was positively related to mindfulness while Conscientiousness was negatively related (van den Hurk et al., 2011). Because the personality profile of individuals in the rural Southeast includes high Conscientiousness and very low Openness, they may have less propensity to be mindful, or less inclination or ability to practice meditation, than participants from other regions. These sample characteristics limit the generalizability of the findings. Moreover, this may have accounted for the limited number of participants with meditation experience in the sample as well as the low practice time of those who volunteered. In this manner, personality may have influenced the small magnitude of the relationship of meditation experience and fluid intelligence, and the absence of a mindfulness experience X age interaction. Furthermore, the meditators who volunteered for the current study were inclined toward meditation practice, which may have resulted in a selection bias. In the case of more experienced meditators, to maintain a practice over a longer period required at least a minimum level of commitment and discipline. Capturing and accounting for such personal traits in future studies may further our understanding of characteristics that may be unique to meditation sample of various experience levels.

A final limitation in regard to the study sample is a characteristic related to sample issues discussed above. Forty-four percent of the participants in the current study were drawn from a university volunteer pool, only 18% of whom had meditation experience. All of the student volunteers with meditation experience were novices. In addition, although this university was a commuter campus, the majority of student volunteers were young. Only one, in fact, was over 29 years old. This university sample was large enough that salient points of divergence from the remainder of the sample may have influenced my findings. These factors may account, at least in part, for inconsistencies in the results of this study with those of prior mindfulness neuroscience research. At the least, this sample characteristic delimits the generalizability of the findings.

Time spent in cognitively stimulating activities, especially solving problems and playing card, board, or video games, has been shown to affect cognitive performance and fluid intelligence (Anguera et al., 2013). Failure to control for this variable is a limitation of the current study. Controlling for educational level, however, accounted for some of the variance in intellectual stimulation (Parisi et al., 2012). Diet and economic status are other potentially confounding control variables not included in this study (Luders, 2014).

Daily practice was not measured in the current study. Although lifetime practice hours is the metric selected to measure meditation experience in recent research (e.g., Gard, Taquet, et al., 2014) and is more directly linked to objective measures (Lazar et al., 2005), the importance of consistent daily practice has been stressed by traditional meditation teachers (e.g., Goldstein, 2003; Mikulas, 2014). In addition, some researchers have found that the amount of time participants spent meditating each day had a more pronounced effect on cognitive performance than the total lifetime hours of practice (Chan & Woollacott, 2007; Tang et al., 2007). Indeed, lifetime practice alone may present an inaccurate picture of the experience level of participants. For example, one meditator may have 1,000 lifetime hours of practice, but none within the past 15 years. It is doubtful that the mindfulness level of this person would be comparable to that of another meditator with 1,000 lifetime hours of recent, consistent, daily practice. Although measuring total lifetime hours is useful for comparisons to recent research, some measure of daily practice would have presented a more complete picture in the current study. This would be particularly important in the case of lower experience levels (e.g., 40 lifetime hours of practice, but none within the last 20 years).

An issue closely related to amount of experience is the quality of meditation practice. While there is also no gold-standard external referent for practice quality, the TMS (Lau et al., 2006) is a self-report measure designed to assess the capacity to invoke a mindful state during meditation. A measure of meditation quality, coupled with information on mindfulness experience duration and recency, would offer three parameters with which to construct a more complete picture of practitioner adeptness. Unfortunately, the TMS suffers from some of the issues with self-report measures noted earlier, and there is indication that the TMS lacks sensitivity to measure practice quality in more experienced practitioners (Lau et al., 2006; Thompson & Waltz, 2007). In addition, studies show little relationship of the TMS and measures purporting to measure trait mindfulness (Carmody et al., 2008; Thompson & Waltz, 2007).

A final limitation concerns the use of a single measure, the CFIT, to measure fluid intelligence. Any measure, no matter how well-constructed, not only captures the construct of interest, but includes some measurement error (Campbell & Stanley, 1963; Fuller, 1987). Therefore the use of a single measure of fluid intelligence leaves open the possibility that non-intelligence components of test performance have been affected by mindfulness. The inclusion of additional fluid intelligence measures, such as the WAIS-III performance scales or Raven's Advanced Progressive Matrices (Raven, Raven, & Court, 1998) would strengthen confidence in the findings.

Conclusion and Future Directions

The longitudinal, randomized research design is an important tool with which to test causal relationships. Traditional Buddhist teachings assert that the most important effects of meditation evolve over extended periods of time. Many effects, particularly on variables such as fluid intelligence, may be only marginal after short periods of meditation training. However, longitudinal meditation research is subject to a number of feasibility constraints, such as budgetary limitations and attrition. In natural environments, meditation training is individualized. Practitioners determine which meditation style, teacher, and routine best suits their interests, inclination, and level of motivation (Luders, 2014). Randomized longitudinal studies require control of instructors, techniques, routines and setting, leading inevitably to artificial conditions that affect attrition and decrease generalizability. Nevertheless, in order to confirm a causal effect of mindfulness on fluid intelligence, a longitudinal study is invaluable, preferably with an active control group. One potential approach is to randomly assign meditation-naïve participants to attend either a series of mindfulness meditation retreats or to participate in a relaxation and psychoeducational group. Shorter-term longitudinal studies may be helpful, but in light of my findings, it is doubtful that under 500 hours of mindfulness practice would be sufficient to produce a discernable effect on fluid intelligence. In terms of cognitive aging research, the findings of Gard, Taquet, et al. (2014) suggest that an excess of 7,000 mindfulness practice hours may be required to detect a moderating effect in the relationship of age on fluid intelligence, thus obviating the utility of shorter-term designs. Additional research will be necessary to determine the amount of meditation experience necessary to accomplish desired effects.

Due to the feasibility constraints of long-term prospective research, well-designed cross-sectional studies with highly experienced meditators will continue to be a valuable avenue to explore the relationship of mindfulness and fluid intelligence, particularly in older adults. In cross-sectional studies, the addition of archival intelligence scores (WAIS performance scale scores in particularly) would bolster causal inference if adequate controls could be established (e.g., the addition of a comparison group matched on age and fluid intelligence scores obtained before meditation practice was initiated). In addition to the variables controlled in the current study, other variables include time spent in cognitively stimulating activities, diet, and socio-economic status (Anguera et al., 2013; Luders, 2014). Combining fluid intelligence measures with a variety of neurocognitive measures (e.g., Gard, Taquet, et al., 2014) would add to our understanding of neural changes underlying the effects of mindfulness meditation on fluid intelligence. Separating mindfulness practitioners into subgroups with difference experience levels may provide insights into how practice levels link with neural correlates.

Considering potential intervening variables produces a range of possibilities for future studies. Among the cognitive variables noted previously, attention, working memory, and executive functioning are related to both mindfulness and fluid intelligence. Future studies should also look at the potentially mediating effects of cognitive flexibility and allocation of cognitive resources (Heeren et al., 2009). Working memory and executive functioning have been shown to be negatively affected by stress (Luethi, Meier, & Sandi, 2009; Schoofs, Wolf, & Smeets, 2009). The stress-reducing properties of mindfulness practices have been well-researched (e.g., Fjorback et al., 2011), indicating another potential intervening mechanism. Finally, future research should also examine the interaction of mindfulness and personality variables. Ziegler and colleagues found that Openness to Experience affected increases in fluid intelligence over time (Ziegler, Danay, Heene, Asendorpf, & Bühner, 2012). Openness has also been found to be positively related to mindfulness (van den Hurk et al., 2011; Carmody, Baer, Lykins, & Oldenzki, 2009), although the direction of this relationship has not been established.

Although often grouped together, Eastern spiritual, religious, or philosophic traditions are numerous and varied. An introductory text lists nine major world religions originating in Asia and the Middle East (Burke, 2004). These spiritual traditions can be further divided into sects, arising both within the countries that birthed the religions and through adaptation in the various regions to which they spread. Meditation, or some form of contemplative practice, is associated with many of these spiritual traditions and sects (Shear, 2006). It is important to appreciate the rich diversity of meditative practices in order to avoid a parochial conception of what meditation entails. Moreover, it is incumbent upon researchers to become familiar with the key texts of the traditions they wish to study. If we base our research solely on Westernized conceptions of mindfulness, particularly without firmly establishing a practice ourselves, we run the risk of sacrificing the subtlety and richness that adept meditation teachers have sought to convey. It is hubris to assume a relatively brief description, or even a body of scientific work, can convey the essence of such a practice. The positivistic, psychological investigation of mindfulness is only a few decades old, whereas the Buddhist phenomenological approach has evolved over millennia. With this in mind, qualitative investigations, particularly with highly experienced meditators, may provide an additional approach to further our understanding of the phenomena of mindfulness and its effect on fluid intelligence (Grossman, 2011). Such studies may provide new insights into the potential mechanisms involved and how they may relate to various stages of practice.

The current research suggests that mindfulness experience is positively associated with fluid intelligence. Methods to increase fluid abilities that are easily accessible and cost-effective have multiple benefits. Mindfulness practices may be such a method. Moreover, mindfulness has positive effects in other life domains that magnify its value, such as decreasing stress and depression and increasing positive emotions and subjective well-being (Goyal et al., 2014). Although extensive practice may be required in order to appreciably modify fluid intelligence, effects on lower-order cognitive processes that may presage changes in fluid intelligence have been found after practice of modest duration (Chiesa et al., 2011; Fjorback et al., 2011). With a higher-order construct such as fluid intelligence, even small improvements may have wide-ranging societal consequences (Au et al., 2014).

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Appendix A – Screening Questionnaire

Date: ____

MEDICAL HISTORY

8. Overall, how would you rate your health? (Check one)

1) Excellent _____ 2) Very Good _____ 3) Good _____ 4) Fair _____ 4) Poor _____

9. Which medical conditions below do you or have you had? (Check all that apply)

I. NERVOUS SYSTEM PROBLEMS

a) Stroke ______

b) Dementia or Alzheimer's Disease ______

c) Parkinson's Disease ______

d) Epilepsy or Seizures ______

e) Head/Brain Injury ______

f) Multiple Sclerosis (MS) ______

II. HEART PROBLEMS

a) Coronary Artery Disease ______

b) Congestive heart failure ______

c) Heart attack ______

III. MENTAL HEALTH PROBLEMS

a) Depression * ______

b) Anxiety, Panic Disorder, PTSD * ______

c) Substance Abuse/Addiction * ______

d) Eating Disorder ______

e) Serious Mental Illness ______

(Schizophrenia, Bipolar Disorder, etc.)

IV. LUNG PROBLEMS

c) Emphysema/COPD ______

d) Tuberculosis ______

V. OTHER

a) Cancer: Type ____________ ______

b) Other Serious or Chronic Illness ______

10. List medicines that you use regularly.

__________________ __________________ __________________

__________________ __________________ __________________

__________________ __________________ __________________

MEDITATION EXPERIENCE

11. Have you ever practiced concentration (one-pointed) a form of meditation focus?

Yes ____ No ____ If YES, what kind? __________________________________

12. Please check your level of experience with concentration meditation:

1) Beginner ____ 2) Brief Experience ____ 3) Intermediate ____ 4) Advanced ____

APPENDIX B – DEMOGRAPHICS, EDUCATION, AND MINDFULNESS QUESTIONNAIRE

Survey Number: ___________________ **Today's Date:** ___________

Date of Birth ____/____/____ (day/mo./yr.) **Age:** _______

Sex: 1)___Male 2)___Female

Race (check one)

1. ___ White/Caucasian
2. ___ Black/African American
3. ___ Hispanic
4. ___ Asian
5. ___ Bi-racial
6. ___ Other

How much school did you complete? (check one)

1. ___ Less than 6th grade
2. ___ Less than high school graduate
3. ___ High school graduate/GED
4. ___ Some college/Technical school
5. ___ College graduate
6. ___ Some post-college
7. ___ Advanced degree

MINDFULNESS EXPERIENCE

1. Have you ever practiced **mindfulness** or **awareness meditation** (such as Vipassana, Insight Meditation, Zen or Tibetan awareness practices, Mindfulness Based Stress Reduction [MBSR]) Yes ___ No ___

IF YES, PLEASE ANSWER THE FOLLOWING QUESTIONS:

2. Do you currently practice mindfulness or awareness meditation? Yes ___ No ___

3. Give your best estimate of your TOTAL LIFETIME HOURS of formal sitting meditation practice: _____________

Appendix C – Baecke Questionnaire of Habitual Physical Activity

Circle the number that corresponds to the description that most applies to you

Work Index	**Response**
What is your main occupation?	______________________
low activity	1
moderate activity	3
high activity	5
At work I sit	
never	1
seldom	2
sometimes	3
often	4
always	5
At work I stand	
never	1
seldom	2
sometimes	3
often	4
always	5
At work I walk	
never	1
seldom	2
sometimes	3
often	4
always	5

At work I lift heavy loads

never	1
seldom	2
sometimes	3
often	**4**
always	5

After working I am tired

very often	5
often	4
sometimes	3
seldom	2
never	1

At work I sweat

very often	5
often	4
sometimes	3
seldom	2
never	1

In comparison of others of my own age
I think my work is physically

much heavier	5
heavier	4
as heavy	3
lighter	2
much lighter	1

Sport Index

Do you play sports?

yes	2
No	1

In comparison with others of my own age think my physical activity during leisure time is

much more	5
more	4
the same	3
	Response
Less	2
much less	1

During leisure time I sweat

very often	5
Often	4
sometimes	3
Seldom	2
Never	1

During leisure time I play sports

Never	1
Seldom	2
sometimes	3
Often	4
very often	5

The sport intensity is divided into 3 levels:
(1) low level (billiards sailing bowling golf etc)
(2) middle level (badminton cycling dancing swimming tennis)
(3) high level (boxing basketball football rugby rowing)

What sport do you play most frequently?

____

	Response
low intensity	1
medium intensity	2
high intensity	3

How many hours do you play a week?

< 1 hour	0.5
1-2 hours	1.5
2-3 hours	2.5
3-4 hours	3.5
> 4 hours	4.5

How many months do you play sports in a year?

< 1 month	0.04
1-3 months	0.17
4-6 months	0.42
7-9 months	0.67
> 9 months	0.92

Leisure Index

During leisure time I watch television

never	1
seldom	2
sometimes	3
often	4
very often	5

During leisure time I walk

never	1
seldom	2
sometimes	3
often	4
very often	5

During leisure time I cycle

never	1
seldom	2
sometimes	3
often	4
very often	5

How many minutes do you walk and/or cycle per day to and from work school and shopping?

< 5 minutes	1
5-15 minutes	2
15-30 minutes	3
30-45 minutes	4
> 45 minutes	5

SCORING:

The work activity includes (1) low activity including clerical work, driving, retail clerk, teaching, studying, housework, medical practice, and occupations requiring a university education; (2) middle activity including factory work, plumbing, carpentry, and farming; (3) high activity includes dock work, construction work, and professional sports.

The sport intensity is divided into 3 levels: (1) low level (billiards, sailing, bowling, golf, etc.) with an average energy expenditure of 0.76 MK/h; (2) middle level (e.g., cycling, dancing, swimming tennis, low-intensity aerobics) with an average energy expenditure of 1.26 MJ/h; (3) high level (e.g., basketball, football, boxing, rowing, high-intensity aerobics) with an average energy expenditure of 1.76 MJ/h

WORK INDEX = [6 – (points for sitting) + SUM (points for the other 7 parameters)] / 8
SPORTS INDEX = SUM (points for all 4 parameters) / 4
LEISURE INDEX = [6 – (points for television watching) + SUM(points for remaining 3 items)] / 4
TOTAL SCORE = (WORK INDEX + SPORTS INDEX + LEISURE INDEX) / 3

Appendix D – Mindful Attention Awareness Scale

Day-to-Day Experiences

Instructions: Below is a collection of statements about your everyday experiences. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what *really reflects* your experience rather than what you think your experience should be. Please treat each item separately from every other item. SCORING: Compute the mean of the 15 items.

1	2	3	4	5	6
Almost Always	Very Frequently	Somewhat Frequently	Somewhat Infrequently	Very Infrequently	Almost Never

I could be experiencing some emotion and not be conscious of it until some time later.	1	2	3	4	5	6
I break or spill things because of carelessness, not paying attention or thinking of something else.	1	2	3	4	5	6
I find it difficult to stay focused on what's happening in the present.	1	2	3	4	5	6
I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.	1	2	3	4	5	6
I forget a person's name almost as soon as I've been told it for the first time.	1	2	3	4	5	6
It seems I am "running on automatic," without much awareness of what I'm doing.	1	2	3	4	5	6
I rush through activities without being really attentive to them.	1	2	3	4	5	6
I get so focused on the goal I want to achieve that I lost touch with what I'm doing right now to get there.	1	2	3	4	5	6
I do jobs or tasks automatically, without being aware of what I'm doing.	1	2	3	4	5	6
I find myself listening to someone with one ear, doing something else at the same time.	1	2	3	4	5	6