THIS IS YOUR BRAIN ON MINDFULNESS: DISPOSITIONAL MINDFULNESS AND NEURAL ACTIVITY IN ATTENTIONAL NETWORKS

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ABSTRACT

Mindfulness is the basis of behavioral therapies treating mental illness. Evidence suggests mindfulness is attentional skill-set composed of two skills, concentrative and receptive attention. It was hypothesized concentrative attention scores would correlate with activity in the dorsal network and receptive attention scores would correlate with activity in the dorsal and ventral networks. Functional magnetic resonance imaging (fMRI) was used to test this relationship. Participants took a mindfulness inventory and completed an attentional task in the fMRI scanner. Receptive attention correlated with activity in both networks as hypothesized. Concentrative attention did not correlate with activity in the dorsal network. These results support an attentional conceptualization of mindfulness, although the hypothesis about mindfulness skills and specific attentional networks was only partially supported.

Dr. Gordon B. Bauer

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Introduction

Mindfulness is a set of skills derived historically from Buddhist meditation. It is a critical component of new, promising behavioral therapies that treat a range of mental illnesses and psychological stress related to physical ailments (Speca, Carlson, Goodey, & Angen, 2000; Schapiro, Schwartz, & Bonner, 1998; Baer, 2003; Ramel, Goldin, Carmona, & McQuoid, 2004; Teasdale et al., 2000; Williams, Teasdale, & Segal, 2000; Williams et al., 2008). These illnesses range from depression to borderline personality disorder, which is a pattern of pervasive instability in the domains of interpersonal relationships, affect, and self-identity (American Psychiatric Association [*DSM-IV-TR*], 2000). Despite their success, the psychological mechanisms that account for the efficacy of these therapies are not well understood or agreed upon (Baer, 2003; Martin, 2007; Bishop et al., 2004; McKee et al., 2007; Vujanovic et al. 2009; Coffey & Hartman, 2008). Ultimately, the goal of mindfulness research is to understand what is driving the efficacy of mindfulness therapies and thus improve the therapies. It is unclear whether attentional or affective self-regulatory skills are the basis of mindfulness (McKee et al., 2007; Vujanovic et al. 2009; Coffey & Hartman, 2008), though there is strong evidence supporting mindfulness as an attention skill (Tang et al., 2007; Slagter et al., 2007; Wenk-Sormaz, 2005; Chan & Wollacott, 2007; Valentine & Sweet, 1999; Moore, & Malinowski, 2009). Furthermore, the most accepted definition of mindfulness presents it as an attentional skill (Bishop et al., 2004).

The attentional definition proposed by Bishop et al. (2004) describes mindfulness as a two-component skill-set. The first component is the “self-regulation of attention,” which is “bringing awareness to current experience” and maintaining focus on a specific object (Bishop et al., 2004). The second component is a unique “orientation to experience” to allow all thoughts and experiences to enter awareness without a specific object of focus or agenda (Bishop et al., 2004). Thus, these skills can be summarized as “concentrative” and “receptive” attention, respectively. Receptive attention poses a conceptual challenge to many Western scientists; it is not a state of having “no attention”, but is an expansion of the focus of attention coupled with rapid deployment and detachment of attention. This classification scheme is the most popular one in the literature currently (Lutz et al., 2008; Jha, Krompinger, & Baime, 2007; Ivanovski & Malhi, 2007; Cahn & Palich, 2006; Brown, Ryan, & Creswell, 2007; Valentine & Sweet, 1999; Chan & Wollacott, 2007). Though these skills are distinct, it is possible they develop sequentially, and that receptive attention develops after the cultivation of concentrative attention (Jha, Krompinger, & Baime, 2007). Indeed, long-term meditators may become proficient in both, regardless of the type of mindfulness training they have received. Even if the two skills are fundamentally intertwined, it is possible to assess the two skills separately. I think it will be the most informative to assess the skills independently and see how they are related to a dependent variable measuring an aspect of attention rather than comparing people given receptive attention training to people given concentrative attention training.

With an attentional conceptualization of mindfulness, it is necessary to discuss current perspectives on attention. Attention is most commonly defined as “the process of concentrating on specific features of the environment, or on certain thoughts or activities” (Goldstein, 2005). However, it is more informative to define it as a skill-set rather than a unitary construct because a two-skill definition is able to better explain the results of current neuroimaging studies of selective visual attention. Moreover, the skill-set definition to be proposed maps onto mindfulness skills nearly perfectly. Attention is composed of both goal-driven and stimulus-driven attention (Corbetta & Shulman, 2008). Goal-driven attention biases the processing of stimuli by generating and maintaining top-down signals using goals and expectations of likely outcomes (Corbetta & Shulman, 2008). Stimulus-driven attention “detects salient and behaviorally relevant stimuli in the environment, especially when unattended” (Corbetta & Shulman, 2008). Goal-driven attention is mediated by a dorsal frontoparietal network, and stimulus-driven attention is mediated by both the dorsal frontoparietal network and a ventral frontoparietal network (Corbetta & Shulman, 2008). The ventral network responds particularly well during a breach of expectation (Corbetta & Shulman, 2008). The evidence clearly suggests that both the dorsal and ventral networks mediate stimulus-driven attention in the context of behaviorally relevant stimuli. However, the relationship between attentional networks and salient but irrelevant stimuli is unclear. Most experiments merely present the relevant stimulus in an unexpected location rather than introducing a novel and task-irrelevant stimulus. Independent of the relationship between neural networks and attentional skills, a striking similarity emerges from the definitions mindfulness skills and attentional skills. In fact, I hypothesize the concentrative attention maps onto goal-driven attention, and receptive attention maps on to stimulus-driven attention.

Indeed, behavioral experiments provide support to the attentional conceptualization of mindfulness. These experiments use different techniques to teach participants mindfulness, one of which is meditation. Mindfulness can be cultivated in many ways. The most common technique is meditation. In several experiments, researchers taught participants how to meditate and then gave them attentional assessments (Tang et al., 2007; Slagter et al., 2007; Wenk-Sormaz, 2005). Afterwards, the participants demonstrated a strong improvement in attentional performance as assessed by a variety of standardized and well-accepted measures of attention (Tang et al., 2007; Slagter et al., 2007; Wenk-Sormaz, 2005). One study examining the relationship between dispositional mindfulness as measured by the Kentucky Inventory of Mindfulness Skills and attention found higher mindfulness scores predicted greater accuracy and speed on two standardized measures (Moore & Malinowski, 2009). Other experiments examined the difference between long-term meditators and controls (Chan & Wollacott, 2007; Valentine & Sweet, 1999). Furthermore, one experiment demonstrated that participants had attentional skill improvements that were specific to the type of mindfulness training they had, either concentrative or receptive (Valentine & Sweet, 1999). One other study, however, found no difference between two groups of participants trained extensively in either concentrative or receptive meditation (Chan & Wollacott, 2007). More evidence is necessary to see if these skills are really distinct and correlate with different attentional processes.

Brain imaging research aids the scientific community in understanding the relationship between mindfulness and cognition. Experiments on the neural basis of mindfulness have shown inconsistent patterns of neural activity, and have generally focused on participants meditating in a scanner rather than engaging in specific cognitive tasks. Because the benefits of meditation lie in the application of mindfulness to daily life, studying meditation is not enough to improve our understanding of mindfulness. The way to test how mindfulness actually “works” is to give participants a series of tasks in the brain scanner, with each requiring different skills and seeing where the differences arise between people scoring high and people scoring low on a mindfulness inventory. For instance, it would be useful to study participants’ performance on tasks assessing different aspects of attention, the self-regulation of emotion, and affect labeling. In this way it would be possible to make specific testable hypothesis about what cognitive mechanism accounts for the beneficial effects of mindfulness. Therefore, more neuroimaging research on the cognitive mechanisms of mindfulness as a skill in daily life on a cognitive task would be helpful to get a clear picture of the psychological mechanisms involved. The goal of this study is to examine the relationship between mindfulness, measured as a skill, and neural activity on a selective visual attention task to test the attentional conceptualization of mindfulness.

Once researchers determine which cognitive mechanisms make mindfulness therapies effective, it may be possible to modify these therapies to maximize their efficacy. The first half of this literature review is on the definition and cognitive components of mindfulness, its relationship to other well-understood psychological constructs, ways to assess it, behavioral experiments on its relationship with attention, and the clinical relevance of mindfulness. The second half is on the nature of selective visual attention and the neural correlates of selective visual attention. Finally, I will synthesize these topics to create a hypothesis relating specific mindfulness skills to activity in distinct neural networks.

Conceptualizing Mindfulness

Structured skill-based therapy programs, such as cognitive behavioral therapy (CBT) and mindfulness-based therapies are becoming increasingly popular because they have been standardized, are easy to teach, and have strong empirical support for their efficacy. Unlike CBT, mindfulness therapies have not been created from new operationalized definitions of desired skills, but have been adapted from a pre-existing religious tradition (Hayes & Shenk, 2004). Thus, the efficacious components and mechanisms are largely unknown and not precisely operationalized.

For the purpose of therapeutic intervention it is useful to conceptualize mindfulness as a set of skills, which can be learned through a variety of practices including formal sitting meditation, and which result in a mindful state.

This mindful state may become an intrinsic part of one's personality, but it must be consistently maintained. I hypothesize what is important for treatment outcomes is not how "mindful" a state one can achieve during formal sitting meditation, but rather how well one integrates this state into daily life as a trait, independently of how the individual learned it. It may be easier to practice mindfulness skills in a particular setting and during a particular time designated for the explicit task of meditation than to consistently apply these skills. Ultimately, the goal of mindfulness interventions is to teach skills which produce long-lasting changes in the individual, including the desire and ability to maintain a continuous mindful state.

One study indirectly supports the conclusion that applying mindfulness skills to daily life is more important than achieving a mindful state during meditation. It does so by suggesting there is actually little relationship between the state cultivated in sitting meditation and the measures of mindfulness as a trait (Thompson & Waltz 2007). The researchers first instructed novice participants to meditate and then gave them a survey to measure how mindful they were in practice, the Toronto Mindfulness Scale (TMS) (Thompson & Waltz 2007). Afterwards, the researchers gave participants a measure of mindfulness in daily life, either the Five Factor Mindfulness Questionnaire (FFMQ) or the Mindful Attention Awareness Scale (MAAS) (Thompson & Waltz 2007). The researchers counterbalanced the order of presentation of the meditation session and the assessment of mindfulness in daily life (Thompson & Waltz 2007). They found either extremely small or non-significant correlations between these two measures (Thompson & Waltz 2007).

Defining mindfulness as a cognitive skill has many advantages. One advantage of the Bishop et al. cognitive definition is that it aims to distinguish the basic cognitive processes from other related positive psychological outcomes. Many researchers who define mindfulness as a construct using behavioral outcomes come to very different conclusions about the nature of mindfulness. These conclusions can ultimately be unified if mindfulness is considered in terms of cognitive mechanisms. One alternative definition, proposed by Leary and Tate (2007) includes diminished self-talk, non-judgment, non-doing, and prosocial philosophical underpinnings. Diminished self-talk, which is ceasing the constant internal dialogue an individual has in his or her head, may be a result of the ability to focus intently on the present. Non-doing, which is the process of acting without the desire for an explicit outcome, may result from the ability to take a detached “receptive” perspective on one’s life.

Before creating the Kentucky Inventory of Mindfulness Skills (KIMS) with its precise cognitive operational definitions, Baer (2003) also proposed several specific outcomes to explain the efficacy of mindfulness which ultimately stem from the basic attentional control mechanisms. Baer suggests mindfulness skills help by providing exposure to difficult thoughts or emotions, much in the same way programs designed to treat phobias or post-traumatic stress do (2003). Mindfulness skills, moreover, may teach self-regulation by helping individuals recognize bodily signals, thoughts, or emotions that may precipitate a maladaptive behavior, such as noticing when negative thoughts turn into rumination (Baer 2003). Emotional self-regulation, however, may be a result of receptive attention as well.

The relationship between mindfulness and relaxation is complex. While mindfulness may result in a state of relaxation, the goal is to accept states which are not ultimately compatible with relaxation such as autonomic arousal (Baer 2003). Ultimately, these mechanisms, like the ones proposed by Leary and Tate (2007) spring from the same source of attentional control.

Assessment of Mindfulness

Even more so than operational definitions, it is necessary to have instruments that quantify mindfulness skills to evaluate mindfulness-based therapies and investigate the cognitive mechanisms responsible for desirable mental health outcomes. One such instrument is the Kentucky Inventory of Mindfulness Skills (KIMS) (Baer, Smith, & Allen, 2004). The KIMS measures the tendency to be mindful in daily life. It is based on the mindfulness skill set created by Marsha Linehan in Dialectical Behavioral Therapy (DBT), a program designed to treat borderline personality disorder (Baer, Smith, & Allen, 2004). The KIMS operates under the assumption that everyone is to varying degrees mindful in daily life. Though it may seem problematic to assess mindfulness skills (or any skill) via self-report, it is important to remember that several disciplines of psychology revolve around self-report measures and to invalidate self-report measures is to invalidate fields such as personality psychology.

The KIMS has four subscales, which include both attentional and affective components. These subscales are Observing, Describing, Acting With Awareness, and Accepting Without Judgment (Baer, Smith, & Allen, 2004).

The Observing subscale measures the tendency to attend a “variety of stimuli, including internal phenomena such as bodily sensations, cognitions, and emotions, and external phenomena, such as sounds and smells” (Baer, Smith, & Allen, 2004). This subscale includes items such as “I notice changes in my body, such as whether my breathing slows down or speeds up” (Baer, Smith, & Allen, 2004). The Observing subscale appears intimately tied to receptive attention, and this assumption is at the core of my experimental design.

The Describing subscale measures the tendency to “covertly apply words” to observed internal or external phenomena (Baer, Smith, & Allen, 2004). Describing, however, is not universally accepted as a valid part of the mindfulness construct because it encourages conceptual processing (Baer, Smith, & Allen, 2004), which mindfulness does not. I agree with this position.

The Acting With Awareness subscale may tap into the "concentrative attention" skill, because it is "engaging fully in one's current activity with undivided attention, or focusing of attention on one thing at a time" (Baer, Smith, & Allen, 2004). The opposite of this skill is the tendency to exist in "automatic pilot" (Baer, Smith, & Allen, 2004). Several of the items on the KIMS are reverse-scored to reflect living in a state of automatic pilot, such as "when I do things, my mind wanders and I am easily distracted" (Baer, Smith, & Allen, 2004).

The last of these four subscales is the Accept Without Judgment subscale. This subscale measures the tendency to be "nonjudgmental or nonevaluative about present moment experience" (Baer, Smith, & Allen, 2004). This subscale, however, measures the affective counterpart of the receptive attentional skill. As discussed earlier, this skill may actually be a by-product of cultivating receptive attention. The KIMS is an interesting instrument because it takes into account the multi-faceted nature of the mindfulness construct, rather than just generating a single mindfulness score. The KIMS thus allows the attentional components of mindfulness to be analyzed separately.

Though the KIMS is a self-report measure of a trait, preliminary evidence suggests these scores correlate positively with successful treatment outcomes of an existing mindfulness therapy, Mindfulness-Based Cognitive Therapy (MBCT). MCBT is different from many cognitive therapies in that it does not teach participants to challenge distorted thinking, emotional regulation skills, or interpersonal skills, but emphasizes mindfulness-practice (Baer, Fischer, & Huss, 2006). In one study ten women with binge-eating disorder participated in a ten-session program, and were given the KIMS before and after the treatment (Baer, Fischer, & Huss, 2006).

After treatment the participants showed an improvement on the Beck Depression Inventory-II, a decrease in objective binge-eating events, and a substantial improvement in eating concerns as measured on the Eating Disorder Examination (Baer, Fischer, & Huss, 2006). In addition, in the post-treatment analysis, there was a significant positive increase in the scores on the “Observation” and “Nonjudgmental Acceptance” subscales, which were the only two subscales of the KIMS used (Baer, Fischer, & Huss, 2006). Thus, though the KIMS is a measure of a trait in everyday life, it also is relevant to clinical outcomes.

In addition to the KIMS, there are other instruments which measure mindfulness. The TMS, mentioned above, measures how mindful one is in the moment as opposed to on a daily basis (Brown, Ryan, & Creswell 2007). This scale may be informative to assess the value of a particular sitting meditation protocol, but the salutary effects of mindfulness come from how effectively you can apply the skills to daily life rather than how effectively you can achieve a mindful state during a structured practice. The Mindful Attention Awareness Scale (MAAS) also measures how mindful one is during daily life, but it treats mindfulness as a unitary construct, which can lead to misleading conclusions (Baer, Smith, & Allen, 2004). For instance, the results of the study discussed above by Thompson and Waltz (2007) which found no relationship between the MAAS and the TMS may be due to the fact the MAAS is a unitary construct when mindfulness is not. Baer (2004) conducted a factor analysis on five independently created mindfulness inventories, and found a consistent five-factor structure.

Mindfulness in Relationship to Other Psychological Constructs

Whenever a new psychological construct emerges, it is often informative to see how it is related to other more well-understood constructs and to establish convergent validity. The NEO Five Factor Inventory (FFI) is a five factor model of personality, including openness, agreeableness, conscientiousness, neuroticism, and extraversion (Baer, 2004). Baer found that the Observe, or receptive attention, subscale correlated positively with openness. Moreover, this subscale correlates positively with several subscales on an emotional intelligence instrument, the Trait Meta-Mood Scale (TMMS) (Baer, 2004). The subscales included Attention to Feelings and Clarity of Feelings (Baer, 2004). Also, the Observe subscale correlated negative with a scale measuring difficulty identifying and describing feelings, the Toronto Alexithemia Scale (TAS) with higher scores meaning more difficulty (Baer, 2004). Baer (2004) also found the Act with Awareness subscale, or concentrative attention, subscale correlated negatively with a measure of dissociation, which is a general lack of awareness of one's behaviors and present experiences. These results suggest the KIMS is measuring the skills it intends to measure.

Controversy: Mindfulness and Attention

As mentioned earlier, the psychological mechanisms responsible for the efficacy of mindfulness-based therapies are not well-understood or agreed upon. Though I am proposing mindfulness is primarily an attentional skill, there are other theories about what the underlying mechanism is. In one study, participants were in either a worry group, a "mind wandering" group, or a concentrative attention breathing group (Arch & Craske, 2006). The worry group was told to worry deliberately, the "mind wandering" group was told to think about whatever came to mind, and the concentrative attention breathing group followed a breathing exercise adapted from the Mindfulnesss-Based Stress Reduction course (Arch & Craske, 2006). All participants given assessments of affect, shown sequences of slides, then assessed again for affect and their ratings of the slides (Arch & Craske, 2006). The slides were negative, neutral, or positive (Arch & Craske, 2006). After the displays, participants were given the option of watching a sequence of slides or quitting (Arch & Craske, 2006). The optional sequence was composed of the most negative slides (Arch & Craske, 2006). Researchers found participants in the mindfulness group rated neutral slides as more positive and were more willing to watch all the optional negative slides (Arch & Craske, 2006). In addition, the participants in the mindfulness group had a flatter, less varied profile on a measure of negative affect (Arch & Craske, 2006). This article suggests that concentrative attention training in the absence of any specific emotional regulation techniques still produces emotional regulatory effects.

Research with the KIMS has been studied in the context of negative affect and anxiety sensitivity and has found similar results (McKee et al, 2007). Anxiety sensitivity is a dispositional variable related to avoidance and fear of anxiety symptoms, and is distinct from trait anxiety (McKee et al, 2007). In one study, participants were given the MAAS to measure mindfulness, the PANAS to measure negative affectivity, and the Anxiety Sensitivity Index (McKee et al, 2007). Higher level of negative affectivity were associated with lower levels of Awareness (concentrative attention) and experiential acceptance (McKee et al, 2007). Participants with higher levels of negative affectivity had a limited ability to focus and direct attention (McKee et al, 2007). Higher levels of anxiety sensitivity were associated with lower levels of concentrative attention and experiential acceptance (McKee et al, 2007). These results suggest mindfulness is related to both attentional skill and experiential acceptance, an emotional self-regulatory strategy.

Post-traumatic stress disorder symptoms present a unique opportunity to study the relationship among emotional self-regulation, attentional self-regulation, and mindfulness. PTSD is a failure of self-regulation, and is related to emotional acceptance of events as well as the attentional component of redirecting attentional focus from a disturbing thought or emotion elsewhere (Vujanovic et al., 2009) . One study gave participants the KIMS and then gave them measures of the number of traumatic events, severity of events, and intensity of symptoms (Vujanovic et al., 2009). The symptoms were defined as re-experiencing traumatic events, avoidance, and hyperarousal. Non-judgmental acceptance was negatively correlated with levels of all PTSD symptoms, even when negative affectivity and trauma exposure were controlled for (Vujanovic et al., 2009). Concentrative attention was negatively correlated with level of re-experiencing traumatic events (Vujanovic et al., 2009). This article suggests that acceptance, an emotional self-regulatory skill, and concentrative attention are both related to PTSD symptomatology, though acceptance may be more important for the treatment of PTSD (Vujanovic et al., 2009). It is also possible that mindfulness is related to different disorders in different ways, and perhaps the attentional component is more relevant for disorders characterized by different cognitive deficits.

Another study used a randomized controlled protocol to test both the relationship between meditation experience and emotional regulation as well as the effect of mindfulness treatment on performance on a cognitive task testing emotional self-regulation (Ortner et al., 2007). In the first study, participants with experience in meditation were recruited from the community and asked to quantify how long they had been meditating (Ortner et al., 2007). For the task, participants categorized tones presented individually after affective slides, and reaction time was used as a dependent measure (Ortner et al., 2007). Participants were given measures of both state mindfulness (using the TMS) and trait mindfulness (using the MAAS) (Ortner et al., 2007). Researchers subtracted baseline responding to neutral slides from the affective slides to measure interference (Ortner et al., 2007). Duration of experience with meditation and state mindfulness correlated negatively with interference (Ortner et al., 2007). In the second study, participant were given one of the following: seven weeks of mindfulness meditation training, seven weeks of relaxation meditation training, or no training (Ortner et al., 2007). After training, only participants in the mindfulness meditation group showed a significant decrease in interference (Ortner et al., 2007).

The attentional conceptualization also has substantial behavioral evidence. Most of the research involves teaching participants meditation, because it is the most common method of cultivating mindfulness. Mindfulness does not exist in a vacuum; it is the end result of training. Though there are other methods of cultivating mindfulness, such as using guided CDs (Tang et al., 2007), meditation is the easiest way to teach mindfulness. There is some evidence suggesting the different types of mindfulness training, focusing on either concentrative or receptive attention skills, affect performance differentially on attentional tasks (Valentine & Sweet, 1999). In several experiments, researchers taught participants daily mindfulness skills independent of formal sitting meditation practice, and other studies focus on sitting meditation practice. The results of the behavioral studies to be discussed below suggest both forms of training are achieving similar behavioral outcomes.

One experiment, broadly using a concentrative attention technique, found improvement in a behavioral measure of conflict monitoring, or the ability to effectively filter out distracters (Tang et al., 2007). Integrative Body-Mind Training (IBMT) is a mindfulness training program that entails following verbal instructions on a CD including guided imagery, posture adjustment, and mindfulness training (Tang et al., 2007). Because this technique involves focusing attention on verbal directions on a CD, it is “concentrative attention” mindfulness skill training. This experiment gave undergraduates a behavioral measure of attentional skills, the attentional network task (ANT), gave them five days of IBMT, and then re-administered the ANT (Tang et al., 2007). The ANT is a task, in which participants must identify the direction a central horizontal arrow is pointing in without being distracted by two surrounding arrows pointing in either the same or opposite direction relative to the central arrow (Tang et al., 2007). Thus, this task involves executive attention, which is the ability to voluntarily filter out distracters. Tasks like the ANT are not very difficult, and thus the most useful measure is reaction time. Participants given the IBMT had significantly faster reaction times than the controls (Tang et al., 2007). These conclusions support my hypothesis that concentrative attention training leads to improvement in executive function and goal-directed attention.

Another experiment examined the relationship between type of meditation, level of meditation expertise, and performance on two attentional tasks, the Stroop Task, and the Global-Local Letters task (Chan & Woollacott, 2007). This experiment is a correlational study rather than teaching mindfulness training and then testing attentional changes (Chan & Woollacott, 2007). Participants were either meditators or controls, and meditators were grouped in terms of concentrative or "opening up" (receptive) style (Chan & Woollacott, 2007). The concentrative style group was composed of Transcendental Meditation, Sufi Meditation, and Hindu Meditation (Chan & Woollacott, 2007). The receptive style group was composed of Vipassana or Tibetan Buddhist Meditation (Chan & Woollacott, 2007). Level of meditation experienced was measured by self-report of the number of minutes of meditation per day and the total lifetime number of hours of meditation (Chan & Woollacott, 2007).

The Stroop Task entails reading color names printed in a different color ink and name the color of the ink aloud (Chan & Woollacott, 2007). The greater the number of words read, the less Stroop interference and the greater the ability of the participant to direct his or her attention. The Global-Local letters task is a task in which a "global" letter is composed of many smaller "local" letters, and the participants must press a button to indicate either what the global letter is or what the local letter is, dependent upon the condition (Chan & Woollacott, 2007). The global and local letters were either congruent (i.e. both the local and global letters were the letter “s”) or incongruent (i.e. the global letter was “h” and the local letter was “s”).

As expected, amount of meditation per day was positively correlated with number of items read on the Stroop task, suggesting meditation improves executive function. However, there was no difference between the two styles of meditation. On the Global-Local letters task, minutes per day of meditation experience was negatively correlated with reaction times on all the global conditions (Chan & Woollacott, 2007). This correlation means that the more participants meditated per day, the faster reaction time they had on the global condition (Chan & Woollacott, 2007). Once again, researchers found no difference between the types of meditation (Chan & Woollacott, 2007). When comparing controls to meditators, meditators had faster reaction times than controls in all three global conditions (Chan & Woollacott, 2007).

Thus, number of minutes of meditation per day predicted a superior attentional performance, as indexed by Stroop interference and reaction times in the Global-local letters task (Chan & Woollacott, 2007). These results support the hypothesis that meditation training, even when independent of a clinical setting, causes improvement on attentional tasks. The Stroop task requires participants to effectively block out distracters, thereby indexes concentrative attention. The Global-Local letters, by contrast, taps into the ability to fluidly shift between perspectives, and thus indexes receptive attention.

This experiment raises an interesting question about the nature of the relationship between concentrative and receptive attention and how functionally independent they are. If the types of meditation are so different, why are participants with long-term experience in both types performing so similarly? I hypothesize the reason the researchers didn’t find any difference was because individuals extensive experience in receptive attention style may require proficiency with concentrative attention (Jha et al., 2007). This experiment might have resolved this problem if they had used an assessment instrument like the KIMS. If experienced meditators showed no difference in their scores of concentrative and receptive attention respectively, it would only be logical that there would be no difference between groups on behavioral measures trying to isolate one skill. In addition, one may naturally cultivate receptive attention with extensive training in a concentrative attention style meditation. Though long-term training may lead to the development of both skills, short-term training in the context of a therapy may lead to the development of one skill in isolation. In addition, this study did not really qualify how much time on average participants spent meditating or how much experience they had on average (Chan & Woollacott, 2007). The researchers only provided a range of values for each parameter (Chan & Woollacott, 2007). Perhaps with more information to paint a portrait of the “average” participant in the study, a different explanation would emerge.

One experiment demonstrates that receptive attention training may cause a different kind of attentional improvement than the improvement Chan & Wollacott (2007) found with their concentrative attention training (Slagter et al., 2007). In this experiment, participants were given an attentional-blink task, received three months of receptive attention meditation (Vipassana) training, and then were given an attentional-blink task again (Slagter et al., 2007). This experiment has a very strong design because it has a control group and used a long period of mediation training. The attentional blink refers to the tendency to miss a second target, when two targets are presented embedded in a rapid stream of information (Slagter et al., 2007). This effect only occurs when the second target is presented within 500 milliseconds of the first target (Slagter et al., 2007). The theory was that if participants learn to effectively detach from a stimulus without becoming absorbed in it, they will have a lower rate of missing the second target when presented within the critical time frame (Slagter et al., 2007). In fact, the practitioner group showed a shorter attentional blink and a greater detection rate of the second target than the control group (Slagter et al., 2007). It is important to note that this style entails cultivating concentrative attention in the early phases of the training.

One way of explaining the results of these attentional studies is that improvements in attention may be due to reductions in arousal. If controlling for a participant's level of arousal eliminates changes between a control and mindfulness-training group on an attentional measure, then mindfulness is not really an attentional skill. If arousal mediates the relationship between mindfulness and attention, the changes due to "mindfulness" are actually related to self-regulation and a reduction in arousal. One study tested this possibility explicitly (Wenk-Sormaz, 2005). It examined the relationship between a concentrative style of meditation (Zen), performance on the Stroop task, and arousal (Wenk-Sormaz, 2005). In this experiment, participants were assigned to one of three conditions: meditation, learning, or rest (Wenk-Sormaz, 2005). In the learning condition, participants had to use memory techniques to learn the presidents of Yale university, specifically the method of loci (Wenk-Sormaz, 2005). Participants created a mental visual image of a place in which they have lived and represented each of the previous presidents in a specific region (Wenk-Sormaz, 2005). In the rest condition, participants, were told to simply rest for 20 minutes (Wenk-Sormaz, 2005). The experimental group was given Zen meditation training (Wenk-Sormaz, 2005). Wenk-Sormaz (2005) used a test-retest protocol. As well as having three groups, the experimenters also measured the galvanic skin response, a measure of arousal, during the first and last three minutes of the exercise (meditation, learning, and rest) (Wenk-Sormaz, 2005). They calculated the measure of arousal by taking the average of these two points during the exercise (Wenk-Sormaz, 2005) .

The participants in the meditation group had significantly less Stroop interference than participants in the other groups, and changes in arousal did not change the relationship (Wenk-Sormaz, 2005). In this context Stroop interference was defined as the difference in reaction time for an incongruent word-ink pairing and a baseline reaction time, in which the participant must complete a block of trials composed of multiple x's in one color (Wenk-Sormaz, 2005). Thus, this experiment demonstrates another case in which participants were trained in a concentrative attention style of meditation, given a concentrative attention task, and performed better than two control groups

Furthermore, a study actually did find differential results for participants as a function of meditation type. This experiment used the Wilkins' Counting Test, in which participants were presented with a repetitive sequence of tones and were asked to count them (Valentine & Sweet, 1999). When the frequency of tone presentation is fairly low, it is easy to develop expectations of when the next tone will come (Valentine & Sweet, 1999). Errors on the slow frequency portion are a result of losing attention out of boredom or distraction (Valentine & Sweet, 1999). However, when the frequency of tone presentation is fairly high, counting the tones becomes more difficult and requires participants to be able to detach their attention rapidly from each tone, and each tone is difficult to predict (Valentine & Sweet, 1999).

The experiment looked at experienced meditators, of both receptive and concentrative styles, and controls (Valentine & Sweet, 1999). In addition, the meditators were given questionnaires to index their meditation experience, as 24 months or less, or greater than 25 months (Valentine & Sweet, 1999). The researchers predicted both groups of meditators would be more accurate than non-meditators, and when the frequency of the tones was high, the receptive attention meditators would be more accurate (Valentine & Sweet, 1999). The results confirmed this hypothesis.

For the low frequency task, meditators were more accurate than controls, those with greater experience were more accurate than those with less experience (though this was not broken down by type), and both groups of meditators were equally accurate (Valentine & Sweet, 1999). The equal accuracy result is in line with result of Chan & Woollacott (2007). If participants must develop concentrative before receptive attention, the Stroop task would not show a difference between types. In addition, the Global-Local letters may not have been sensitive enough to detect differences between types. For the high-frequency task, receptive attention meditators were more accurate than concentrative attention meditators (Valentine & Sweet, 1999). This study, however, did not teach participants meditation, but used participants already having this training.

One study, however, did not find differences in attentional performance between a control and a mindfulness experimental group (Anderson et al., 2007). Participants took an eight-week MBSR while participants in the control group did not get any sort of training (Anderson et al., 2007). This experiment has a very strong design, because the MBSR course is relatively long, they had a control group, they used a wide array of attentional measures. Both groups were given standardized measures of attention, including a measure of sustained attention, the ability to shift attention flexibly between stimuli, an object detection task, and the Stroop test (Anderson et al., 2007). Presumably, the sustained attention task and Stroop test were intended to measure concentrative attention and the tests of attention shifting and object detection were intended to tap into receptive attention. The mindfulness group did not demonstrate improvements in performance relative to the control group after the course (Anderson et al., 2007). One explanation of these results is the nature of the MBSR course. It involves elements of cognitive therapy, yoga, and relaxation (Chambers, Yee Lo, & Allen, 2007).

A study using an intensive pure meditation program without the other added elements of MBSR did find improvements between a mindfulness group and a control group. In this study, participants in the mindfulness group went on a ten day mediation retreat, during which they meditated for 110 hours (Chambers, Yee Lo, & Allen, 2007). Participants were given a measure of working memory, the Digit-Span Backwards test, and an internal switching task. The internal switching task measured participants' ability to keep a mental tally of words belonging to one of two categories while the words were presented in random order (Chambers, Yee Lo, & Allen, 2007). The researchers found that participants in the meditation group had significantly faster reaction times after the retreat relative to controls for the internal switching task (Chambers, Yee Lo, & Allen, 2007). They also demonstrated improved working memory (Chambers, Yee Lo, & Allen, 2007).

A different study examined the relationship between dispositional mindfulness, like the current study does, and performance on an attentional measure. Participants were either experienced meditators or meditation naïve controls (Moore & Malinowski, 2009). The meditators were either in intermediate meditation classes or recently completed a six-week introductory course (Moore & Malinowski, 2009). All participants completed both the Stroop task and the d2-concentration and endurance task (Moore & Malinowski, 2009). This task requires participants to scan a sheet of paper for targets, mark through them, and ignore similar distracters (Moore & Malinowski, 2009). The target was either the letter "d" or the letter "b", and had a unique configuration of quotation marks around it (Moore & Malinowski, 2009). All other targets had to be ignored. Participants were given the KIMS to measure dispositional mindfulness (Moore & Malinowski, 2009). Total mindfulness scores correlated positively with the total number of words read on the Stroop task, and the number of correct targets identified on the d2-concentration and endurance task when the data from both groups were plotted together (Moore & Malinowski, 2009). In addition, the meditators had significantly higher mindfulness scores the controls (Moore & Malinowski, 2009). This study implies measures of dispositional mindfulness can distinguish meditators from controls, and that these measures do correlate positively with improved attentional control (Moore & Malinowski, 2009).

Thus, the research strongly suggests mindfulness training causes improvements in attentional performance, and KIMS scores correlate positively with superior attentional performance. The relationship between receptive and concentrative attention is less clear, though there is support for the notion that receptive attention only develops after concentrative attention. The training methods to develop receptive attention inevitably start with exercises in concentrative attention. The KIMS presents an opportunity to study both components of mindfulness independently, and see if there is a correlation between the two skills, using the two subscales.

Clinical Relevance of Mindfulness

Mindfulness is clinically relevant because it is the basis of several new behavioral therapies that are in the process of being investigated. Mindfulness-Based Stress Reduction (MBSR) is probably one of the most well-known mindfulness programs (Ivanovski & Malhi, 2007; Baer 2003). It is an eight to ten week program, composed of intense two to two and a half hour weekly meetings, and one full day retreat (Ivanovski & Malhi, 2007). Rather than trying to change the individual’s cognitions or teach the participant to cognitively confront distorted cognitions, MBSR changes the participant's relationship with his or her thoughts (Baer 2003; Baer 2006). The participant learns to see thoughts as fleeting mental events and becomes comfortable experiencing them, leading to a reduction in stress and improved emotional self-regulation (Ivanovski & Malhi, 2007). MBSR was developed to treat chronic pain and stress disorders; participants label their feelings with words rather than avoiding them (Baer, 2003). Though there is an abundance of research on mindfulness-based therapies, much of the research is not adequately controlled. Research will only be considered here if it has a control group. Control groups here are defined as an active treatment group (either placebo or empirically demonstrated), a wait-listed control group, or an active but non-specific and non-controlled treatment (called "treatment as usual")

One experiment using random assignment examined levels of mood disturbance in cancer patients (Speca, Carlson, Goodey, & Angen, 2000) after an MBSR course. They found a significant improvement in depressive symptoms, emotional irritability, anger, and symptoms of stress compared to a wait-listed control group (Speca, Carlson, Goodey, & Angen, 2000). An analysis of this study by Baer (2003) found a substantial effect of treatment ($d = 0.60$). In addition, a study examining stress levels in medical students and premedical students using random assignment found a significant improvement on measures of depression, state and trait anxiety, empathy in comparison to a wait-listed control group (Schapiro, Schwartz, & Bonner, 1998). Baer (2003) calculated a medium effect for this study ($d= 0.50$). A third study examining symptoms of depression, anxiety, and rumination in a group of veterans with a history of lifetime depression found a significant decrease in rumination after the course in comparison to wait-listed controls (Ramel, Goldin, Carmona, & McQuoid, 2004). The researchers calculated a very large effect size ($d = 1.47$) (Ramel, Goldin, Carmona, & McQuoid, 2004). This research demonstrates that MBSR has the potential to be a very successful treatment, and that further research is necessary.

As of this review, two studies with an active standardized treatment control group was found examining the efficacy of MBSR. This study used a population of individuals with moderate to severe psoriasis and used rate of skin clearing as a dependent measure, as assessed by a blind evaluator (Kabat-Zinn et al., 1998). An MBSR plus light treatment group was compared to a light treatment alone group (Kabat-Zinn et al., 1998). Researchers found participants in the MBSR condition had a significantly faster clearing rate than participants in the light treatment alone group (Kabat-Zinn et al., 1998). The second study compared MBSR to CBSR, which is a program based on CBT that is aimed at changing and replacing distorted cognitions (Smith et al., 2008). This study measured depression (using the BDI), psychological well-being, perceived stress, perceived pain level, energy level, and neuroticism (Smith et al., 2008). Within the MBSR group, there was a positive increase in well-being and energy and a decrease in depression, neuroticism, binge eating, and pain (Smith et al., 2008). Within the CBSR group, there was an increase in well-being and a decrease in perceived stress and pain (Smith et al., 2008). The MBSR group had larger effect sizes in the positive direction than the CBSR group (Smith et al., 2008). Furthermore, a multivariate analysis demonstrated that there was a greater change on all variables in the MBSR group compared to the CBSR group (Smith et al., 2008). The only limitation to this study is that it was not random assignment; community member had short descriptions of the programs and chose which group to be part of (Smith et al., 2008).

Mindfulness-based cognitive therapy (MBCT) is another mindfulness based intervention, and is specifically an adaptation of MBSR for depression (Baer, 2003). It teaches individuals with depression to learn to observe their thoughts and emotions, in order to try and prevent them from entering the downward cycle of negative affect and cognitive rumination (Baer, 2003). In one randomized study, participants with a history of lifetime depression who were currently in remission but off medication were significantly less likely to experience recurrence of depression within the year following completion of MBCT than controls who were instructed to continue Treatment As Usual (TAU) (Teasdale et al., 2000). Interestingly, for patients with three or more episodes of depression, MBCT reduced relapse rates, but not for patients with two or fewer episodes (Teasdale et al., 2000). Baer (2003) calculated a medium-large effect size (d = 0.60) for this study. In another randomized study examining participants with recently remitted depression who were not on medication, participants who received MBSR had greater recall of specific autobiographical memories than participants in the TAU group (Williams, Teasdale, & Segal, 2000). What is interesting about this study is that usually individuals with a history of depression have impaired recall of specific autobiographical memories whether they are currently experiencing depression or not (Williams, Teasdale, & Segal, 2000). Baer (2003) calculated a strong effect of the mindfulness treatment (d = 0.70). In another randomized trial using both bipolar and unipolar depression patients currently in remission, researchers found decreased depression in the MBCT group relative to wait-listed controls (Williams et al., 2008). Thus, MBCT is a promising treatment which should continue to be studied.

One study using an active treatment group studying MBCT was found (Teasdale et al., 2008). A randomized controlled study tested MBCT while participants were tapering off medication against maintenance antidepressant medication (m-ATM) (Teasdale et al., 2008). It used time to relapse, residual symptoms, and quality of life as dependent measures (Teasdale et al., 2008). This study is the first MBCT study using an active treatment arm, and has several very strong methodological features (Teasdale et al., 2008). In addition, the raters on the dependent measure were blind to group assignment, and two raters coded each taped interview (Teasdale et al., 2008). A trained therapist watched all group therapy sessions to ensure protocols were being adequately followed (Teasdale et al., 2008). In the MBCT arm, the relapse rate was 47% while in the ATM arm the relapse rate was 60%. MBCT significantly reduced residual symptoms as measured on the clinician rated Hamilton Rating Scale for Depression (HRSD) and the self-report Beck Depression Inventory (BDI) (Teasdale et al., 2008). In the MBCT group, 75% of participants successfully tapered off medication (Teasdale et al., 2008).

Another common therapy is Acceptance and Commitment Therapy (ACT). ACT does not try to change the content of thought either. It uses mindful acceptance to target experiential avoidance and thought suppression (Hayes, 2004). One study examined the effect of ACT on frequency and duration of epileptic seizures and quality of life (Lundgreen, Dahl, Melin, & Kies, B, 2006). The experimental group received ACT in addition to behavioral seizure control technology, and the control group received supportive therapy (ST) (Lundgreen, Dahl, Melin, & Kies, B, 2006). Supportive therapy is a placebo treatment in which the therapist asks participants to reflect on their experiences and feelings regarding having seizures providing a supportive environment but providing no advice (Lundgreen, Dahl, Melin, & Kies, B, 2006). Participants in the ACT group reported fewer and shorter seizures than participants in the control group (Lundgreen, Dahl, Melin, & Kies, B, 2006). They also reported greater life satisfaction (Lundgreen, Dahl, Melin, & Kies, B, 2006).

A second study examined the relationship between ACT and workplace-related stress, using the general health questionnaire (GHQ), a measure of general mental health, and Beck Depression Inventory (Bond & Bunce, 2000). There were three groups: ACT, an inactive control group, and an Innovation Promotion Program (IPP) (Bond & Bunce, 2000). The IPP taught participants to seek new creative solutions to problems. Both groups showed improvements on the BDI and GHQ relative to controls (Bond & Bunce, 2000). The ACT group showed a significant improvement over the IPP training on the GHQ (Bond & Bunce, 2000).

A different of a non-clinical population found an improvement in broad psychological health relative in an ACT group relative to controls in a CBT control group (Lappalainen, 2007). Both groups were given the BDI and a general checklist measuring psychopathological symptoms (SCL-90) before and after the intervention (Lappalainen, 2007). There was a medium between-group effect size after treatment and at follow-up favoring ACT relative to CBT (Lappalainen, 2007). In addition, there was a medium effect size again favoring ACT for the BDI scores (Lappalainen, 2007).

Therefore, mindfulness therapies show promise, though additional resarch is needed. Unfortunately, the vast majority of mindfulness-based therapy studies use uncontrolled designs. Recommendations for improvement can be found in the discussion section of this literature review.

Cognitive Components of Selective Visual Attention

Given the studies on the effect of mindfulness training on attention, and the efficacy of mindfulness interventions for depression, it is likely that there is an attentional mechanism driving the efficacy of these interventions. To examine the neural correlates of mindfulness, however, it is necessary to understand the neural correlates of selective visual attention. As described earlier, attention is a cognitive process that is composed of stimulus-driven and goal-driven attention. (Corbetta & Shulman 2008).

One example of behaviorally relevant goal-driven attention is noticing a stranger in a green hat when you are looking for a friend in a green shirt in a crowd; it is based upon expectation (Corbetta & Shulman 2008). The "breach" of expectation refers to the fact it shares similar properties with the target stimulus and is occurring in an unexpected location. On the other hand, irrelevant stimulus-driven attention is a function of stimuli salience, and may occur in response to loud noises, motion, color contrast, or changes in luminance (Corbetta & Shulman 2008). It is controversial whether task-irrelevant but salient distracters or targets activate the same network as distracters or targets which are relevant but not salient (Corbetta & Shulman, 2008).

Properties of Selective Visual Attention: Biased Competition Model

Apart from its cognitive components, the properties of attention are a direct result of its limited capacity. Because attention is limited, stimuli compete for neural representation and processing, and the organism must have the ability to filter out irrelevant stimuli (Desimone & Duncan 1995). There is abundant behavioral evidence that suggests when multiple stimuli are presented together, accuracy and speed diminish (Desimone & Duncan 1995). Indeed, accuracy is restored when stimuli are presented in sequence rather than simultaneously (Desimone & Duncan 1995).

Neural evidence from single-cell recording in monkeys also supports the conclusion that attentional resources are limited and stimuli must compete for them. When two objects are presented within a center-surround neuron's receptive field, one effective stimulus and one ineffective stimulus, the activity of the neuron is suppressed (Pessoa, Kastner, & Ungerleider 2003). An effective stimulus here refers to one that evokes the maximal firing of the neuron, such as with contours in V1. In addition, as information travels from receptors on the retina to the cortex, the size of the receptive field increases from 0.2 degrees to 25 degrees. Thus, inessential information is lost at each stage of processing (Desimone & Duncan 1995) and receptive fields are the basic unit of competition.

Properties of Selective Visual Attention: Top-Down and Bottom-Up Mechanisms

The two cognitive mechanisms which bias the competition for object processing are the top-down and the bottom-up mechanisms. The top-down mechanism biases competition when stimuli in the environment are relevant to the task at hand (Desimone & Duncan 1995). The top-down mechanism is analogous to concentrative attention. In fact, directing attention to a stimulus can modify the neural response to the stimulus. When monkeys are given a spatially directed cue to the location of the target, the neuron responds as if the receptive field effectively shrunk around the target during single-cell recording studies (Pessoa, Kastner, & Ungerleider 2003). The single-cell studies with monkeys are the most direct way to measure neural activity. Blood oxygen level dependent (BOLD) signals are an indirect method for measuring neural activity; it assumes greater activity reflects summed activity of many local neurons. However, these signals measure inputs to an area as well as local cortical processing, including both inhibitory and excitatory interneurons (Pessoa, Kastner, & Ungerleider 2003).

The bottom-up mechanism biases competition when they contain salient features, like local discontinuities, novelty, movement, color contrast, etc (Desimone & Duncan 1995). Top-down and bottom-up processes are directly related to goal-driven attention and stimulus-driven attention. Goal-driven attention is probably only influenced by top-down processes, and stimulus-driven attention is probably influenced by both processes. Stimulus-driven attention may be influenced by top-down processes if the stimulus is relevant or to the task at hand.

The relationship between attention and visual processing, however, is not simple. Some unattended stimuli do undergo processing, and thus processing is not limited to attended stimuli alone. The degree to which unattended stimuli are processed depends on the available attentional load. Even so-called “pre-attentive” tasks, such as tasks requiring a participant to recognize a unique stimulus within an array of different but homogenous distracters, require attention (Pessoa, Kastner, & Ungerleider 2003).

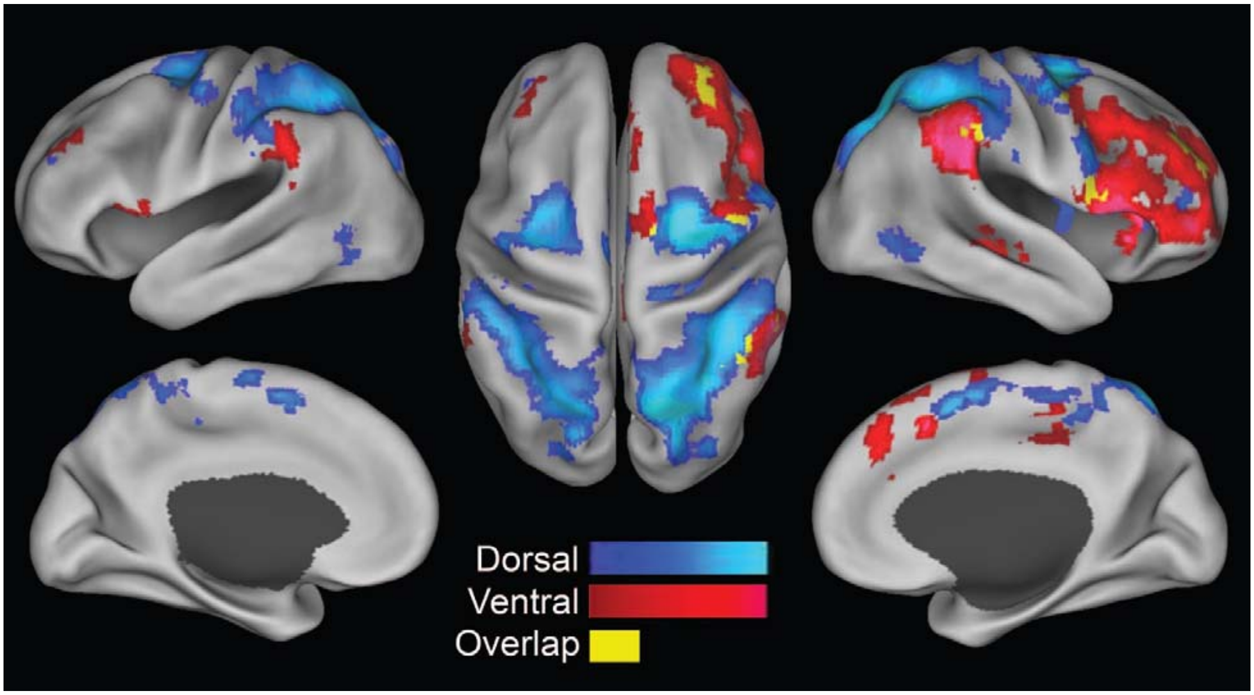
Even emotional stimuli, which researchers thought were processed automatically, may be contingent upon available attentional resources (Pessoa, Kastner, & Ungerleider 2002). In one experiment, experimenters used two tasks to isolate neural responses in the context of emotion while participants were in one of the following two conditions, an attended condition or an unattended condition. In the attended condition, participants viewed faces with different emotional valence and responded with a button-push to indicate the sex of the central face. In the unattended condition, participants pushed a button to indicate whether two bars adjacent to the same series of faces were in the same orientation and were told to ignore the faces. Researchers found differential activity in response to the fearful faces in the unattended compared to the attended condition. It was only in the attended condition the researchers found amygdala activation. Negative faces are more likely to involuntarily attract attention than neutral or positive faces (Pessoa, Kastner, & Ungerleider 2002).

Neural Correlates of Attention

The relationship between attention and neuroanatomy is complex and controversial. One of the most widely accepted models postulated two types of attention, goal-driven attention and stimulus-driven attention (Corbetta & Shulman, 2008). Goal-driven attention biases the processing of stimuli by generating and maintaining top-down signals using goals and expectations of likely outcomes (Corbetta & Shulman, 2008). In this model, a bilateral dorsal frontoparietal network is responsible for goal-driven attention. It is composed of the intraparietal sulcus (IPS), frontal eye field (FEF), and the superior parietal lobe (SPL) (Corbetta & Shulman, 2008). Stimulus-driven attention detects behaviorally relevant stimuli, especially in an unexpected location (Corbetta & Shulman, 2008). Stimulus-driven attention, in the case of behaviorally relevant stimuli, is mediated by the dorsal network as well as a primarily right-lateralized ventral frontoparietal network. The ventral network is composed of the temporoparietal junction (TPJ), inferior frontal gyrus (IFG), and anterior insula (aI) (Corbetta & Shulman, 2008). As mentioned earlier, the relationship between salient irrelevant stimuli and attentional networks is unclear. One study suggests there is no relationship between salient irrelevant stimuli and the attentional networks as defined above (Indova & Macaluso, 2007). Another study suggests it may be mediated by the dorsal network exclusively (de Fockert et al., 2004).

The dorsal and ventral frontoparietal networks may respectively have intrinsic functional connectivity (Fox et al., 2006a). Indeed, one way to measure functional connectivity of networks is to examine spontaneous neural activity that is not task-dependent (Fox et al., 2006a). In the brain there are significant neural fluctuations that are unrelated to the stimulus or task at hand (Fox et al., 2006b). These fluctuations, however, are not random but are consistent within a system (Fox et al., 2006b) .Because most of the brain’s energy is used to maintain internal functions, spontaneous activity may illustrate fundamental underlying patterns of connectivity (Fox et al., 2006b).

One experiment found that correlation maps within the ventral network (between the TPJ and ventral frontal cortex) were significantly different from the correlation maps within the dorsal network (the IPS and FEF) (Fox et al., 2006a). In addition, the correlations between the two regions in both networks respectively were stronger than correlations between any other region pair (Fox et al., 2006a). The results of this functional connectivity analysis provide an informative and empirically-based map of the dorsal and ventral networks:



The areas in red are the ventral network, and the areas in blue are the dorsal network. The topmost left and right images are showing the brain as if it were butterflied, with the top left image showing the left hemisphere and the top right image showing the right hemisphere. On the top right image, the frontal cortex is pointing to the right. On the top left image, the frontal cortex is pointing to the left. These images show how right-lateralized the venteral network is. In particular, in the top right image, the ventral network is primarily composed of the ventral frontal cortex, including the inferior frontal gyrus, and the temporoparietal junction, which is the red region posterior to the central sulcus. The dorsal network is best viewed from the overhead image, which is the top central image. The region anterior to the central sulcus contains the frontal eye field, and the region posterior to the central sulcus contains the intraparietal sulcus and superior parietal lobe.

Though these regions may have intrinsic functional connectivity, they have overlapping functions and do not separate as neatly as Corbetta and Shulman (2002) originally suggested (Corbetta & Shulman, 2008). One of the most common experimental designs is the classic spatial cueing Posner design. It usually entails an expectation period, followed by a cue, and then a target (Kincade et al. 2005). During the expectation period, no target or cue is presented. It is designed to capture neural activity during goal-driven attention. In some experiments, the cue period is not preceded by an expectation period and the cue alone is thus intended to capture goal-driven attention. The cue is usually an arrow pointing one way or an asterisk, and the target is then presented on the same hemifield (a congruent condition) or the opposite hemifield (an incongruent condition) (Kincade et al. 2005; Lepsien & Pollman, 2002; Indova & Macaluso, 2007). This way it is possible examine activity as a result of expectations being validated or invalidated (Kincade et al. 2005; Lepsien & Pollman, 2002; Indova & Macaluso, 2007). The participant typically has to respond behaviorally to a feature of the target, for instance its orientation, with a button (Kincade et al. 2005; Lepsien & Pollman, 2002; Indova & Macaluso, 2007; Hopfinger, Buonocore,& Mangun, 2000).

In many of these designs the cue correctly predicts the location of the cue fairly consistently, or about 75-80% of the time (Kincade et al. 2005; Lepsien & Pollman, 2002; Indova & Macaluso, 2007). In addition, some studies have a very salient but irrelevant cue or feature of the cue, to try and capture stimulus-driven attention (Kincade et al., 2005; Indova & Macaluso, 2007; Hopfinger, Buonocore,& Mangun, 2000; de Fockert, Rees, Frith, & Lavie, 2004).

To separate the different patterns of neural activity associated with attention, many studies use event-related functional magnetic resonance imaging (fMRI) design. With this kind of design it is possible to separate cue activity from target activity (Kincade et al., 2005; Corbetta 2000; Corbetta 2002).

In addition to discussing common designs, it is necessary to understand common methods of analysis. One of the most common ways to analyze data is through the use of a contrast. A contrast is a method in which activity in one condition is essentially statistically “subtracted” from activity in another. A simple example would be to look at a cue condition and a baseline condition. In the contrast cue – baseline, one is “subtracting” baseline activity (focusing on a fixation point for example) from neural activity while the participant is viewing a cue. This notation is usually written in the literature as cue > baseline rather than cue – baseline. The whole-brain analysis is conducted this way for each volumetric pixel (voxel). There are 100,000 voxels in the brain, and each one represents a space of 1 mm^3.

The articles presented below showcase both typical Posner designs and variations on it to illustrate the nuances of the relationship between the dorsal and ventral networks. These atypical experiments go outside the realm of the usual method, for instance by using different modalities (Downar, Crawley, Mikulis, Davis, 2001), incorporating a visual search element without spatial expectations (de Fockert, Rees, Frith, & Lavie, 2004) or creating spatial expectations without the need for reorienting (Hopfinger, Buonocore,& Mangun, 2000). I hypothesize the function of the dorsal network is for both task-relevant stimulus-driven attention and goal-driven attention. In addition, I hypothesize the ventral network is primarily active during stimulus-driven attention, especially when it is relevant. I will first analyze the typical Posner method experiments and propose that seemingly contradictory results are due to whether studies image targets and cues together (Peelen, Heslenfeld & Theeuwes, 2004; Indova & Macaluso, 2007)or image them separately (Kincade et al., 2005; Corbetta et al. 2000; Corbetta et al. 2002). Afterwards, I will describe the modified Posner designs.

One event-related classic Posner design found differential activation for the networks when data were acquired for both cue and target periods, though they still shared overlap (Kincade et al., 2005). In this experiment there was a cue period, an inter-trial interval, and a target (Kincade et al., 2005). The cue array was composed of a central diamond flanked by eight colored boxes of different colors (Kincade et al., 2005). In the endogenous (goal-driven) condition, one half of the diamond changed luminance to indicate the likely location of the target (Kincade et al., 2005). This experiment also had an exogenous (stimulus-driven) attention component. In the exogenous condition, seven of the eight boxes were the same color, with an eighth one a different color (Kincade et al., 2005). The theory was that the color contrast would involuntarily capture attention and would direct it to that location (Kincade et al., 2005) In the exogenous condition the cue did not predict target location at all. In addition, there was a neutral condition with eight different colored boxes, and no specific cue (Kincade et al., 2005)

During the cue period, there was both dorsal and ventral activity. However, there was temporal separation of the networks suggesting different, though related functions. Immediately after cue presentation, the researchers found dorsal activity (FEF and IPS) (Kincade et al., 2005). This results supports the conclusion that the dorsal network is responsible for goal-driven attention. Two seconds after this initial activity the researchers found ventral activity (TPJ and IFG) (Kincade et al., 2005). Given how few studies use event-related designs and collect imaging data during cue presentation, it is possible the activity that is observed in the ventral network actually comes slightly before target presentation but after cue presentation. Given the way these two pairs of regions appeared together, it supports the idea that these two networks are distinct, though they share overlapping functions. It is possible there is a gradual transition between usage of the networks between cue presentation and target presentation.

When the experimenters analyzed the data more thoroughly, some regions showed greater responses to invalid targets than valid targets in the endogenous condition after target presentation. These regions were the FEF (dorsal) and the TPJ (ventral) (Kincade et al., 2005). These results support the conclusion that both dorsal and ventral networks are responsible for stimulus-driven attention, especially involving a breach of expectation of location.

Thus, Kincade et al. (2005) implies the dorsal network is responsible for goal-driven attention and also responds during a breach of expectation when it is task-relevant. In addition, the article suggests the ventral network is also responsive to behaviorally relevant violations of expectations in the context of relevance. This study has a few very good methodological features which not all experiments share. It has a fixed inter-stimulus interval between the cue and target. A fixed inter-stimulus interval between cue and target al.lows participants to maintain a goal-driven expectation, which is an implicit feature of the dorsal network. The article also monitored eye fixation, supporting the conclusion that FEF activity was not due to saccade activity (Kincade et al., 2005). FEF activity is strongly related to saccades, so it is vital to monitor eye fixation. In addition, exogenous and neutral trials were mixed together, and kept separate from endogenous trials, which may have allowed participants to develop goal-driven expectation between blocks (Kincade et al., 2005).

Several other experiments which use event-related fMRI to separate cue and target activity have come to similar conclusions, reserving a special place for the dorsal network in goal-driven attention, while the stimulus-driven attention requires both networks (Corbetta et al.

2000; Corbetta et al. 2002). Corbetta et al. (2000) found IPS activity alone during a cuing period, and both TPJ and IPS activity during target presentation. Corbetta et al. (2002) found cue-related activity in the IPS, and near the FEF. In addition, Corbetta et al. (2002) both dorsal and ventral activity for target related activity for the invalid > valid contrast.

Another basic spatial cueing Posner experiment examined the effect of stimulus salience on reorienting using a similar design and also came to similar conclusions about the relationship between the ventral network and the stimulus-driven attention. This experiment, however, supports the conclusion that the ventral network is preferentially active for stimuli which are relevant and non-salient rather than irrelevant and salient. In this experiment participants were given a cue identifying location of the target, and given the color of the target in advance (Indova & Macaluso, 2007). The cue could also be valid or invalid predicting location; they had to respond to the orientation of the target to test endogenous attention. In addition, sometimes they unpredictably saw a checkerboard at the cued (valid) or uncued (invalid) region, which did not require a behavioral response (Indova & Macaluso, 2007). For the contrast testing invalid target > valid target activity, researchers found activity in the IPS, IFG, insula, and FEF (Indova & Macaluso, 2007). These results support the conclusion both dorsal and ventral activity are present for stimulus-driven attention, especially when it is at an unexpected location.

This pattern of response suggests behaviorally relevant shifts of attention require both networks. Interestingly enough, creating a contrast with [invalid targets > valid targets] – [invalid checkerboard > valid checkerboard] did not reveal any new regions of activity. Though this contrast looks complicated, it is simple in principle. The two contrasts invalid targets > valid targets and invalid checkerboard > valid checkerboard are created to isolate activity related to presentation of a target in an unexpected location that is different from targets in an expected location. The final operation is subtracting the two contrasts, to create a new contrast. The new contrast isolates activity related to the presentation of a low-salience but high relevant target from activity related to the presentation of a high-salience irrelevant target. These results suggest activity resulting from salient irrelevant distracters does not even affect the same attentional networks as behaviorally relevant stimuli (Indova & Macaluso, 2007). Valid, invalid, and checkerboard trials were randomly intermixed. This experiment found no distinction between networks, probably because it did not image cue and target periods separately.

A third familiar Posner method experiment suggests this same conclusion. This experiment used a familiar Posner design with a spatial cue either predicting target location or not predicting location and cues that were either valid or invalid (Peelen, Heslenfeld & Theeuwes, 2004). In a goal-driven attention condition, the cue predicted target location (Peelen, Heslenfeld & Theeuwes, J. 2004). In the stimulus-driven attention condition, the target did not predict location (Peelen, Heslenfeld & Theeuwes, 2004). This experiment separated cue and target activity, and is also mixed the stimulus-driven and goal-driven trials together so participants could not develop goal-driven expectations (Peelen, Heslenfeld & Theeuwes, 2004). In an analysis examining both stimulus-driven and goal-driven condition, experimenters found both dorsal (FEF) and ventral activity (IFG, TPJ) (Peelen, Heslenfeld & Theeuwes, 2004) during cue presentation, regardless of whether it was predictive or not. Due to the method of analysis, combining both predictive and non-predictive cues, it is unsurprising both networks were active.

Interestingly, one study imaging both cue and target activity together found ventral activity alone in the invalid > valid contrast. This experiment, on the other hand, used both an arrow and a geometric shape to as a cue. Object-based reorienting may have a different mechanism (Arrington et al., 2000).

In contrast with the above typical Posner methods with valid/invalid conditions and stimulus-driven/goal-driven conditions, other experiments systematically vary one of these components or collapse one level of variable. One such experiment used a modified Posner paradigm (Hopfinger, Buonocore,& Mangun, 2000) and was designed to primarily test goal-driven attention. Fitting in with previous research, it found primarily dorsal activity (Hopfinger, Buonocore,& Mangun, 2000). In this experiment participants were cued to determine whether the reversing checkerboard presented at that location contained some grey checks or only black and white checks (Hopfinger, Buonocore,& Mangun, 2000). This design, however, differed from the majority of the other experiments because it did not entail shifting attention. Participants had to respond only based upon the stimulus at the cued location (Hopfinger, Buonocore,& Mangun, 2000). Unsurprisingly, researchers found dorsal activity rather than ventral activity. During the cue period, participants showed increased activity in the IPS, SPL, FEF, and MFG, which are all components of the dorsal network (Hopfinger, Buonocore,& Mangun, 2000). Perhaps participants in this study had this strong of a dorsal response because they knew they would not have to reorient attention and could thus fixate at the cued location with confidence. Targets alone evoked dorsal (SPL), ventral activity (IFG), and a region which may link the two, the MFG (Hopfinger, Buonocore,& Mangun, 2000).

Another experiment, using a modified Poser paradigm, presented participants with a cue that did not provide any information about target location (Lepsien & Pollman, 2002). It was intended to capture stimulus-driven attention only. Thus, results are not contaminated by goal-driven spatial expectation. The cues were either valid or invalid (Lepsien & Pollman, 2002).The researchers found that for both valid and invalid trials, the following regions were active: the FEF, MFG, aI, SPL, and TPJ (Lepsien & Pollman, 2002). This pattern suggests a general stimulus-driven network composed of both dorsal and ventral regions. The only region that showed a main effect of validity was the MFG, which may be a mediator between networks (Corbetta & Shulman, 2008). Given participants could not create spatial orienting expectations, it would have been interesting to see what was going on during cue presentation if the researchers used event-related fMRI.

The experiments discussed earlier have only shown dorsal activity while participants are focusing on a stationary fixation point or during presentation of a stationary cue. One experiment, however, found dorsal activity using a visual search design (de Fockert, Rees, Frith, & Lavie, 2004). In this unique experiment, there was no explicit cue to indicate location (de Fockert, Rees, Frith, & Lavie, 2004). Without a cue to create spatial expectations, participants thus could not have an expectation mismatch (de Fockert, Rees, Frith, & Lavie, 2004). Participants had to indicate the orientation of a line within a green circular target though they did not know where it would occur (de Fockert, Rees, Frith, & Lavie, 2004). In some conditions of the experiment, the target circle was red, and in some conditions a distracter diamond was red (de Fockert, Rees, Frith, & Lavie, 2004). The usage of red and green targets makes the display highly visually salient. Participants thus must filter out irrelevant distracters but do not have any spatial expectation.

The contrast of presence > absence of the colored distracter was associated with activity in the SPL and a region near the FEF, two regions of the dorsal system (de Fockert, Rees, Frith, & Lavie, 2004). The results provide more support for the hypothesis that the dorsal system is responsible for maintaining task-relevant goal-driven signals and filtering out distracters. The experiment also involved monitoring eye movement of participants.

A different experiment suggests that this reorienting response is not limited to the visual modality. Participants were given either an auditory or visual cue, and were presented with visual and auditory stimuli simultaneously (Downar, Crawley, Mikulis, Davis, 2001). Researchers first presented participants with a buzzing sound and the visual image of a square. After a varying interval the square rotated or the pitch changed by five percent (Downar, Crawley, Mikulis, Davis, 2001). Once again the cues could have been either relevant or irrelevant (i.e. a visual cue was followed by the change in orientation of the square) (Downar, Crawley, Mikulis, Davis, 2001). Several regions were common to both auditory and visual stimuli for both validity contrasts (invalid > valid), suggesting a common network when participants are given an explicit sensory expectation (Downar, Crawley, Mikulis, Davis, 2001). These ventral regions were the TPJ and left aI (Downar, Crawley, Mikulis, Davis, 2001). The presence of ventral activity only suggests stimulus-driven attention shifts may be mediated by the ventral network only when participants have to shift attention between modalities. When validity is not part of the analysis, both dorsal and ventral regions are active (IFG, MFG, aI, and IPS) (Downar, Crawley, Mikulis, Davis, 2001).

In conclusion, current neuroimaging evidence supports the hypothesis that spatially directed goal-driven attention is mediated by the dorsal network. Stimulus-driven task-relevant attention, however, is mediated by both networks in the case of. The relationship between task-irrelevant salient stimuli and attentional networks is very unclear.

With an understanding of mindfulness, how to measure it, its cognitive mechanisms, the clinical significance of mindfulness, and the neural correlates of the attentional changes associated with it, it is possible to create a hypothesis about the relationship between dispositional mindfulness and neural activity in attentional networks. I hypothesize that concentrative attention is analogous to the goal-driven attention, and thus concentrative attention mindfulness scores will correlate positively with activity the magnitude of activity in dorsal frontoparietal network (i.e. the SPL, FEF, and IPS). I also hypothesize that receptive attention is analogous to stimulus-driven attention, and thus that receptive attention mindfulness scores will correlate positively with activity in the ventral frontoparietal network (i.e. the TPJ, IFT, and aI) and the dorsal frontoparietal network. The data on mindfulness-based therapies mindfulness skills help alleviate symptoms of depression, and thus I hypothesize that the same relationships will hold for the depressed participants.

Methods

Overall Considerations and Overview

The data used for this experiment is archival data. The information below is an outline of the design of the study and how the data were collected. To provide a brief overview of the procedure, all participants took a battery of instruments including the KIMS, and then within the week they completed the selective visual attention scanner in the fMRI scanner.

Participants

Participants ranged in age from 20 to 48, inclusive, and fell into either the category of patients with Major Depressive Disorder (n = 5, four females and one male) or healthy controls (n = 6, five females and one male). Depressed patients were recruited from ongoing studies of depression in the Department of Psychiatry, Vanderbilt University and through ComCast television advertisements. Controls were recruited from the Vanderbilt Hospital Database of volunteer subjects. Anyone who goes to Vanderbilt Hospital has the opportunity to become a part of the database and experimenters may contact people in this database to serve as healthy controls at any point in the future. All participants provided informed consent approved by the Vanderbilt University Institutional Review Board.

Depressed participants met several inclusion criteria. They had to have a diagnosis of major depressive disorder (MDD) according to the DSM-IV criteria, a minimum score of 16 or above on the first 17 items of the clinician-rated Hamilton Depression Rating Scale (HRSD), a 20 or above on the self-report Beck Depression Inventory, and they had to be legally competent and willing to give informed consent.

Participants did not meet any of the following exclusion criteria. They did not have a history of bipolar affective disorder, psychosis, any other Axis I disorders, a history of substance dependence in the past six months, personality disorders, or subnormal intellectual potential (IQ below 85). Women who were pregnant or planning to become pregnant were also excluded. Participants were not on antidepressant medication or on catecholaminergic antihypertensive medication, however, they were not excluded based on previous antidepressant medication usage. In addition, participants did not have current suicide risk sufficient to preclude treatment on an outpatient basis (e.g., stated intent and a formulated plan).

Prospective matched control participants did not meet criteria for personality disorders, any current Axis I disorder except simple phobias, or have HRSD greater than 6 or BDI less than 10. Participants were excluded if there was evidence of chronic disease (such as cardiovascular disease or neurological disorder), obesity, or claustrophobia. All clinical interviews were conducted by Dr. Merida Grant at the Village at Vanderbilt in the Department of Psychiatry.

Procedure

Upon identifying a potential participant, the researchers conducted a phone screen to rule out general medical conditions. When the participant came in, Dr. Grant conducted the SCID and

HRSD with him or her. The KIMS and BDI are self-report measures, which the participant completed in the same sitting. Because the HRSD is a time-sensitive instrument, all participants came in for the brain scan within a week of completing the instruments.

Task

The participant completed a modified flanker task in the MRI scanner. The instructions were presented using on a high-resolution display screen attached to the head coil. The stimuli and instructions were presented using E-Prime software (PST, Pittsburgh, PA). Participants identified the sex of the central face in an array of three faces by pressing an arbitrary predetermined button, the index or middle key. There were three difficulty levels. The most difficult was the incongruent condition, in which the central face was flanked by faces of the opposite sex (e.g., FMF). The intermediate difficulty level was the congruent condition, in which the central face was flanked by faces of the same sex (e.g., FFF). In the third and easiest condition, the baseline condition, there was only a single face surrounded by a fixation cross on each side. In addition, each array had a valence, which was happy, sad, or neutral. There were nine possible stimulus conditions, with three levels of valence (happy, sad, and neutral) and three levels of difficulty (hard, intermediate, and easy).

There was a semi-structured presentation of the faces in each session. Each session was composed of six runs, with the first and sixth runs being neutral (N) valence. There were two different sequences of runs, with the positive (P) and negative (S) images occupying different positions, but with each valence condition adjacent to itself (i.e. either N, P, P, S, S, N or N, S, S, P, P, N). This scheme of ordering was used to minimize mood induction. Each run was composed of twelve blocks. One block was composed of nine trials, with each trial being the presentation of a single array. Each participant completed one session, and the two sequences of runs were counterbalanced across participants.

Image Acquisition

The imaging component of the study took place in the Philips Intera Achieva 3T MRI scanners at Vanderbilt University Institute of Imaging Science (VUIIS). To facilitate spatial normalization, the MRI scanner acquired high resolution structural images in the axial plane using a 3D IR prepped 3DFFE sequence (TR = 450 ms, TE=17 ms, FOV = 24 cm, slice thickness = 4 mm). Twenty-eight axial interleaved 4.0mm functional slices (0.5 mm skip) were acquired parallel to the AC-PC line using a gradient echo pulse sequence (EPI) providing whole brain coverage (T2*-weighted images sensitive to BOLD signal changes; TR = 3000 ms, TE = 28 ms, FOV = 24 cm, flip = 90, slice thickness = 4mm).

Image Analysis

All image analysis was conducted with BrainVoyager QX. Each subject had 6 EPI runs, which were collapsed together to create one data file per participant. In this preprocessing phase (relative to the statistical analysis), 3-D motion correction, slice time scan correction, and temporal data smoother with a high pass filter were performed to remove linear trends. Then, the functional data were manually aligned with the anatomical data, by interpolating the image sets into $3mm^3$ voxels. Afterwards, the data were translated in to Talairach space, which is a standardized coordinate system to allow for averaging images across subjects and to identity regions of activation. Data were then smoothed with an 8mm full-width at half-maximum Gaussian kernel.

It is important to note that brain imaging uses statistics differently than many other disciplines, and it is necessary to provide a brief explanation of the statistical analyses used here to interpret the results of this experiment. A General Linear Model (GLM) is created to look at patterns of activity among multiple individuals completing the same task (de Haan, 2008). A multiple regression analysis is used to model the time course of the signal at one specified voxel and at one point in time (the dependent variable) (Goebel, 2008). The model looks at this signal as a function of the different stimulus conditions (the independent variables, also called predictors) (de Haan, 2007). Stated in other words, the voxel time course is modeled as the sum of the defined predictors with their associated beta weights. A beta weight, in this context, is therefore indexing the contribution of the specified predictor in explaining the activity of the voxel at a given point in time (Goebel, 2008). Thus, a region at which the beta weight is large while the participant is viewing the stimulus of interest is interpreted to mean there is significant neural activity in that region relative to other regions where the beta weight is small. Statistical significance is determined by comparing the estimated parameters, or a linear combination of them in a contrast, to zero (de Haan, 2007). This comparison is often done using a *t*-test (de Haan, 2007).

To provide a simple example illustrating how the predictors work, consider a simple experiment in which participants see only two kinds of faces, happy and sad faces. Imagine that at time zero the participant is staring at a blank screen, at time points one and two the participant is viewing a happy face, and at times three and four the participant is viewing a sad face. In this hypothetical experiment imagine activity at voxel X is being examined. The predictors are happy and sad faces. The model assumes that if the stimulus is being shown, neural activity will have a defined magnitude (say “one” here). While the stimulus is not being shown, neural activity will have a defined magnitude of zero. The predictor function for happy faces would then have the value zero at time point one, the value one at time points two and three, and the value of zero again at time points three and four. For the sad faces, the predictor function would have the value zero at time point one, the value zero at time points one and two, and the value one at time points three and four. Thus, the way to analyze which regions are active during viewing happy faces is to select voxels which have a large beta weight associated with the happy predictor function during time points one and two. Consider the following equation, which would be modeling the observed value of voxel X at time point one using the happy predictor function (X_1), the sad predictor function (X_2), and an error term *e*:

$$Y = b_1 X_1 + b_2 X_2 + e$$

From the equation, regions with significant brain activity while the participant is viewing the happy faces will have a larger beta weight associated with X_1 than associated with X_2.

Analyzing a correlation between a continuous variable, such as mindfulness scores, and brain activity is done with the beta weights described above. Each individual has a mindfulness score and a beta weight associated with one voxel. Plotting each individual's mindfulness score against his or her beta weight associated with a given region will provide a measure of the strength and direction of the relationship between mindfulness scores and neural activity in one region. The final analysis of this data will result in a graph with one data point per individual, with mindfulness scores on one axis and beta weights on the other. The Pearson's *r* statistic can therefore be used to analyze the relationship between mindfulness and neural activity in a given region for a specific task.

As mentioned earlier, imaging software conducts a different *t*-test for each voxel. There are 100,000 voxels in the brain (Goebel, 2008). As a result, it is necessary to have methods to control for the risk of spurious correlations. One such way is to use the *r*-statistic itself as a criterion, and eliminating all data points which show a correlation with mindfulness scores below a pre-specified *r*-value. Another way to limit spurious correlations is to create a minimum cluster size threshold. The theory behind this method is that when a group of voxels is activated together, it is more likely the activity observed is the result of true underlying neural activity rather than statistical chance. After these thresholds are set, it is unnecessary to report specific statistical values for any region that was activated.

In the current experiment, there are nine different predictors. As mentioned earlier, there are three levels of valence (happy, sad, and neutral) and three levels of difficulty (incongruent, congruent, baseline). To analyze activity associated with attention, two different contrasts were used. These contrasts were incongruent > neutral baseline, and neutral incongruent > neutral baseline. The incongruent condition was chosen because it was the most difficult and would require more attentional processing than the congruent condition. The neutral incongruent condition was chosen to examine the neural correlates of the cognitive task in the absence of any emotional distraction. The negative incongruent condition was used because ignoring the negative valence to make a cognitive task requires additional cognitive control relative to the neutral condition. The neutral baseline was subtracted from these two incongruent conditions in order to eliminate activity associated with making the motor response and the visual perception of the stimuli independent of attention. In the current experiment, *r*-value thresholds were manipulated so the resulting p-value would be below 0.01 for the controls and patients, respectively. In addition, a minimum cluster size of 100 voxels was set.

Results

Concentrative Attention

There was only one significant positive correlation between the concentrative attention subscale (Act With Awareness) and the magnitude of neural activity in either the dorsal or ventral network. It was in the control group in the left IFG (Talairach coordinates -59, 10, 17). The IFG is a part of the ventral network. There was no significant activity in either attentional network with respect to the concentrative attention measure in the patient group. This result does not fit with the hypothesized relationship between concentrative attention and the dorsal network; the IFG is exclusively a part of the ventral network. See Table 1 and Figure 1 for a summary.

Receptive Attention

In contrast with the concentrative attention measure, there were multiple sites of significant activity in both the dorsal and ventral networks correlated with the measure of receptive attention (the Observe subscale). Activity was found in the frontal lobe, the junction of the temporal and parietal lobes, and in a subcortical region. For the control group, there was significant activity in the FEF (-25, 4, 59), ACC (-3, 19, 22), IFG (47, 1, 16) and TPJ (-42, -36, 14). In the patient group, by contrast, the only significant activity was in the FEF. These results conform to the hypothesis that receptive attention is positively correlated with magnitude of neural activity in both the dorsal and ventral networks. The dorsal and ventral networks together are responsible for the reorienting response. The FEF and ACC are part of the dorsal system, and the TPJ and IFG are part of the ventral system. See Tables 2 and Figures 1 and 2 for a summary of the regions active in each condition

Table 1. List of Regions Associated with Concentrative Attention

		Negative Contrast			*Neutral Contrast*		
Region	*Side*	*x*	*y*	*z*	*x*	*y*	*z*
Controls							
Inferior Frontal Gyrus	L	-59	10	17			

Table 2. List of Regions Associated with Receptive Attention

		Negative Contrast			*Neutral Contrast*		
Region	*Side*	*x*	*y*	*z*	*x*	*y*	*z*
Controls							
Inferior Frontal Gyrus	R	47	1	16			
Temporoparietal Junction	L	-42	-36	14			
Anterior Cingulate		-3	19	22			
Frontal Eye Field	L				-25	4	59
Patients							
Frontal Eye Field	R	17	-1	50			

Figure 1. Regions Associated with Concentrative and Receptive Attention in Controls

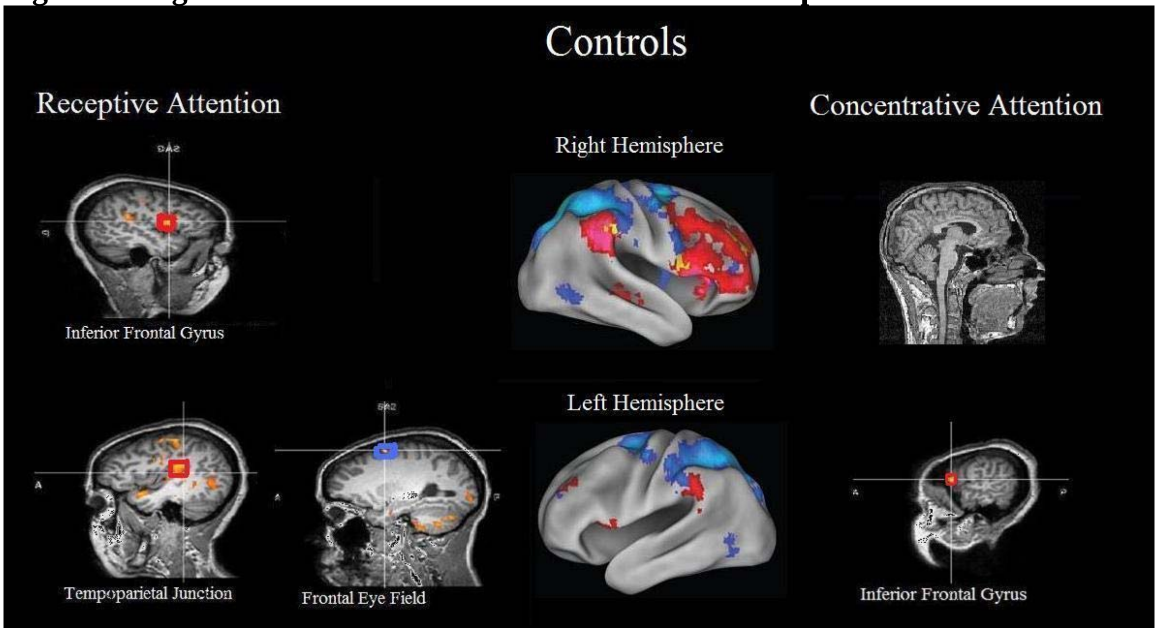
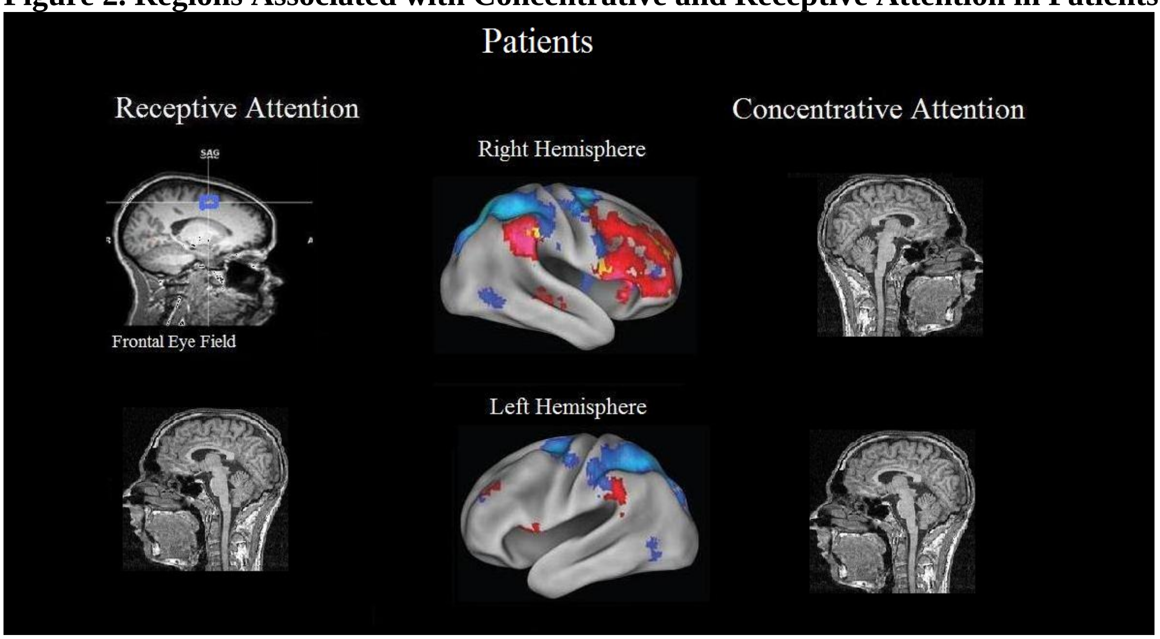


Figure 2. Regions Associated with Concentrative and Receptive Attention in Patients



Discussion

My hypothesis about the relationship between mindfulness and activity in attentional networks was partially supported. I hypothesized that receptive attention scores would predict activity in regions associated with the stimulus-driven attention, which were in both the dorsal and ventral networks. In healthy controls, receptive attention scores correlated positively with the magnitude of neural activity in both the dorsal (FEF, ACC) and ventral networks (IFG, TPJ, and ACC). Thus, the hypothesis was true for the controls. In patients, receptive attention scores correlated positively only with the magnitude of neural activity in the FEF, which is part of the dorsal network. I also hypothesized that concentrative attention scores would predict activity in regions associated with the goal-driven attention, which is the dorsal network only. Concentrative attention scores correlated positively with activity only in the ventral network, the IFG, in controls. Thus, the hypothesis that concentrative attention correlates positively with neural activity in the dorsal network only is false. These results support an attentional conceptualization of mindfulness, although the hypothesis about mindfulness skills and specific attentional networks was only partially supported. In this discussion, I will first discuss what these results mean for mindfulness therapies. Then, I will discuss finding activity in the ventral network. The task at hand varied significantly from tasks which typically recruit ventral activity. Afterwards, I will discuss the limitations of using a network approach and discuss the limitations of the archival data I was using.

Receptive attention may be the primary mindfulness skill because receptive attention scores correlated with more regions in attentional networks than concentrative attention scores did. The overarching conclusion thus is that receptive attention may be the underlying skill driving the efficacy of mindfulness-based therapies. As discussed in the introduction, a study found no difference in attentional performance between a group of long-term meditators trained in concentrative attention styles of meditation and a group trained in receptive attention styles of meditation (Chan & Wollacott (2007). Theoretically, if the skills are distinct, any attentional differences would be magnified in long-term meditators. The lack of difference the study found can be explained if receptive attention develops from concentrative attention as Jha, Baime, & Krompinger (2007) suggest and meditators both eventually ended up with the same skill set. If receptive attention is the primary underlying skill and it eventually develops from concentrative attention, mindfulness techniques that cultivate receptive attention may be the most efficient way to bring about the benefits of mindfulness therapy. One such receptive attention therapy is Vipassana meditation.

In addition to directing mindfulness therapies more specifically, clinical trials need more rigorous methodology to be labeled empirically-supported therapy. The primary issue is offering an active treatment control group. The majority of studies have used a “treatment as usual” or a wait-listed control group. The treatment as usual group is not standardized and is not a suitable control. The most conservative and ideal control group is a comparison with a proven therapy. I think a control condition using deep breathing exercises or guided imagery exercises would be an ideal control condition. These treatments have been shown to be effective, and mindfulness purports to be a better treatment and work with different mechanisms compared to most relaxation treatments. Moreover, studies need to use multiple therapists, and each therapist needs to provide therapy to only one treatment condition. Furthermore, well-validated and accepted dependent measures are necessary, such as a diagnosis using the DSM, BDI scores, BAI scores, etc. Many mindfulness therapies seem to show benefits in the long term relative to an active control treatment, such as with the depression relapse study and MBCT compared to antidepressant medication (Teasdale et al., 2008). Thus, adding a long follow-up procedure may show benefits to these therapies that are not readily apparent. Cost-benefit analyses may also help make a stronger case for mindfulness-based therapies. Most mindfulness therapies are designed to be conducted in a group setting, which may pose financial advantages over an individual medical treatment or psychotherapy.

The current study also found a strong correlation between receptive attention scores and activity in both the dorsal and ventral networks. According to the literature, the ventral network responds primarily to the presentation of a behaviorally relevant stimulus in an unexpected location (Indova & Macaluso, 2007; Kincade et al., 2005; Corbetta et al. 2002; Arrington et al. 2000). Therefore, it is somewhat surprising there was significant activity in the ventral network in this current task. The stimuli here appeared consistently in the same location, in the center of the screen. It is possible this activity is the result of the inherent salienc of negative faces, which may be intrinsically behaviorally relevant to humans for evolutionary reasons. Responding appropriately and in a timely manner to situations in which negative emotion is involved may have been beneficial for survival.

Given the dissimilarity of the current experiment to the majority of the experiments in the literature review but still finding ventral activity raises several possibilities. The first possibility is that the ventral network does play a role in affective processing, and thus it is not merely an attentional network. Two core components of the ventral network, the IFG and TPJ, were active during the presentation of these very salient negative faces. The way to see if it is the ventral network at play rather than the spontaneous appearance of activity in both brain regions is to use a functional connectivity analysis. If the time course of the fMRI signal is strongly correlated between two regions, compared to the correlation with one region to the rest of the brain, it supports the idea that a network is responsible for the observed phenomenon rather than both regions spontaneously being active together (Fox et al., 2006). In fact, the FC analysis performed by Fox et al. (2006), showed that the time course of activity in one region of the ventral network, the ventral frontal cortex (VFC), correlated the most strongly with the time course of activity in another region, the TPJ. The IFG, one of the regions in which the current study found activity, is a part of the VFC. Thus, the research by Fox et al. (2006a) supports the conclusion that perhaps true ventral network activity was found during the course of the present study because the TPJ and IFG may be the most important components of the ventral network. They also found the same relationship with a pair of regions in the dorsal network, the frontal eye field and the intraparietal sulcus. There is clearly the need for more investigation into the function of both attentional networks, their relationship to each other, and the relationship of regions within each network.

On the other hand, it may be useful to abandon a network approach to major cognitive processes, such as attention. Using a network to explain a major function may be overly reductive, because it assumes a relatively large area of the brain serves the same function and we have it precisely operationalized. The key example of this is with Richard Davidson’s model of cerebral asymmetry to explain motivation and affect (Davidson, 1992). According to this model, the left hemisphere is associated with positive, approach-related emotions and the right hemisphere is associated with negative, avoidance-related emotions (Davidson, 1992). This model is reductive because it devotes each whole hemisphere to a single function. When contradictory results were found, researchers revised the hypothesis multiple times to try to make the data fit a clear left/right hemisphere model. Most of this research was conducted with EEG methods, due to its extremely high temporal resolution (Sobotka, Davidson, & Seunulis, 1992; Davidson et al. 1990; Davidson, Marshall, Tomarken, & Henriques, 2000). However, much of it has been done with tasks like asking participants to bisect a line and measuring the asymmetry of the bisection (Friedman & Forster, 2005), dichotic listening tasks (Kaprinis, 2005), and tasks with chimeric faces (Friedman & Forster, 2005). These methods are very indirect.

Evidence supporting the left-right hemisphere usage asymmetry conclusion comes from research on facial expressions during emotion-eliciting films (Davidson et al. 1990), tasks with an approach or avoidance-based financial game (Sobotka, Davidson, & Seunulis, 1992), emotional anticipatory responses of individuals with phobia to public speaking (Davidson, Marshall, Tomarken, & Henriques, 2000), and even with 72-hour old infants responding to aversive-tasting solutions (Davidson et al., 1990). The simple dichotomy presented here makes very straight-forward and concrete predictions.

However, conflicting evidence abounds. Research by Friedman and Forster (2005) suggests that anticipatory responses in the absence of affective arousal show an opposite pattern of lateralization. I, however, doubt that affective arousal and anticipation can ever be truly separated. In addition, the same study by Friedman and Forster (2005) found that when participants were given a task that primes approach-related behavior (but not avoidance), participants showed increase creativity and increased right-hemisphere activity. Why would creativity be associated with avoidance? Moreover, a study on dichotic listening in bipolar patients during the acute mania phase showed a similar reversal of expectations from Davidson's predictions (Kaprinis et al., 1995). This theory has been continually tested and reformulated to try and make sense of all the incongruities in the data, but it probably will be unable to do so because grouping the brain into halves and saying each half has a single, unified, and consistent function is a gross oversimplification. One example of seemingly desperate reorganization is from a current study in press (Koch, Holland, & van Knippenberg) saying the inconsistent findings can be explained by controlling how “diffuse” versus “concrete” the stimuli and affective inductions are while still admitting concrete stimuli can induce “diffuse” states. Thus, the network approach to cognition has major limitations. An alternative to the network approach is to look at brain regions separately, without postulating there are many regions serving a single, specific, and operationalized function. The limitation to this approach though is that brain imaging risks becoming the new phrenology, meaning it assigns a single function to a single region rather than looking at interactions. Though we do not understand the relationship among different neural regions, they are never truly independent.

Because this study used archival data, it is necessary to discuss the limitations inherent to the design. Firstly, there were only 11 participants in total, with five depressed patients and six healthy controls. The small number of participants greatly limits the statistical power. Also, the use of emotional faces in the stimulus array may limit the interpretation of the results for a selective visual attention task. It is difficult to say which activity is the result of emotional face processing and which activity is the result of attentional control processes. This potential confound is particularly salient in the negative incongruent > neutral baseline contrast. The majority of the activity found was using this negative incongruent > neutral baseline contrast.

The selective visual attention tasks discussed in the literature review used simple geometric shapes, and varied parameters like contrast and luminance. If I could design the study, I would have used a simple stimulus array like the one used by Kim et al. (1999) that does not contain any emotionally salient features. My ideal experiment would follow the general pattern of experiments in the literature review, the Posner paradigm. I would give the participants the

KIMS, then have them complete the central expectancy task used by Kim et al. (1999). In this task, participants were given a cue that predicted the location of the target accurately 80 percent of the time, and predicted it incorrectly 20 percent of the time (Kim et al., 1999). They had to respond by pushing a button when the target was an X but not a cross (+) (Kim et al., 1999). Furthermore, the experiments which show differential activity in the dorsal and ventral networks use event-related designs, meaning they acquire images during both an anticipation period and a target presentation period. Thus I would use an event-related design to improve the experiment and monitor eye movements.

In addition to changing the experimental task, I would use a repeated measures design and actually teach the participants mindfulness skills and use a between-group comparison. I would also have a control group which would receive relaxation training or some variant of attentional training. I would give the participants the Five Factor Mindfulness Questionnaire, an improved version of the KIMS. Furthermore, I would have them complete the attention task in the scanner before and after the mindfulness training. This way, it would be possible to study the mindfulness therapy itself, track changes in mindfulness skills, and examine the relationship between mindfulness and neural activity in attentional networks in a true selective visual attention task. It would be interesting to see if improvements in symptoms correlate with an increase in activity in attentional brain areas.

In conclusion, though the relationship between mindfulness and neural activity in attentional networks is still unclear, there is a strong relationship between mindfulness scores and the magnitude of neural activity in both attentional networks. Just because the evidence did not show the predicted relationship between the two types of mindfulness skills and the attentional networks, it still supports the conclusion that mindfulness is intrinsically tied to attentional processes. Indeed, with the modifications in experimental design proposed above and addition of functional connectivity analyses, there is fertile ground for future exploration of the relationship between mindfulness and attention

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