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The Immediate Effect of a Brief Mindfulness Intervention on Attention and Acceptance

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The Immediate Effect of a Brief Mindfulness Intervention on Attention and Acceptance

by

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A dissertation submitted in partial fulfillment of the requirements for the degree of
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DEDICATION

This dissertation is dedicated to the memory of my grandparents, who inspired me to be curious about the world and stay hungry for knowledge from a young age. Thank you to my grandparents for planting the seed of enjoy learning in my heart, my parents for supporting my decision to pursue graduate studies in the US, Dr. Emanuel Donchin for mentoring me during his last years and believing in me to be a good researcher, and many other mentors, colleagues, and friends for generously helping me accomplish this milestone in my journey.
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ABSTRACT

Given the increased popularity of mindfulness in both the clinical settings and the general public, it is important to understand the active mechanisms of mindfulness. Mindfulness practice (MP) involves two active components, attention regulation and acceptance of experience, being aware of the current experience as it is without evaluating the experience as positive or negative. Much research has evaluated the attention regulation component and found that MP improves high-level (effortful) attention with few reported effects on low-level (automatic) attention. It is unclear whether MP affects merely low- or high-level attention, or both, because little empirical research has examined both low- and high-level attention simultaneously. Existing mindfulness studies on acceptance have often employed emotional labeling tasks, which might not elicit reliable emotional experience as self-generate emotional events because emotional experience arising from self-generate emotional events is more relevant to the subject. The current project adopted a randomized pretest-posttest design to examine both components of mindfulness through inducing a brief 10-minute guided mindfulness intervention (MI) among participants who have no prior experience with mindfulness-related exercise. The control group listened to a 10-minute TED talk about green living. Neural indices of attention and affective reactivity were measured using event-related-potentials (ERPs), summed activity of postsynaptic potentials among a large scale of neurons. Study 1 examined whether MI affected low-level attention (indexed by P3a), high-level attention (indexed by P3b), or both. Participants completed a visual Novelty Oddball Task that captures both low- and high-level attention. Our results showed that MI improved high-level attention to a greater extent than the control condition. We were not able
to evaluate the impact of MI on low-level attention because the experimental design failed to elicit a P3a component. Possible reasons are discussed in the Discussion and Limitations. Study 2 examined whether MI improves the general state of acceptance measured by self-report decentering and reduces affective reactivity to negative experience as measured by the error-related negativity (ERN) and post-error slowing (PES). Participants completed a Flanker Task, a speeded reaction time task that is prone to errors. The results demonstrated increased self-reported acceptance, but this effect was not manifested in behavioral and neural measures of affective reactivity; instead, a practice effect was revealed as indicated by faster RT and increased certainty of response. Taken together, these findings suggest that attention, but not acceptance, can be reliably altered through a brief MI. MI is more efficient than the control intervention in improving attention.
BACKGROUND AND SIGNIFICANCE

In recent years, mindfulness practice (MP) has been incorporated into various therapies to target a broad range of health conditions including chronic pain, stress, anxiety, depression, addiction, and suicidality (Dimidjian & Segal, 2015; Good et al., 2016; Grossman, Niemann, Schmidt, & Walach, 2004). Meanwhile, online mindfulness-based interventions (MBI) have also been quickly growing as people seek ways to reduce stress and improve well-being (Burns, Davenport, Durkin, Luscombe, & Hickie, 2010; Christensen & Hickie, 2010; Mani, Kavanagh, Hides, & Stoyanov, 2015; Spijkerman, Pots, & Bohlmeijer, 2016). Given its increased popularity in both the clinical settings and the general public, it is important to understand the active mechanisms of MP and whether the effectiveness of MP may vary as a function of individual differences.

As a construct with a long history in Buddhism but only a brief history in Western psychology, mindfulness has been facing considerable challenges in its definition, operationalization, and measurement (Grossman, 2008). A widely cited definition of mindfulness is “paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally” (Kabat-Zinn, 1994, p. 4). Paying attention “on purpose” refers to one actively choosing where to put attention in a specific moment, as opposed to wherever it wanders off to; one may also purposefully redirect their attention to the focus if it drifted away. Paying attention “in the present moment” means that one concentrates on the moment-to-moment experience, as opposed to thinking about the past or future events. Paying attention “nonjudgmentally” means that one views the current experience as it is without evaluating an experience as positive or
negative, but simply being aware of its occurrence. Based on this definition, several conceptualizations of MP have suggested that two of its core components are attention regulation and acceptance of experience (Bishop et al., 2004; Brown & Ryan, 2003; Carmody, 2009; Lindsay & Creswell, 2017), which will be the main constructs of the current investigation.

Attention is the cognitive capacity that guides information selection prior to further processing. William James says, “Everyone knows what attention is” (1890, p. 403). Depending on whether the attentional process is automatic or voluntary, attention is often conceptualized as a dichotomy: low-level (automatic or exogenous) attention and high-level (effortful or endogenous) attention (e.g., Posner & Cohen, 1984). While much research has evaluated the attention regulation component and most studies found that MP improves high-level attention (Chiesa, Calati, & Serretti, 2011; Norris et al., 2018; Tang & Posner, 2015) with a few reported effects on low-level attention (Biedermann et al., 2016; Cahn & Polich, 2009), it is unclear where the effect of MP fits in the dichotomy: MP affects exogenous attention, endogenous attention, or both. Given the requirement of attentional control during MP, it is important to ask whether MP is efficient for individuals with attention deficit. Acceptance of experience refers to one being aware of the current experience as it is without the attempt to change it or evaluate it. The acceptance component may reduce one’s affective response to emotional events; therefore, studies have often presented participants with emotional stimuli and then measured their emotional reactivity through self-report surveys. Affective response can also be assessed via neural (i.e., event-related-potentials) and behavioral measures previously shown to be altered by emotion; to our knowledge, studies have rarely measured a combination of general state of acceptance, behavioral and neural measures of affective reactivity to examine the acceptance component.
Mindfulness, attention, and acceptance are all broad constructs and not always clearly defined. A full account of these constructs is beyond the scope of the present work. Instead, the goal of the current investigation is to contribute to the understanding of the mechanisms underlying mindfulness by carefully operationalizing the constructs of interest: attention and acceptance, along with using a very specific mindfulness intervention and an active control intervention. Therefore, in serving the aims of the current investigation, the discussion of attention is centered around the distinction between low-level (automatic or exogenous) attention and high-level (effortful or endogenous) attention, and acceptance is assessed through affective reactivity to self-generate errors. Taken together, the current investigation aims to elucidate how MP affects attention and acceptance using measures of self-reported data, behavioral outcome, and neural indices of attention and affective reactivity among individuals with no prior MP experience, and whether these effects will be moderated by ADHD symptoms.

Mindfulness

The term “mindfulness” has been used to refer to three distinct constructs: mindfulness practice, state mindfulness, and trait mindfulness (Kiken, Garland, Bluth, Palsson, & Gaylord, 2015; Van Dam et al., 2018).

Mindfulness Practice

Common traditional mindfulness practices include Zen meditation and Vipassana meditation. “Zen” means sitting meditation, sitting quietly, concentrating on breathing and learning to accept (Wienpahl, 1964. p.3 & p. 122); Vipassana meditation is a Buddhist practice that involves focusing on present-moment sensory awareness (e.g., breath) with an equanimous
and non-reactive mental set. Vipassana meditation is the foundation for the widely practiced mindfulness-based stress reduction (Hart, 1987; Kabat-Zinn, 1982). Based on traditional mindfulness meditation, mindfulness has been transformed into a wide variety of health interventions for clinical populations in the west since the 1970s. Jon Kabat-Zinn was the first to integrate mindfulness with western therapy by developing the mindfulness-based stress reduction (MBSR) program, a once-a-week training program that runs for 8 weeks to help people manage stress, anxiety, depression, chronic pain, and other chronic health issues (Kabat-Zinn, Lipworth, & Burney, 1985). Since then, mindfulness has been incorporated into a variety of treatment programs such as Mindful Awareness Practices (MAP) (Zylowska et al., 2008) and Mindfulness-based cognitive therapy (MBCT) (Segal et al., 2012) to treat a wide array of mental illnesses. In addition, there are programs developed to help with addiction recovery, such as Mindfulness-Based Relapse Prevention (MBRP) (Bowen, Chawla, & Witkiewitz, 2014) and Mindfulness-Oriented Recovery Enhancement (MORE) (Garland, 2014). These mindfulness-based interventions (MBIs) typically comprise educational advice and mindfulness meditation (Bowen et al., 2006; Garland & Howard, 2018; Kingston, Dooley, Bates, Lawlor, & Malone, 2007).

Bishop, Lau, Shapiro, Carlson and Anderson (2004) proposed a two-component model of MP, suggesting two key components, self-regulation of attention and awareness to experience with an attitude of acceptance. In line with this conceptualization, the recent developed Monitor and Acceptance Theory (MAT) proposed that MP involves (1) the ongoing monitoring of present-moment experience and (2) with an orientation of acceptance. To integrate both the two-component model and the MAT on mindfulness, the current paper will term the two components as attention regulation and acceptance of experience.
The Mind Wandering hypothesis proposes that there is a state of undirected attention in which the mind is occupied with task-irrelevant thoughts, impairing task performance (Broyd et al., 2009; Mason et al., 2007). To maintain a state of mindfulness by focusing attention here-and-now (e.g., sensation of breathing) requires consistent monitoring of attention and bringing the attention back to focus once the attention has been detected as drifting away. Therefore, Bishop and colleagues further proposed that self-regulation of attention involves three elements: sustained attention, attention switching, and the inhibition of elaborative processing. Specifically, sustained attention is responsible for maintaining attention in current experience (e.g., breath), and attention switching is in control of shifting the focus of attention back to the current experience once the attention is distracted (Jersild, 1927; Posner, 1980). The inhibition of elaborative processing both aids the refocus and comes as a consequence of sustained attention and attention switching, because further elaborative thought streams about the distractors is prevented by shifting attention back to the present moment (Bishop et al., 2004). For instance, if one’s attention on the breath is distracted by a noise outside the door, one would acknowledge attention to the noise without further elaborating on the meaning of the noise and bringing attention back to the breath to prevent further processing of the noise.

The second component of mindfulness, acceptance of experience, refers to taking an attitude of openness and receptivity toward momentary experience (Bishop et al., 2004; Quaglia, Brown, Lindsay, Creswell, & Goodman, 2014). This experience can not only be related to the focused-object such as breath-induced sensation, but can also be related to internal thoughts, emotions, or feelings. When one is mindfully aware of the experience of thoughts and emotions, one can observe the experience nonjudgmentally instead of engaging with the experiences. For example, if one feels anxiety arising during MP, one would acknowledge its appearance as if watching the
clouds (thoughts and emotions) float across the sky (the mind). Instead of engaging with the experience, one would simply acknowledge it in order to cultivate a sense of acceptance of our state of being. Such psychological processes of acceptance are essential in maintaining a state of balance, which is critical in MP (Bishop et al., 2004; Quaglia, Brown, Lindsay, Creswell, & Goodman, 2016).

**State Mindfulness**

State mindfulness refers to a momentary state characterized by being mindful: attending to current experiences with non-judgmental awareness that arises during MP (Lau et al., 2006a). While state mindfulness is commonly used to assess whether the activity of MP results in a mindful state, other activities such as progressive muscle relaxation may also result in a mindful state, similar to MP resulting in similar scores on the assessment (Caldera, 2017; Vinci et al., 2014). To date, state mindfulness is often measured by one of two scales: the Toronto Mindfulness Scale (TMS; Lau et al., 2006) and the state version of the Mindful Attention Awareness Scale (State-MAAS) (Brown & Ryan, 2003b). Examples of statements that measure state mindfulness are “I was more concerned with being open to my experiences than controlling or changing them,” and “I was curious to see what my mind was up to from moment to moment” (TMS, Lau et al., 2006). These statements require responses indicating the degree of agreeableness. For example, a deeper state of mindfulness will yield a higher agreeableness with the above statements.

In addition to state mindfulness, changes in cardiovascular functions have also been used as a manipulation check for MP. Earlier studies in meditation have intensively examined the physiological effects of mindfulness. One of the earliest studies to examine the physiological
effects of transcendental meditation found that oxygen consumption and heart rate decreased, and skin resistance increased during meditation (Wallace, 1970). Since then, studies have reported consistent changes in the autonomic nervous system including lower respiration rate, slower heart rate, increased skin resistance and lower blood pressure. A systematic review of 45 studies with meditators found a consistent reduction in blood pressure across all meditation subtypes (Pascoe, Thompson, Jenkins, & Ski, 2017).

**Trait Mindfulness**

Trait mindfulness is one’s pre-existing disposition to behave in a mindful matter in daily life (Brown & Ryan, 2003a; Cobb-Clark & Schurer, 2012). As a result, an individual who has never practiced mindfulness may be high in trait mindfulness in their daily life. Unlike state mindfulness, trait mindfulness can be assessed across a few distant time points and generally remains stable. Trait mindfulness can also be plastic and modifiable by long-term mindfulness mediation practice (Carmody & Baer, 2008; Davidson, 2010; Vago & Silbersweig, 2012). A few questionnaires to measure trait mindfulness include Kentucky Inventory of Mindfulness Skills (KIMS; Baer, Smith, & Allen, 2004), Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003), and Five-Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006). Examples of statements that measure trait mindfulness are “When I’m walking, I deliberately notice the sensations of my body moving,” and “When I take a shower or bath, I stay alert to the sensations of water on my body.” (FFMQ; Baer et al., 2006). One has to respond by indicating the frequency of experiencing such circumstances.

A closer look at the questionnaires might lead one to infer that state mindfulness is different from trait mindfulness in terms of time period. That is, state mindfulness is a
momentary mental experience measured by the extent of being mindful in a given moment, whereas trait mindfulness is a long-term personality-like characteristic measured by how often an individual experiences mindfulness in daily life. For example, the statement, “When I’m walking, I deliberately notice the sensations of my body moving” (FFMQ; Baer et al., 2006) measures trait mindfulness by having one rate how often they experience mindful moments, and individuals high in trait mindfulness would score high on this item to reflect frequent mindful moments in daily activity—e.g., walking. In comparison, the statement used to measure state mindfulness, “I was curious to see what my mind was up to from moment to moment” (TMS, Lau et al., 2006), requires responses indicating the degree of agreeableness with this statement. Individuals high in state mindfulness would score high on this item to reflect a highly mindful moment of being—state mindfulness. Indeed, increases in state mindfulness over the course of MP can contribute to the enhancement of one’s trait mindfulness (Kiken, Garland, Bluth, Palsson, & Gaylord, 2015). However, the distinction between state and trait mindfulness is not merely about their differences in longevity; trait mindfulness also has features that are not possessed in state mindfulness. First, trait mindfulness has been found to be correlated with a range of symptoms indexing well-being and personality traits. For example, trait mindfulness is positively correlated with life satisfaction, conscientiousness, and negatively correlated with psychological distress (depression, anxiety, stress-related symptoms), neuroticism and impulsivity (Cash & Whittingham, 2010; Fetterman, Robinson, Ode, & Gordon, 2010; Giluk, 2009; Jordan, Wang, Donatoni, & Meier, 2014; Lattimore, Fisher, & Malinowski, 2011). Second, trait mindfulness impacts the practice outcome of MP. People with higher trait mindfulness resulting in greater improvements (Shapiro, Brown, Thoresen, & Plante, 2011). Lastly, state and trait mindfulness are not always correlated (B. L. Thompson & Waltz, 2007).
that individuals who score high in state mindfulness can be low in trait mindfulness, and vice versa. For instance, individuals low in trait mindfulness can be high in state mindfulness during mindfulness meditation, and individuals high in trait mindfulness can experience trouble managing difficult emotional moments, such as having a driver recklessly cut in front of them. Moreover, a study recorded participants’ state mindfulness weekly over an 8-week MBI and found no correlation between the initial levels of trait mindfulness and the individual trajectories of state mindfulness (Kiken et al., 2015). These findings suggest that state mindfulness and trait mindfulness are distinct constructs.

In conclusion, the term “mindfulness” can be used to describe a practice of cultivating mindfulness, a state of being, or a personality trait. Trait mindfulness is an innate predisposition that can be improved through MP, while the frequency of experiencing a mindful state can be a hallmark in evaluating one’s progress in developing trait mindfulness. However, trait mindfulness is not simply an extension of state mindfulness, which is evidenced by changes in fundamental brain function and structure relating to trait mindfulness, and distinct responses to MP. Future measurements of state mindfulness and trait mindfulness should reflect the qualitative difference between the two, and studies should explicitly state what aspect of mindfulness is being examined: the psychological construct of mindfulness, state mindfulness, trait mindfulness, or MP, to minimize possible confusion.

Attention

Living in an information-rich environment, we need attention to guide information processing. William James says, “Everyone knows what attention is” (1890, p. 403). However, people have conceptualized attention in various ways. Most researchers have defined attention as
a different either-or components (Table 1; Anderson, 2011). Depending on whether the attentional process is governed by “low-level” effortless reflexive mechanism or “high-level” effortful voluntary mechanism, attention can be categorized into exogenous attention and endogenous attention (Posner & Cohen, 1984).

Exogenous Attention

When attention is involuntarily captured by highly perceptually salient stimuli (e.g., bright light, loud noise), it is exogenous attention (bottom-up or stimulus-driven) (Posner, 1980; Prinzmetal, Zvinyatskovskiy, Gutierrez, & Dilem, 2009; Yantis, 1993). Exogenous attention is featured with rapidness and automaticity; thus, it only requires little conscious awareness or effort (Keele, 1972; Michael I. Posner, 1980; Prinzmetal et al., 2009). Types of exogenous attention include alerting and orienting. Alerting is responsible for maintaining a vigilant state that facilitates behavioral performance, while the orienting network is responsible for selectively attending to a sensory modality or a location in space by prioritizing only a subset of possible inputs (Posner & Petersen, 1990). Both alerting and orienting can be studied using the Posner spatial cueing paradigm, in which participants fixate at a central point that is flankered by two boxes, one on each side; about 100 -1000 ms following an attentional cue (e.g., the box brightens), a target that requires a response (usually key press) appears at either the cued box or the uncued box. Participants respond faster if target appears at the cued location than the uncued location, suggesting that the attentional cue facilitates response to targets appearing in that same location (Posner, Snyder, & Davidson, 1980). The cue serves as both a spatial cue that draws attention to the location, and an alerting signal that warns a target is coming.
In the real world, the orienting system and the alerting system work together closely since a signal event often provides information on both when and where a target will appear (Fan et al., 2009). For example, hearing someone calling our names both alert us and make us look for the sound source.

**Endogenous Attention**

When the attentional process is in service of goals, it is endogenous (top-down or goal-driven) attention (Johnston & Dark, 1986; J. Theeuwes, 1994), which requires conscious effort to voluntarily control the selection (Todd S Braver & Cohen, n.d.; Müller & Rabbitt, 1989; Prinzmetal et al., 2009; Wright & Richard, 2000). Types of endogenous attention include sustained attention and executive attention. Sustained attention is “the ability to self-sustain mindful, conscious processing of stimuli whose repetitive, non-arousing qualities would otherwise lead to habituation and distraction to other stimuli” (Robertson et al., 1997, p. 747). Sustained attention is closely related to the mental state of ‘vigilance’ or tonic alertness, the ongoing intrinsic arousal that fluctuates on the order of minutes to hours (Degutis & Van Vleet, 2010). It is important to distinguish sustained attention from the alerting network discussed above. Sustained attention may last from minutes to hours and is enhanced by intrinsic will or mentally-held goal, while the alerting network is related to phasic alertness that is transient and enhanced by unexpected and brief external stimuli (Posner, 2008; Posner & Petersen, 1990).

Animal research has shown that sustained attention activates the basal forebrain corticopetal cholinergic system, a major component of the top-down processes initiated by the ‘anterior attention system’ to facilitate goal-directed detection by enhancing sensory information processing of target and attenuating the processing of distractors (Sarter, Givens, & Bruno,
further supporting that sustained attention is more than increased alerting. Sustained attention can be measured with the Sustained Attention to Response Task (SART, Robertson, Manly, Andrade, Baddeley, & Yiend, 1997a), a computer-based Go/no-go task that requires one to respond to a stream of repetitive stimuli (go) but withhold responses to infrequent stimuli (no-go). High level of sustained attention to the stimuli improves the performance in this task.

Executive attention (also known as attentional control or attentional inhibition) comprises the capacity to monitor and resolve conflicting information including responses, stimuli, and thoughts (Posner & DiGirolamo, 1998; Rueda, Posner, & Rothbart, 2005; Jan Theeuwes, 1991). Executive attention has been frequently studied using the Eriksen Flanker task (Eriksen & Eriksen, 1974) and the Stroop task (Stroop, 1935). The flanker task contains congruent trials with same stimuli, and incongruent trials with both target and distractors. The response time to the incongruent trials is slower than congruent trials due to the competing stimuli conflicting responses the incongruent elicits. Likewise, the interference in a Stroop task is the mismatch between word and its ink color, e.g., the word BLUE is printed in red ink. The instruction is to respond to ink color instead of word. Conflict arises here since word reading is relatively automatic and rapid, which interferes with color naming, thus slowed down the response time (Donohue, Liotti, Perez, & Woldorff, 2012).

Endogenous attention is central to executive function (EF), which refer to a broad range of top-down (high-level) cognitive processes that are critical for many aspects of life such as mental health, school success, and interpersonal skills (Espy, 2004; Miller & Cohen, 2001). While some consider EF as a unitary construct (Baddeley, 1986; Duncan, Emslie, Williams, Johnson, & Freer, 1996; Duncan, Johnson, Swales, & Freer, 1997; Stuss & Alexander, 2000; Teuber, 1972), more recent research has conceptualized EF as distinct functions: inhibition
(inhibitory control), cognitive flexibility (also called switch or set shifting), and Working Memory (WM) (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000). Inhibition involves the ability to control one’s thoughts, behavioral, emotions, and/or attention in order to adhere to goals or rules (Rothbart, Posner, & Kieras, 2008). The inhibitory control of attention resembles executive attention as it enables us to focus attention on goal-driven stimuli to and suppress attention to distractors; thus, the inhibitory control of attention has often been studied using tasks that measure executive attention as discussed above (for reviews, see Diamond, 2013). Cognitive flexibility refers to the ability to change one’s perspective to handle new and unexpected conditions (Cañas, Quesada, Antolí, & Fajardo, 2003). It is often investigated using task-switching and set-shifting tasks such as the Wisconsin Card Sorting Test (WCST; Berg, 1948; Grant and Berg, 1948; Heaton et al., 1993; Nelson, 1976) or the Dimensional Change Card Sort Test (DCCS) (Zelazo, Frye, & Rapus, 1996). In DCCS, the cards need to be sorted by one dimension (e.g., color) but the rule changes during the task that the cards need to be sorted in a new way (e.g., by shape). Three or four-year olds tended to use the old rule despite they were told about the new rule. This error is due to tendency to focus attention on previous dimension and trouble in switching attention to new dimensions (Chatham, Yerys, & Munakata, 2012; Klo & Perner, 2005). WM involves processing information that is holding in mind rather than being perceptually present (Baddeley & Hitch 1994, Smith & Jonides 1999). WM is closely related to sustained attention that enables us to maintain attention on the information in mind, so that we can work with such information (Awh, Anllo-Vento, & Hillyard, 2000; Gazzaley & Nobre, 2012).

The above discussion illustrates that endogenous attention is an integrated part of various EFs. Although each EF can be examined using a specific task (N. P. Friedman et al., 2008;
Miyake et al., 2000; van der Sluis, de Jong, & van der Leij, 2007), it is important to note that one task usually measures multiple cognitive processes rather than one pure process (Jacoby, 1999). For instance, to succeed in the Stroop task requires not only execution attention, but also sustained attention to continually monitor the stream of stimuli.

**Neural Circuits of Exogenous and Endogenous Attention**

Both exogenous and endogenous attention rely on the fronto-parietal attention network. For exogenous attention, the alerting network involves the locus coeruleus, the parietal, and right frontal cortex (Marrocco & Davidson, 1998), and the orienting network involves the activation of a dorsal fronto-parietal network (Corbetta & Shulman, 2002; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). Among endogenous attention, executive attention activates the anterior cingulate cortex (ACC) and the lateral prefrontal cortex, and with dopamine (Botvinick, Carter, Braver, Barch, & Cohen, 2001; Bush, Luu, & Posner, 2000; Fan, Flombaum, Mccandliss, Thomas, & Posner, 2002), and sustained attention activates the right hemispheric fronto-parietal regions (Cohen, Semple, Gross, King, & Nordahl, 1992; Coull, 1998; Fink et al., 1997; Pardo, Fox, & Raichle, 1991; Sarter et al., 2001). However, regions of this network are differentially engaged over time for each type of attention (Corbetta, Miezin, Shulman, & Petersen, 1993; Corbetta & Shulman, 2002b; Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005; Meyer, Du, Parks, & Hopfinger, 2018; Peelen, Heslenfeld, & Theeuwes, 2004). Specifically, exogenous attention activates posterior region first or more strongly, while endogenous attention activates the anterior region first, which includes the prefrontal cortex (PFC) and the anterior cingulate cortex (ACC) (Braver & Cohen, 2000; Buschman & Miller, 2007; Corbetta, Miezin, Dombeyer, Shulman, & Petersen, 1991; Posner & Petersen, 1990). Buschman and Miller (2007) recorded
neuronal firing from frontal eye fields and the lateral intraparietal area during macaque monkeys performing endogenous and exogenous attention tasks and found that parietal areas activated before frontal areas in exogenous attention, whereas the reverse was true for endogenous attention. Similar results have been found in humans (Li, Gratton, Yao, & Knight, 2010). Specifically for exogenous attention, a study found that disrupting the right parietal cortex in humans using repetitive transcranial magnetic stimulation (TMS) interferes with exogenous attention but not endogenous attention (Hodsoll, Mevorach, & Humphreys, 2009), indicating that the parietal network is more involved in processing low-level stimulus features. In contrast, lesioning lateral prefrontal cortex in non-human primates impairs endogenous but not exogenous attention (Rossi, Bichot, Desimone, & Ungerleider, 2007), suggesting that endogenous attention relies more on the anterior system.

In line with these findings, a more recent investigation showed that during visual discrimination in endogenous or exogenous attention conditions, fMRI activation in the fronto-parietal network are differentially engaged across hemispheres depending on the type of attention. Specifically, during the endogenous condition, frontal areas were more active than parietal areas in the left hemisphere, whereas the exogenous condition showed the opposite pattern (Meyer et al., 2018). Together, these findings suggest that endogenous attention is more frontally dominated, whereas exogenous attention is more parietally-dominated (Baluch and Itti, 2011, Buschman and Miller, 2007, Li et al., 2010).

**ERP Indices of Attention**

Event-related potentials (ERPs) are summed post-synaptic activity of the local pyramidal neural population(s) and a broad array of ERP components has been used to study attention
including P1, N1, P2, P2a, N2, N2b, N2pc, P3a, P3b, MMN, etc. (Luck, Woodman, & Vogel, 2000). It is beyond the scope of the current paper to thoroughly discuss each ERP component; instead, an overview will be given on selected ERPs to illustrate the idea that early ERP components usually index low-level exogenous attention, whereas late ERP components index high-level endogenous attention (Hopfinger & West, 2006).

**Low-level attention: P1, N1, and P3a.** The P1 is a positive component that peaks around 100-130 ms after stimulus onset and its neural generator is likely in lateral extrastriate visual areas (Luck, Woodman, & Vogel, 2000). The P1 is closely followed by the N1, a negative component that peaks around 100-170 ms post-stimulus. The neural generators of the N1 are largely unknown due to its wide distribution on the scalp (Mangun & Hillyard, 1991), but it is thought to have multiple generators in the occipito-parietal, occipito-temporal, and possibly frontal cortex (Clark, Fan, & Hillyard, 1994). Both the P1 and the N1 reflect early process of low-level physical features (e.g., loudness or brightness) of the stimuli (Alcaini, Giard, Thevenet, & Pernier, 1994; Näätänen & Picton, 1987). Sensory gain model of attention (Hillyard et al., 1998) interprets the P1 and N1 attention effect as increased visual processing of attended stimuli, and reduced visual processing of unattended stimuli since they are larger to attended stimuli than unattended stimuli (Luck, 1995; Luck, Woodman, & Vogel, 2000; Wascher et al., 2009).

The P3a is a positive deflection that peaks around 250 ms over frontal-central scalp post-stimulus (for reviews, see Polich, 2003, 2007) and its neural generators are broadly localized in anterior cingulate, frontal area and parietal cortices (Polich, 2007; Strobel et al., 2008; Volpe et al., 2007). The P3a is also called novelty P300 and is thought to index the automated low-level stimulus-driven attention (orienting) to task irrelevant and novel stimuli. The P3a is usually assessed in a 3-stimulus oddball task or novelty oddball task, which consists of standards
(frequent irrelevant), targets (rare relevant), and novels (rare irrelevant). Each novel stimulus is unique, thus novel stimuli engage automatic orienting response (because it’s rare) but not executive attention (because it’s task irrelevant) (Katayama & Polich, 1996; Squires, Squires, & Hillyard, 1975), whereas the targets engage both executive attention (because they are task relevant) and orienting but to a less extent because their probability is higher than novels. The standards do not engage either type of attention because they are neither rare nor task relevant, thus providing the contrast condition to the novels and targets. For example, in a visual novelty oddball task in Courchesne et al. (1975), an array of novel patterns (10%) were embedded in an oddball paradigm with rare 4s (10%) and frequent 2s (80%). Participants were instructed to mentally count the 4s while ignoring the 2s and novel patterns. The P3a was elicited to the novel patterns although they were task irrelevant, indicating that it indexes an orienting to novelty response.

**High-level attention: P2a, N2b, and P3b.** P2a occurs between 180 to 300 ms post-stimulus with a inferior prefrontal distribution and has been source localized to orbitofrontal cortex (Potts, 2004). A negative component that occurs at the same time as the P2a is the N2b, whose scalp distribution may vary depending on the selection requirement (see review, Folstein & Van Petten, 2008; Potts, Liotti, Tucker, & Posner, 1996; Simson, Vaughan, & Ritter, 1977). One study employed two target detection tasks to study the P2a and N2b (Potts & Tucker, 2001). The task showed four placeholder boxes on the screen, and one of four symbols appeared randomly in one of the boxes. When the target was a particular symbol (object detection), participants pressed a key to the target regardless which box it appeared in; when the target was a specific box (spatial detection), participants then responded to the box regardless which symbol it contained. P2a to the targets was enhanced in both conditions. Interestingly, the N2b was
located over posterior dorsal leads in visual-spatial target detection and over posterior ventral leads in visual-object target detection. These findings suggested that the P2a measures the top-down evaluation of target relevance and N2b indexes the relevant features of the target depending on task requirement (Potts & Tucker, 2001).

The P3b is a positive deflection that peaks around 300-450 ms over the parietal cortex following stimulus onset (Donchin, 1981). Its broad scalp distribution suggests the involvement of multiple generators including superior and medial temporal, posterior parietal, hippocampal, cingulate and frontal structures (Polich, 2007, Strobel et al., 2008, Volpe et al., 2007, Wronka et al., 2012). The amplitude of the P3b is reversely correlated with the frequency of the target, the rarer the target, the larger the P3. The P3b is larger to targets in either the 3-stimulus oddball, as described above, or in the simplified 2-stimulus oddball which is the same except it doesn't contain the novels. Since searching for the target stimuli requires conscious effort to hold the target in mind and suppress irrelevant stimuli, thus the P3b is thought to reflect high-level goal-driven attention. The elicitation of the P3b is not affected by response type, e.g., silent count or press a key.

**Effect of MP on Exogenous and Endogenous Attention**

Due to the relevance of endogenous attention to EF, it is not surprising that most mindfulness studies have focused on the investigation of high-level endogenous attention. Among studies that investigated the effects of mindfulness on sustained attention, most studies employing the SART task. Several studies observed significant improvement in sustained attention among naïve participants without MP experience (MacLean et al., 2010; Mrazek et al., 2012; Semple, 2010; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010), and one observed
significant improvement in sustained attention among meditators (Valentine & Sweet, 1999). Only few studies did not observe significant improvement in sustained attention in meditators (Josefsson, Broberg, 2011; Johnson, Gur, David, & Currier, 2015). However, Josefsson & Broberg (2011) did find a relationship between high mindfulness state and fewer SART errors and lower Stroop interference, indicating that task performance did not capture the outcome of mindfulness meditation. Overall, MP has been found to be efficient in improving sustained attention.

Similarly, there is also abundant evidence that MP improves executive attention. Most studies have found better behavioral performance in either the Stroop task or the Flanker task following MP (Basso et al., 2018; Bing-Canar, Pizzuto, & Compton, 2016; Wenk-Sormaz, 2005; Andreu et al., 2017; Sauders et al., 2015; Larson, Steffen, & Primosch, 2013). Only few studies did not observe any behavioral differences between the two groups performing a Flanker task (Larson, Steffen, & Primosch, 2013; Norris, Creem, Hendler, & Kober, 2018). However, Norris et al. (2018) found that individual differences in neuroticism moderates the outcome of MP. Among participants who listened to a 10-min mindfulness tutorial, individuals lower in neuroticism showed improved attentional control (a larger N2—an anterior negative component thought to index detection of stimulus mismatch) to the incongruent trials than the control group, whereas individuals higher in neuroticism did not (Norris, Creem, Hendler, & Kober, 2018). This finding demonstrates the importance of considering individual differences when evaluating the impact of MP on attention and provides a possible explanation for the null finding in Larson et al. (2013).

To our knowledge, only one study has examined the effect of mindfulness on low-level attention (Cahn & Polich, 2009). Cahn & Polich (2009) employed a three-stimulus auditory
oddball task with three types of tones: irrelevant novel tones (novel, 10%), irrelevant frequent tones (standard, 80%), and relevant tones (target, 10%) to a group of Vipassana meditators during meditation versus a thought period (think about emotionally neutral past events). They found a reduced P3a to the novels, but not to the targets during meditation when compared to the control state, showing that meditation reduced the processing of task-irrelevant distractors at early processing. The drawback of this study is that it did not include a control group of non-meditators, making it impossible to determine whether the observed effect was due to trait (unique to meditators), state (whenever one meditates), or an interaction of both trait and state.

**Acceptance**

Acceptance refers to the willingness to take in current experience without the attempt to change it or letting it interfere with ongoing behavior (Hayes, Pistorello, & Levin, 2012). Although acceptance is not explicitly defined to change emotions, it has been labeled as an emotion regulation strategy to change how people relate to their feelings (Bishop et al., 2004; Brown & Ryan, 2003). The acceptance aspect of mindfulness has been found to be most strongly associated with reduced affective symptoms and lower levels of psychopathology (see review MacBeth & Gumley, 2012). Being able to adaptively cope with emotions, especially negative emotions, is important to psychological health (Petrocchi & Ottaviani, 2016; Soysa & Wilcomb, 2015).

Within the framework established by Gross (1998), emotion regulation is the ability to control one's own emotions and emotional responses (Gross, 1998b). Two common emotion regulation strategies are suppression and cognitive reappraisal (Gross, 1998a; Gross & Thompson, 2007). Suppression refers to individuals effortfully inhibit their emotions while
cognitive reappraisal refers to reinterpret a situation in a way that changes its emotional impact (Gross & John, 2003). Cognitive reappraisal is generally more efficient in reducing the intensity of emotion, while suppression may actually lead to increased emotional intensity (Goldin, McRae, Ramel, & Gross, 2008). People with psychological disorders might have difficulty using reappraisal, since it requires cognitive control (Keightley et al., 2003; Liotti, Mayberg, McGinnis, Brannan, & Jerabek, 2002). Another adaptive emotion regulation strategy, acceptance, has been found to have similar effects as cognitive reappraisal in reducing negative affective reactivity (Kohl, Rief, & Glombiewski, 2012; Wadlinger & Isaacowitz, 2006; Wolgast, Lundh, & Viborg, 2011) and is perceived as less cognitively demanding than reappraisal (Troy, Shallcross, Brunner, Friedman, & Jones, 2018) because it may require less recruitment of autonomic, cognitive, and neural resources (Goldin, Moodie, & Gross, 2019). Acceptance has been integrated into several therapeutic approaches, including Acceptance and Commitment Therapy (ACT, said as a single word instead of initials; Hayes, Strosahl, & Wilson, 1999), Dialectical Behavior Therapy (DBT; Linehan, 1993), and Mindfulness-Based Cognitive Therapy (MBCT; Segal, Williams, & Teasdale, 2001). These acceptance-based therapies have been found to benefit individuals with various mental health conditions, e.g., depression, anxiety, and eating disorder (see reviews, Louise, Fitzpatrick, Strauss, Rossell, & Thomas, 2018; Veehof, Trompetter, Bohlmeijer, & Schreurs, 2016; Wakefield et al., 2018).

**Neural Circuits of Acceptance**

Common neural substrates have been observed in both acceptance and cognitive reappraisal, perhaps due to their similar effects in reducing negative affectivity (Kohl et al., 2012; Wadlinger & Isaacowitz, 2006; Wolgast et al., 2011). Studies on cognitive reappraisal
have revealed a general pattern that attempts to regulate emotion is associated with increased activation in prefrontal cortical areas (PFC) and dorsal anterior cingulate cortex (dACC), areas that are involved in cognitive control; and reduced subjective experience of the emotion intensity is related with decreased activation in amygdala, an area that is critical in detecting and evaluating emotional significance of stimuli (Ochsner et al., 2004; Ochsner, Bunge, Gross, & Gabrieli, 2002; Schaefer et al., 2002; Beauregard, Levesque, & Bourgouin, 2001). Similarly, increased activation of PFC regions has also been reported in studies of acceptance toward emotional reactivity to sad films in healthy adults (Smoski et al., 2015), acceptance toward personally salient worry statements in females with generalized anxiety disorder (Ellard, Barlow, Whitfield-Gabrieli, Gabrieli, & Deckersbach, 2017), and acceptance toward idiographic negative self-beliefs among healthy adults (Goldin et al., 2019). The last two studies also found reduced activation in amygdala.

Both acceptance and cognitive control strategies of emotion regulation appear to involve increased activation of PFC and reduced activation of the amygdala, indicating prefrontal regulation of limbic response to affective, particularly negatively affective, stimuli and experiences.

**Effect of MP on Acceptance**

One of the well-documented benefits of MP is improved well-being characterized by lower levels of negative affective symptoms (for reviews, see Alsubaie et al., 2017; Gu, Strauss, Bond, & Cavanagh, 2015). Emotion regulation is also closely related to well-being, especially the ability to downregulate negative emotion, which is critical for psychological health that impaired emotion regulation abilities is often found in people with mood disorders (Cicchetti,
This session will first discuss the effect of MP on the broader construct of emotion regulation and then discuss the effect of MP on acceptance, one specific strategy of emotion regulation.

**Emotion regulation.** Correlational studies have revealed that people high in trait mindfulness are more likely to use adaptive emotion regulation strategies than maladaptive emotion regulation strategies such as experiential avoidance, thought suppression, and rumination (Baer et al., 2004; Brown & Ryan, 2003; Feldman, Hayes, Kumar, Greeson, & Laurenceau, 2007). Tendency to adopt adaptive emotion regulation strategies is also evident in neuroimaging studies that higher trait mindfulness has been found to be associated with increased activation in the prefrontal areas such as lateral prefrontal cortex (LPC) and medial prefrontal cortex (MPFC), as well as reduced activation in amygdala during an affect labeling task (Creswell, Way, Eisenberger, & Lieberman, 2007), suggesting increased cognitive control and decreased subjective evaluation of emotional intensity over the affect being labeled, a pattern consistent with that involved in cognitive reappraisal and acceptance as discussed above.

One of the earliest studies that employed a brief MP induction suggested that MP contributes to emotion regulation by fostering one’s ability to cope with negative emotion (Arch and Craske, 2006). The study compared the effects of a 15-minute mindfulness breathing induction with the effects of 15-minute recorded inductions of unfocused attention and worrying on response to emotional slides. The mindfulness group reported lower negative affect and overall emotional volatility to the post-intervention emotion slides than the worry group and greater willingness to view negative slides than the unfocused group, suggesting that mindfulness promoted adaptive responding to negative stimuli. This study also demonstrated that the ability to cope with negative emotion (acceptance) can be enhanced with a brief MP. Overall,
these findings suggest that MP facilitates emotion regulation by promoting the use of adaptive emotion regulation strategies in reducing aversive emotions (Arch & Craske, 2006; Feldman et al., 2007; Kross, Davidson, Weber, & Ochsner, 2009).

**Acceptance.** Most studies have examined the effect of MP on acceptance through the assessment of affective reactivity to emotional stimuli (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Kohl et al., 2012; Szasz, Szentagotai, & Hofmann, 2011; Wadlinger & Isaacowitz, 2006; Wolgast et al., 2011). Findings from neuroimaging studies are largely consistent with the earlier discussion that MP reduces activation in amygdala (Gaëlle Desbordes et al., 2012; Goldin & Gross, 2010; Kral et al., 2018; Phelps, Delgado, Nearing, & Ledoux, 2004). For example, one study had participants passively view emotional pictures from the International Affective Picture Set (IAPS; Lang et al., 2008), showing that healthy adults who underwent 8 weeks of mindfulness training showed reduced amygdala activity to the emotional pictures when compared to a group who underwent an 8-week Cognitively-Based Compassion Training (a program based on Tibetan Buddhist compassion meditation practices) and a group that attended a health discussion (Gaëlle Desbordes et al., 2012). Another study had participants press a button to indicate the valence (negative, neutral, or positive) of affective pictures from the IAPS database. Relative to the controls who completed an 8-week Health Enhancement Program, both short-term mindfulness group (8-week of MBSR) and long-term meditation group (86% mindfulness-based practitioners; an average of 9081 lifetime hours of meditation practice) showed less amygdala reactivity to positive pictures but not negative pictures, despite self-reported lower emotional reactivity measured by FFMQ (Kral et al., 2018). Similar results were found in a clinical population of individuals with social anxiety disorder who completed an 8-week MBSR course and subsequently reported decreased negative emotional experience and
showed decreased amygdala activation while viewing phrases expressing negative self-beliefs when compared to baseline (Goldin & Gross, 2010).

This evidence from self-report data and neurobiological data suggests that MP reduces affective reactivity to emotional stimuli via a similar mechanism as acceptance strategies. Although the nonjudgmental aspect of acceptance is thought to facilitate the coping with negative emotions, most mindfulness emotion regulation studies have not explicitly measured acceptance. Moreover, most studies have employed various forms of MBIs, which integrated MP with educational materials, potentially confounding acceptance with other intervention factors.

**Behavioral and ERP Indices of Affective Response**

Negative experience is of great relevance to depression and anxiety disorder (Watson, 2009), thus the acceptance component of mindfulness has been studied as a strategy for dealing with unwanted experience. Making errors can be such an unwanted experience because it elicits negative emotion and is accompanied by increased activation of the defensive motivational system (Hajcak & Foti, 2008).

**Post-error slowing (PES).** PES is a phenomenon that people tend to respond slower to the subsequent trial after they have made an error (Rabbitt, 1966). Cognitive control theories suggest that PES is resulted from the adaptive control mechanisms that promote more careful behavior to improve performance in the following trial (Botvinick et al., 2001; Notebaert et al., 2009). However, the literature suggests that PES does not usually lead to increased accuracy in the post-error trial (e.g., Hajcak & Simons, 2008; Hajcak, McDonald, & Simons, 2003; Rabbitt & Rodgers, 1977). Thus, PES is closely related to the error itself rather than an intentional behavior to avoid errors in the subsequent trial. An alternative view is the orienting account,
suggesting that errors are salient events that are embedded in an array of correct events during performance, such that errors draw attention away and thereby slow down response to the post-error trial (Notebaert et al., 2009). While this account did not indicate the exact internal processes taking away one’s attention following an error, it is likely to be the negative affect resulting from errors. This can be evident by the observation that alpha power tends to increase (more relaxed status) following correct responses and decreased (heightened arousal) following erroneous response (Carp & Compton, 2009; Compton, Arnstein, Freedman, Dainer-Best, & Liss, 2011). The affective state elicited by the error commission may interfere with subsequent responses, resulting in PES. Thus, people who are more accepting to their errors may show a reduced orienting to errors thus shortened PES.

**Error-related negativity (ERN).** The ERN, also called error negativity (Ne), is a negative deflection that occurs over central-frontal within 100 ms following an incorrect response selection (Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; William J. Gehring, Goss, Coles, Meyer, & Donchin, 1993). The ERN has been source localized to the ACC (Dehaene et al., 1994).

The response monitoring theory has proposed that the ERN indexes error detection because the ERN occurs following making a wrong response but not correct responses in tasks that require a speeded response (e.g, Flanker task, Stroop task) (Coles, Scheffers, & Holroyd, 2001; Falkenstein et al., 1991; W. J. Gehring, Goss, Coles, Meyer, & Donchin, 1993; Holroyd & Coles, 2002; Yeung, Botvinick, & Cohen, 2004). However, growing research has suggested that the ERN might reflect the affective distress to errors, the stronger the affective distress, the larger the ERN (Luu, Collins, & Tucker, 2000; Luu, Tucker, Derryberry, Reed, & Poulsen, 2003; Luu & Tucker, 2004). Hajcak et al. (2005) designed two experiments to examine the relationship
between the significance of errors and the ERN amplitude. In Experiment 1, the value of errors was manipulated on a trial-by-trial basis that errors on some trials were associated with higher monetary value. In Experiment 2, participants in the evaluation condition were informed that their performance would be evaluated on-line by a researcher, who would compare their performance to others, but not in the control condition. The rational is that making a high-value related error or being evaluated is associated with stronger affective distress than making a low-value related error or not being evaluated. Both experiments showed that more significant errors (i.e., higher monetary value or being evaluated) were associated with a larger ERN. These findings indicate that ERN can be used as a measure of the degree of affective distress to erroneous responses.

This affective distress proposal of the ERN is not conflicting with the response monitoring theory but an extension of it. Detecting an error is directly linked with the elicitation of affective distress because a correct response is in line with expectation, thus it will not elicit such an affective distress as a wrong response does.

**Attention Deficit Hyperactivity Disorder (ADHD) and MP**

Since the core procedures in MP involve attention regulation, it is important to examine whether MP is effective for individuals with difficulty regulating their attention, i.e., Attention deficit hyperactivity disorder (ADHD) symptoms. ADHD is a highly prevalent neurobehavioral disorder that affects approximately 5% to 7% of children and adolescents worldwide in addition to 4.4% of adults (APA, 2013), with effects on children and teens that may continue into adulthood (Biederman, 2005). ADHD is characterized by the inability to concentrate (inattention) and impulsivity such that individuals with ADHD have trouble with focusing
attention on daily activities (e.g., sitting still during classes, concentrate on a conversation) and are often at risk of poor grades, poor job performance, and interpersonal difficulties (Barkley, 2002).

The inhibition deficit model of ADHD (Barkley, 1997) proposed that impairments in inhibitory control constitute the core deficit. In line with this proposal, a meta-analytic review revealed that response inhibition is one of the most consistent group differences between people with ADHD and controls (82% of all studies) (Willcutt, Doyle, Nigg, Faraoe, & Pennington, 2005). Moreover, several studies have shown that individuals with ADHD were poor at inhibitory control as measured with the stop task (Chamberlain et al., 2011, Lijffijt et al., 2005, Lipszyc and Schachar, 2010, Logan et al., 1997, Logan and Sergeant, 1998, Willcutt et al., 2005). This impaired inhibitory control is likely to challenge individuals with ADHD during mindfulness practice because it requires one to remain physical steady and maintain mental focus by constantly bringing attention back to the current experience (Bishop et al., 2004).

Traditionally, medication (mostly stimulants) and behavioral treatments are the two main treatments for individuals with ADHD (Van der Oord, Prins, Oosterlaan, & Emmelkamp, 2008). In recent years, treatment programs for ADHD have integrated MP with therapeutic techniques such as Mindfulness-Based Cognitive Therapy (van de Weijer-Bergsma, Formsma, de Bruin, & Bögels, 2012; Saskia van der Oord, Bögels, & Peijnenburg, 2012) and Acceptance and Commitment Therapy (Murrell, Steinberg, Connally, Hulsey, & Hogan, 2015). Therefore, it would be helpful to evaluate whether mindfulness works for this population due to their impaired inhibitory control.

Several recent reviews have examined the efficacy of MP in reducing the core symptoms of ADHD (i.e., inattention and impulsivity) including: two meta-analytic reviews (Cairncross &
Miller, 2016; Chimiklis et al., 2018) and two systematic reviews (Evans et al., 2018; Lee et al., 2017). The majority of the results seem to favor the efficacy of MP in adults rather than children. Specifically, Lee et al (2017) reported that mindfulness intervention was effective for improving ADHD symptoms in 6 studies of adults, but no conclusion could be made with children or adolescents since only 3 studies were conducted in these age groups. The authors suggested that adults have more self-control to adhere to the practice than children. Related, Evans et al (2018) reviewed studies in children with ADHD and revealed that the most consistent improvements in ADHD symptoms were found in interventions that involved both the parent and the child. This finding may suggest that the presence of the parent is likely to increase the child’s compliance to the program. Further, all of these reviews suggested that no definitive conclusions could be made due to high bias and methodological limitations in existing studies (Chimiklis et al., 2018; Evans et al., 2017a). For example, a few studies did not include a control group (Zylowska et al., 2008; Haydicky et al., 2015).

In conclusion, MP may have the potential to alleviate symptoms of ADHD (Mitchell, Zylowska, & Kollins, 2015), but the efficacy of MP in this population warrants further investigation. Given the requirement of attentional control during MP, it is important to ask whether individuals with attention deficit can equally benefit from MP.
THE CURRENT PROPOSAL

MP has gained increased attention in recent years because its efficacy in lowering psychological distresses (e.g., depression, anxiety, stress) and improving cognitive functions (e.g., attention, memory, emotion) (see reviews Chambers, Gullone, & Allen, 2009; Chiesa et al., 2011; Keng, Smoski, & Robins, 2011; Lomas, Medina, Ivtzan, Rupprecht, & Eiroa-Orosa, 2018). A better understanding of the active components of MP will help us identify the unique mechanisms that drive the reported effects and better incorporate these components into existing therapeutic approaches that could potentially benefit more people.

Cumulative research has suggested that MP involves two active components, attention regulation and acceptance of experience (Bishop et al., 2004; Lindsay & Creswell, 2017). Although most studies have reported that short-term MP improves high-level attention, it is unclear whether short-term MP impacts merely high-level attention or also low-level attention because most studies have focused on high-level attention. A review of the literature returned two studies that examined the effect of MP on both low- and high-level attention. Both studies reported improvement in executive attention, but not alerting or orienting when assessed using the attention networks test (Elliott, Wallace, & Giesbrecht, 2014; Tang et al., 2007). However, the mindfulness interventions in both studies did not strictly illustrate the two components of mindfulness, attention regulation and acceptance of experience, thus hampers the validity of the findings. One study used a 5-day integrative body–mind training (IBMT) program with three components, body relaxation, mental imagery and mindfulness training (Tang et al., 2007).
Another study adopted a 7-day retreat including mindfulness of breathing and Shamatha meditation that emphasize physical and mental relaxation and maintaining attention on the object of meditation, but not acceptance of experience; furthermore, Shamatha meditations included meditation practices on loving kindness; the control group were not naïve participants because they had completed one or two days of the retreat involving watching lectures, attending discussions, and learning guided meditation (Elliott, Wallace, & Giesbrecht, 2014).

Self-regulation of attention is the basic and fundamental requirement in MP (Bishop et al., 2004; Lindsay & Creswell, 2017). Such an effortful “high-level” activity trains the ability to effortfully control one’s attention (Biedermann et al., 2016); therefore, MP might be more likely to impact high-level attention that utilizes this ability of voluntary control, and less likely to impact low-level attention that does not demand the ability of voluntary control.

Among studies reporting that MP improves acceptance indexed by reduced affective response, most of them adopted emotion labeling tasks by presenting emotional images or phrases to participants. However, studies have suggested that viewing external emotional stimuli and labeling cannot reliably elicit strong, self-relevant affective experiences (Kral et al., 2018). Thus, an experimental design that allow participants to self-generate affective events may promote stronger and self-relevant affective responses in the laboratory. Moreover, existing studies have rarely explicitly examined the mechanism through which mindfulness improves acceptance. One such mechanism is decentering (Shapiro, Carlson, Astin, & Freedman, 2006), a process that promotes one to perceive thoughts, feelings, or physical sensations with some distance (Teasdale et al., 2002). Decentering changes one’s relationship to negative thoughts or feelings so that one can let go negative thoughts and feelings rather than reacting to them. Two studies examined decentering as an outcome by comparing 10 to 12 minute of mindful breathing
(MB) to a neutral control condition consisting of listening to educational recordings and completing mental puzzles (Erisman & Roemer, 2010), a group practicing progressive muscle relaxation (PMR), and a group practicing loving-kindness meditation (LKM) (Feldman, Greeson, & Senville, 2010). Both studies found that participants who received MB reported more decentering (measured by the Toronto Mindfulness Scale (TMS; Lau et al., 2006) than all the other groups. Several studies have explicitly examined the relationships between decentering and negative affective reactions including reduced pain, anxiety, and depression (Fresco et al., 2007; Hoge et al., 2014; Lau et al., 2006; Shoham, Goldstein, Oren, Spivak, & Bernstein, 2017), reduced cravings for food (Papies, Winckel, & Keesman, 2016) and reduced impulses to grab food (Papies, Barsalou, & Custers, 2012). To date, most studies have not examined the effect of mindfulness on acceptance by assessing both the general state of acceptance measured by self-reported decentering and the specific behavioral outcome of acceptance, reduced reactivity to self-relevant affective experience.

Given the clinical relevance of negative affect, the current investigation will focus on negative experience. As discussed above, one way to study acceptance of negative unwanted experience is to measure the degree of affective distress to erroneous response. Errors are negative emotional events that can reliably elicit affective distress, as evidenced by increased activation of the defensive motivational system following errors (Hajcak & Foti, 2008). An individual who is more accepting to his experience is likely to experience a lower level of affective distress when compared to an individual who is less accepting.

Taken together, the current investigation will examine the two active components of MP, attention and acceptance, in two studies. Both studies will be using the same questionnaires, interventions, and follow the same procedure, except for analysis and task. Thus participants will
be enrolled in both studies and task order will be counterbalanced among participants. To strictly follow the two-component proposal of MP, the current investigations will adopt a specific and simplified form of mindfulness — mindful breathing. Mindful breathing or attending to one’s somatosensory experience of breathing, is central to all forms of MP. Mindful breathing has been integrated into all forms of phone-based applications that are accessible to the general public and proved to be appropriate for meditation-naïve individuals (Bing-Canar & Compton, 2015; Norris et al., 2018). Study 1 will test the hypothesis that a brief MP will improve high-level attention (selective attention) but not low-level attention (orienting) by having participants completed a novelty oddball task that captures both low- and high-level attention to allow a thorough examination of the impact of mindfulness on both levels of attention. Study 2 will test the hypotheses that a brief mindfulness intervention improves decentering and reduces affective response to negative experience (erroneous response). Participants will complete a flanker task (a speeded reaction time task) that to allow for the examination of error-related affective response and post-error slowing. As discussed above, the efficacy of MP in people with attention deficit warrants further investigation since self-regulation of attention is a fundamental requirement in MP. ADHD symptoms will be measured through self-reported questionnaires in both studies to allow the evaluation of the moderating role of ADHD symptoms to the effects found in both studies. Findings from this investigation will contribute to our understanding of the two active mechanisms underlying MP and whether its efficacy might be moderated by individual differences in attention deficits.
Specific Aims

The proposed study addresses three aims:

Aim 1. To show that a brief MP will improve high-level attention (executive attention) but not low-level attention (orienting) (Study 1)

H1a. The mindfulness group will have a larger P3b to target stimuli in the post-intervention novelty oddball task

H1b. The mindfulness group will have faster responses to target stimuli in the post-intervention novelty oddball task

H1c. P3a’s to novel stimuli in the novelty oddball task will not differ between pre- to post-intervention in both groups

Aim 2: to show that a brief MP will improve acceptance of erroneous response (Study 2)

H2a. The mindfulness group will show increased general acceptance by scoring higher on the Decentering factor measured by the TMS survey

H2b: The mindfulness group will show less reactivity (more acceptance) to unexpected erroneous response by displaying an attenuated ERN and a smaller post-error slowing effect

Aim 3: The above effects will be larger in individuals low in ADHD symptoms (Study 1 & Study 2)
STUDY 1

Method

Participants

121 psychology undergraduate participants were recruited from the research participation online system (SONA) at the University of South Florida. Participants filled out a pre-screen survey to determine their eligibility. Eligible participants were between the ages of 18 and 31 years old, right-handed, English-speaking with no reported neurological conditions or concussions, with normal or corrected-to-normal vision, normal hearing ability, and indicated no prior formal or informal meditation experience. Exclusion criteria were: 1) prior experience with any kind of practice featuring mindfulness (e.g., meditative yoga, Taiji, Qigong, etc.; 2) the presence of substance abuse; and 3) history of neurological disorders. Participants earned 4 course credits in exchange of participation in the study.

Questionnaires

All surveys were administered through Qualtrics (Qualtrics, Provo, UT).

Demographic Questionnaire. Demographic information including gender, age, ethnicity, and race were recorded.

Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003). The 15-item MAAS was designed to assess trait mindfulness: attentiveness and awareness. The MAAS was administered before the study to examine pre-existing group difference in dispositional
mindfulness. Items were rated on a six-point Likert scale from 1 (almost always) to 6 (almost never). Examples of items are “I find myself doing things without paying attention”, “I find myself preoccupied with the future or the past”. The total score is computed by taking the average of the responses to the 15 items. Higher scores reflect greater levels of dispositional mindfulness. It has been shown good validity and reliability ($\alpha = 0.89$) (Brown & Ryan, 2003; MacKillop & Anderson, 2007).

**Adult ADHD Self-Report Scale Symptom Checklist (ASRS-v1.1; Kessler et al., 2005).** The ASRS-v1.1 symptom checklist consists of 18 items with 9 items measuring inattention, and 9 items measuring hyperactivity/impulsiveness. Each item was scored in the range 0 (never) to 4 (very often) and all items were summed to generate the total score ranging from 0 to 72. Higher scores indicate more severe ADHD symptoms. Examples items are “How often are you distracted by activity or noise around you?”, “How often do you interrupt others when they are busy?”. It has good validity in assessing ADHD symptoms in adults (Adler et al., 2012; Kessler, Adler, Barkley, et al., 2005; Kessler, Adler, Ames, et al., 2005), and it has high test–retest reliability even in adults without ADHD ($\alpha = 0.86$) (Silverstein, Alperin, Faraone, Kessler, & Adler, 2018).

**Toronto Mindfulness Scale (TMS; Lau et al., 2006).** The TMS is a 13-item self-report measure that asks participants to reflect on a preceding meditation session and to indicate the degree to which each of the statements described what they just experienced on a 5-point scale from 0 (not at all) to 5 (very much). Higher scores reflect higher levels of state mindfulness. The measure shows good internal consistency and validity (Lau et al., 2006). Lau et al. (2006) described the two subscales of the TMS as reflecting curiosity and decentering. Cronbach’s alphas range from 0.86 to 0.91 for Curiosity and 0.85 to 0.87 for Decentering (Park, Reilly-
Spong, & Gross, 2013). Both Curiosity and Decentering were positively correlated with reflective self-awareness and psychological mindedness, while only the Decentering subscale was positively correlated with acceptance of experience, which reflects an open attitude towards one’s thoughts and feelings such that one can see thoughts and feelings simply as passing events in the mind rather than reflections of reality (Lau et al., 2006). The TMS was used as a manipulation check to determine the effectiveness of MI ($\alpha = 0.86$).

**Practice Quality-Mindfulness (PQ-M) (Del Re, Flückiger, Goldberg, & Hoyt, 2013).** This 6-item scale assesses mindfulness practice outcome, which is defined as a balanced perseverance involving two factors: receptive (the willingness to welcome experiences) and present-moment attention (constantly bringing attention back to the current focus). For each given item statement, participants choose from 0–100% to indicate the percentage of time during mindfulness practice that their experience reflected the statement. A sample item is, “During the activity, I attempted to return to my present-moment experience, whether unpleasant, pleasant, or neutral.” Items were summed to get the total score. While some studies have treated it as a scale for measuring state mindfulness (Quaglia et al., 2019), current study used it to enhance participants’ engagement during the mindfulness intervention. Participants were informed that they would answer questions regarding the audio.

**Manipulation check survey for the control group.** The questions below was used to enhance participants’ engagement during the control intervention. Participants were informed that they would answer questions regarding the audio.

Control survey: Which of the following is not mentioned as a benefit of zero-waster living?

A. Eat better

B. Save money
C. Lose weight
D. Need less sleep

Task

**Novelty Oddball task (Courchesne, Hillyard, & Galambos, 1975).** The three-stimulus oddball task consisted of three types of stimuli: 70% standard letters (“X”), 15% target letters (“O”) and 15% novel letters (45 unique Asian Characters) (Figure 2). There were a total of 200 trials being evenly divided into two blocks. A trial began with a fixation mark ‘+’, which was randomly jittered between 500 and 1000 ms to avoid subject expectancy effects on the stimuli presentation time, followed by the presentation of one of the three stimuli for 200 ms. Targets did not appear consecutively. Participants were instructed to press key “1” when they saw the target letter O. Prior to the experimental trials, participants performed 10 practice trials with no EEG recorded. The stimuli were in black presenting on a grey background and were presented using E-Prime (Psychology Software Tools, Inc., Pittsburgh, PA).

**Interventions**

**Mindfulness intervention.** A 10-minute guided mindful breathing audio (Adams et al., 2013; Vinci et al., 2014) was developed based on the excerpts of Kabat-Zinn, 1994; Kabat-Zinn, 2002. The instructions specifically asked the participants to note their breath and other sensations that may be occurring, while doing this with an attitude of nonjudgment and acceptance (see Appendix B). The protocol was based on findings indicating that induction periods in the range of 10 minutes were sufficient for producing noticeable changes on subsequent measures of attention (Tang et al., 2007)
Control intervention. A 10-minute audio about zero-waste living was retrieved from Youtube.com (Singer, 2015) (see Appendix B). The control audio was chosen to avoid overlapping components with mindfulness, such as attention to personal experience and an attitude of nonjudgment and acceptance.

Equipment

Auditory device. All sounds were presented through PreSonus Audiobox USB (PreSonus® Audio Electronics, Inc, Baton Rouge, Louisiana). Participants were fitted for foam eartips from E-A-RLINK (3M Multinational conglomerate company, Saint Paul, MN) through insert tube headphones. Both audio files were played at ~75 dBs.

Blood pressure monitor device. The ReliOn BP100 Upper Arm digital Blood Pressure Monitor gave three readings: Systolic blood pressure (SBP), Diastolic blood pressure (DBP), and heart rate/min. Participants were informed if their blood pressure or heart rate was out of normal range (<120 mmHg Systolic; <80 mmHg Diastolic; 60-100 beat/min). In addition to state mindfulness, blood pressure is another common measure used to validate the induction of mindfulness. Existing studies have reported consistent changes in the autonomic nervous system following MP including: lower respiration rate, slower heart rate, increased skin resistance and lower blood pressure (Chen, Yang, Wang, & Zhang, 2013; Fjorback, Arendt, Ornbol, Fink, & Walach, 2011; Pascoe, Thompson, Jenkins, & Ski, 2017).

EEG acquisition and preprocessing. EEG data were recorded with 128-electrode Geodesic Sensor net (Electrical Geodesics International, Eugene, OR), sampled at 250 Hz, and referenced to the vertex with 0.1-100 Hz analog filtering. EGI Netstation 5.4.0 was used in offline processing. Data were low pass filtered at 20 Hz and segmented into 1000 ms epochs
with 200 ms before and 800 ms after stimulus onset. Segments were then inspected for artifacts (e.g., eye blinks and movement, muscle noise) and faulty channels using a combination of visual inspection and the Netstation artifact detection tool. Artifact free data were sorted by conditions and averaged to create the ERPs. Individual averaged ERPs were baseline corrected to the pre-stimulus period of 200ms and re-referenced to the average reference. Resulting ERPs were then averaged across participants within each group to create the grand averaged ERPs.

**Procedure**

Psychology undergraduate students at the University of South Florida voluntarily signed up to take part in the study through the online research participation system (SONA). Upon arriving in the laboratory, participants were provided with the consent form and given time to ask questions. Consented participants first filled out the demographic questionnaires, MAAS, and ASRS-v1.1 on a computer in the testing room, then completed a baseline blood-pressure measurement (BP1). Participants were randomly assigned to the Mindfulness or Control group and were fitted with the appropriate EEG net before completing the novelty oddball task in a sound attenuated and dimly lit room. Following the initial oddball task, participants were fitted with foam eartips for audio presentation. The mindfulness group listened to the 10-min mindfulness audio and the control group listened to the 10-min Ted talk about green living. Immediately following the intervention, a post-intervention blood pressure (BP2) was measured and participants completed the novelty oddball task again. During each one-minute inter-block break in the novelty oddball task, participants in the mindfulness group were informed to continue practicing mindfulness as instructed during the intervention, while the control group were simply told to rest. After the post-invention novelty oddball task, a post- invention blood
pressure was measured (BP3). Lastly, participants in the mindfulness group filled out the Practice quality of mindfulness (PQ-M; Re et al., 2013) and TMS, while the control group filled out a question about the Control manipulation check survey and TMS. Each blood pressure measurement was averaged from two readings that were taken with one-minute interval. Participants were debriefed about the study aims and granted course credit for participation.

**Analyses**

Group differences in demographic data were analyzed using chi-square test; group differences in age, MAAS score, and ASRS-v1.1 score were analyzed using independent t-tests.

**Manipulation Check**

TMS score were analyzed using independent t-tests. Practice Quality-Mindfulness (PQ-M) score were summed up across items and the Control survey was performed. Physiological data. Blood pressures and heart rate were submitted to separate 2 (Group: mindfulness, control) by 3 (Time: time 1, time 2, time 3) mixed ANOVAs with Group as the between-subjects variable and Time as the within-subjects variable.

**Behavior**

Reaction time and error rate of the Oddball task were submitted to a 2 (Group: mindfulness, control) by 2 (Time: pre, post) by 3 (Stimulus: frequent, rare, novel) mixed analysis of variance (ANOVA) to examine the change score from pretest to posttest. Data from nine participants were excluded due to committing over ten (~30%) missing responses. While we hypothesized that the mindfulness group would respond faster to target stimuli in the post-
intervention novelty oddball task, we did not expect any effect on the error rate because the novelty oddball is an easy reaction time task.

**ERPs**

Data from eleven participants were excluded due to excessive artifact, leaving 101 participants for further analysis. Regions of interest (ROI) for the ERPs were selected based on the scalp distributions of the waveforms: fronto-central for P3a, centro-parietal for P3b. Mixed ANOVAs were performed on the mean amplitudes of the P3a (250-300 ms post-stimulus) and P3b (300-500 ms post-stimulus) from these ROIs, with Group (mindfulness, control) as the between-subjects variable, Time (pre, post) and Stimulus (frequent, rare, novel) as the within-subjects variable. Bayes factor (BF) *-test (Rouder, Speckman, Sun, Morey, & Iverson, 2009) was conducted to examine non-significant ANOVA results.

**Moderation by ADHD Symptoms**

Moderation analyses were conducted using the SPSS PROCESS package (Hayes, 2018) and included ASRS-v1.1 score as the moderator to examine the relationship between group and change in attention indexed by difference P3b to target using post minus pre (ΔP3b), as moderated by ADHD symptoms.

**Results**

Sample Demographic Information was displayed in Table 2. There were no pre-existing group differences in age, gender, or ethnicity. MAAS score did not differ between the
mindfulness group \((M = 3.85, SD = .78)\) and the control group \((M = 3.80, SD = .77)\), \(t(1,119) = .36, p > .05\). There was no difference in the ASRS v1.1 score, \(t(1,119) = .11, p > .05\).

**Manipulation Check**

TMS score was higher in the mindfulness group \((M = 31.42, SD = 8.44)\) than the control group \((M = 28.21, SD = 6.68)\), \(t(1,119) = 2.32, p < .05\). The score on PQ-M ranged from 82 to 600 out of the possible range of 0 to 600. 52\% of the participants answered correctly on the Control manipulation check survey.

Physiological data. There was a main effect of Time for Systolic blood pressure, \(F(2,206) = 11.24, p < .001, \eta^2_p = .098\), diastolic blood pressure, \(F(2,206) = 7.61, p < .01, \eta^2_p = .07\), and heart rate, \(F(2,206) = 41.4, p < .001, \eta^2_p = .29\). Follow-up pairwise comparisons revealed that all three measures were higher at pre-intervention than post-intervention, \(p < .01\), and both Systolic blood pressure and heart rate at post-intervention did not differ from that measured at end-of-task, \(p > .05\), while diastolic blood pressure was higher at end-of-task than at post-intervention, \(p < .001\). There was no group effect or other interaction effects. See Table 3 for the descriptive statistics of the physiological Data.

**Behavior**

ANOVA on RT and error rate did not reveal any significant effects regarding Time or Group. (Table 4)
ERPs

**P3a.** Visual inspection of the ERPs did not reveal a P3a, thus no follow-up analysis was performed.\(^1\) (Figure 4)

**P3b.** There was a main effect of Stimuli, \(F(2,198) = 181.88, p < .001, \eta_p^2 = .65\). P3b elicited by targets (\(M = 4.82, SE = .30\)) was larger than P3b elicited by standards (\(M = .45, SE = .13\)) and novels (\(M = 1.92, SE = .19\)); and a main effect of Time, \(F(1,99) = 11.07, p < .01, \eta_p^2 = .10\). P3b was larger at post-intervention (\(M = 2.60, SE = .17\)) than pre-intervention (\(M = 2.19, SE = .19\)). There was a Stimulus \(\times\) Time interaction effect, \(F(2,198) = 24.88, p < .001, \eta_p^2 = .20\). Simple Effect Analysis revealed that P3b was larger at post-intervention than pre-intervention for targets, \(p < .001\), but not for standards or novels. There was also a Time \(\times\) Stimuli \(\times\) Group interaction, \(F(2,198) = 3.06, p < .05, \eta_p^2 = .03\). P3b to targets increased in both the mindfulness group, \(p < .001\), and the control group, \(p < .05\). P3b to novels also increased in the mindfulness group, \(p < .05\), but decreased in the control group, \(p < .05\). Grand average ERPs is plotted in Figure 5. Mean P3b amplitude for Group \(\times\) Time \(\times\) Stimuli interactions is displayed in Figure 6. The BF \(t\)-test on the difference score of P3b to target revealed strong evidence that the increasement in P3b to target in the mindfulness group is larger than that in the control group, \(BF_{10} = 81.87\).

Moderation by ADHD symptoms

Distribution of the ASRS-v1.1 score is shown in Figure 7. Moderation analysis revealed a marginally significant Group \(\times\) ASRS-v1.1 score interaction, \(p = .08\). Change in P3b to targets

\(^{1}\) A spatial-temporal Principal Component Analysis (PCA) did not reveal a frontal component that corresponds to the scalp distribution of the P3a (see Appendix C).
using post minus pre ($\Delta P_{3b}$) tended to decrease as ASRS-v1.1 score increased in the control group (Figure 8).

**Study 1 Discussion**

Study 1 examined the impact of a brief mindfulness invention on executive attention ($P_{3b}$ to targets) and orienting attention ($P_{3a}$ to novels) in a novelty oddball task. The mindfulness manipulation was successful as participants in the mindfulness group reported higher state mindfulness relative to the controls. Both mindfulness and the control manipulation altered autonomic physiology as evidenced by decreased systolic blood pressure, diastolic blood pressure, and heart rate.

The results partially supported Aim 1 that a 10-minute mindful-of-breathing exercise improved executive attention indexed by a larger $P_{3b}$ to target (H1a). This finding is in accordance with existing studies that also reported increased executive attention resulting from MP (see review Chiesa, Calati, & Serretti, 2011). The enhancement of executive attention has been reported from both brief MI and long-term mindfulness meditation including one study that compared a one-session 6-minute guided MI to a relaxation group (Lakey, Berry, & Sellers, 2011) as well as studies that compared non-meditators to mindfulness meditators with an average of 9.09 years of experience (Payne et al., 2019) and mindfulness meditators with an average of 13.1 years of experience (Jo, Schmidt, Inacker, Markowiak, & Hinterberger, 2016). Despite $P_{3b}$ to target increased, RT to target did not become faster following the intervention (H1b). This could be due to a ceiling effect that the baseline performance was already high (ER < 1%) since the novelty oddball task is a simple reaction time task only requiring response to targets.
Surprisingly, the controls also showed a larger post-intervention P3b to target, indicating that executive attention also benefited from listening to a 10-min Ted talk about green living. One possible explanation is that relaxation allows for attention restorative opportunities (Rutschman, 2004; Yesavage & Jacob, 1984). Participants in the control group were instructed to rest during the break between trial blocks and they showed reduced BP, suggesting increased relaxation. Notably, previous between-group studies that also compared MI to a relaxation condition did not report a relaxation effect on attention (Lakey et al., 2011; Mrazek, Smallwood, & Schooler, 2012). The reason for the discrepant findings might be that the previous studies only measure attention after, not before intervention, such a design only allow for examination of group effect, not the change in attention in response to intervention.

Despite that both interventions improved executive attention, MI was superior than listening to a talk about green living as evident by the Bayes factors. While the improvement in attention in both groups may benefited from increased relaxation, the mindfulness group also benefited from its active component, attention regulation, a more powerful strategy in improving attention than purely relaxation (Elliott et al., 2014; Tang et al., 2007).

The increased P3b to target is resulted from the interventions rather than practice effect or time passing because the P3b to target has good test-retest reliability in visual modality (Cassidy, Robertson, & O’Connell, 2012; Ip et al., 2018; Jodo & Inoue, 1990). For example, studies have observed stable P3b to target across six blocks with 20-minute inter-block interval (Geisler & Polich, 1994) and across two blocks with one-hour interval (Wesensten, Badia, & Harsh, 1990). These inter-block intervals resemble the time intervals between the novel oddball tasks in the current study. To the contrary, practice effect may even reduce the P3b, which has been found to habituate when the inter-block interval is relatively short, e.g., across ten blocks with 10-minute
inter-block interval (Ravden & Polich, 1999) and across three blocks with 30-second inter-block interval (Wesensten, Badia, & Harsh, 1990). Short inter-block intervals is thought to familiarize participants with the task and reduce the attention required to perform the task (Kramer, Schneider, Fisk, & Donchin, 1986; Polich, 1989), especially when the task is easy (Kok, 1990, 1997; Strayer & Kramer, 1990). To our knowledge, no reports of increased P3b to target with repeated testing or time passing have been documented.

Contrary to our hypothesis, Novels did not elicit a P3a (H1c). Two factors might be responsible for the absence of the P3a, task difficulty and the characteristic of the novels (Comerchero & Polich, 1999a; Donchin, Spencer, & Dien, 1997; D. Friedman, Cycowicz, & Gaeta, 2001; Gaeta, Friedman, & Hunt, 2003; Katayama & Polich, 1998). First, the current novelty oddball task might be too easy to engage sufficient attention resource for eliciting a P3a (Comerchero & Polich, 1998, 1999b; Hagen, Gatherwright, Lopez, & Polich, 2006). In an auditory novelty oddball task, Katayama and Polich (1998) varied the difficulty levels of discrimination of targets by varying the difference in pitch between target and standard tones. They found that the novels elicited a larger novelty P3a when the difficulty level of discrimination was high (i.e., pitch difference between targets and standards is small). Difficult tasks may engage the processing of the novels more strongly by increasing attention resource to the stimuli than easier tasks (Hagen et al., 2006). The difficulty level should induce a 10–15% error rate, which is much higher than the error rate in the present study, < 1%. Second, the deviance of the novels from the standards and targets was too small to elicit a P3a in the current novelty oddball task. Katayama and Polich (1998) also varied and the difference in pitch between the nontarget tones and the targets and found that the novels elicited a larger novelty P3a when the pitch difference between novels and the other stimuli was large. In auditory
novelty oddball task, the novels were complex environmental sounds (e.g., key ring, dog barks) (for review, see Friedman, Cycowicz, & Gaeta, 2001). When the novels were single tones, P3a was not elicited because single tone did not resemble the richness and novelty of complex environmental sounds (Comerchero & Polich, 1998, 1999a). Similarly, visual novelty oddball tasks that have successfully elicited a P3a have made the novels perceptually salient (e.g., complex in form or larger in size than the standards and targets). The first visual novelty oddball task used highly colorful abstract-type drawings, making the stimuli unrecognizable or difficult to categorize (Courchesne, Hillyard, & Galambos, 1975); in another Novelty oddball task, the distracter was a large black/white checkerboard square, and the target was a blue circle that was larger than the standard (blue circle) (Conroy & Polich, 2007). Both tasks have made the novel stimuli perceptually salient, which was lack in the novels in the current study because the novels were in the same color (i.e., black) and size as the standards and targets. Taken together, the low level of task demand and the low deviance of the novels were largely responsible for the absence of the P3a in the current novelty oddball task.

Aim 3 was not supported that individuals with high ADHD symptoms actually showed similar improvement in executive attention following MI as individuals with low ADHD symptoms. Remarkably, in the control group, individuals with high ADHD symptoms tended to show a smaller improvement in response to the control intervention with a marginally significant p value (.08). Together with the results from Bayesian analysis, these findings suggested that MI was superior than listening to a talk about green living in improving attention.

In the current study, the P3b was driven by both targets and novels. Relative to task-irrelevant novel stimuli, task-relevant targets contributed substantially more to the P3b. Unlike P3b to target, the cognitive correlates of P3b elicited by novels largely remain unclear (D.
Friedman et al., 2001; Polich, 2003, 2007). Some argue that P3b to novels indexes task-relevance processing of the novels, with larger P3b meaning more task-relevant (Gaeta et al., 2003). Others proposed that P3b to novels reflects a classification process, larger P3b indicating greater processing due to the unfamiliarity of the novels (D. Friedman et al., 2001). Based on these theoretical assumptions, one tentative explanation is that P3b to novels may index the level of stimuli engagement or processing, which increased in the mindfulness group but decreased in the control group. Although P3b to target does not reliably habituate with repeated testing, P3b to non-targets (i.e., standards and novels) do habituate (Courchesne, Courchesne, & Hillyard, 1978; Ravden & Polich, 1999). The reduction in P3b to non-targets has been attributed to sensory stimulus adaptation (Koelega & Verbaten, 1991). However, the habituation in P3bs to both standards (did not reach a significance) and novels was only evident in the Control group; the mindfulness group actually showed a larger P3b to non-targets (P3b to standards did not reach a significance), suggesting that MI not only counteracts the habituation effect but also increases processing to task-irrelevant stimuli. This could be due to the characteristic of MP being “attentive to and aware of what is taking place in the present” (Brown & Ryan, 2003, p. 822), even the stimuli were task irrelevant.
STUDY 2

Method

Study 2 followed the same procedure as Study 1 so this session will focus on the description of task and analyses.

Task

Participants performed a modified Flanker task. The stimuli in the modified Eriksen Flanker task (Eriksen and Eriksen, 1979; Potts, 2011) were four types of letter strings: congruent (HHHHH or SSSSS) and incongruent (HHSHH, SSHSS) (Figure 3). Congruent trials contained flanking congruent letters that matched the central target whereas incongruent trials contained a target letter flanked by incongruent letters. Subjects were instructed to respond to the central letter as accurately and as quickly as possible, specifically, press 1 for H, 4 for S. Subjects were instructed that response time longer than 500ms would be considered wrong to encourage fast response. The stimulus duration time was 200 ms, inter-trial interval varied randomly between 1200 and 1700 ms. There were 300 trials (4 types of stimuli are equiprobable) in total being evenly divided into 3 blocks. The stimuli were in black presenting on a grey background and were presented using E-Prime (Psychology Software Tools, Inc., Pittsburgh, PA).
**EEG Recording and Preprocessing**

EEG data were recorded with 128-electrod Geodesic Sensor net (Electrical Geodesics International, Eugene, OR), sampled at 250 Hz, and referenced to the vertex with 0.1-100 Hz analog filtering. EGI Netstation 5.4.0 were used in offline processing. EEG data were segmented into 500 ms epochs: 100 ms before and 400 ms after response. The epochs were inspected for artifacts (e.g., eye blinks and movement, muscle noise) and faulty channels using a combination of visual inspection and the Netstation artifact detection tool. Artifact free data were sorted by conditions, correct and error, and re-referenced to the average reference. Individual ERPs were baseline corrected to the pre-response period of 100ms and averaged across participants within each group (Mindfulness vs Control) to create the grand averaged ERPs.

**Analyses**

**Self-reported and Behavioral Data**

The TMS subscale, Decentering, was calculated. An independent t-test was conducted to examine the difference in the Decentering score between the two groups. Data from 20 participants were excluded due to making excessive errors (> 20%). Error rate was submitted to a 2 (Group: mindfulness, control) by 2 (Time: Time 1, Time 2) mixed ANOVA, while reaction time and PES were submitted to a 2 (Group: mindfulness, control) by 2 (Time: Time 1, Time 2) by 2 (Response: error, correct) mixed ANOVA with Group as the between-subjects variable, Time and Response as the within-subjects variable.
ERPs

Data from 14 participants were excluded from further analysis (11 due to not having a minimal of six good error trials and 3 did not make enough errors (Olvet & Hajcak, 2009)).

Regions of interest (ROI) for the ERN were selected based on the scalp distributions of the waveforms: fronto-central for ERN. Mixed ANOVAs were performed on the mean amplitude of the ERN (10-110 ms post-response), with Group (mindfulness, control) as the between-subjects variable, Time (Time 1, Time 2) and Response (correct, error) as the within-subjects variables.

Moderation by ADHD Symptoms

Moderation analyses were conducted using the SPSS PROCESS package (Hayes, 2018) and included ASRS v1.1 score as the moderator to examine the relationship between group and affective reactivity measured by the ERN, as moderated by ADHD symptoms.

Results

Self-reported Acceptance and Behavioral Data

Mindfulness group ($M = 15.22$, $SD = 4.9$) scored higher on TMS_decentering than the control group ($M = 12.95$, $SD = 3.39$), $t(1,119) = 2.95$, $p < .05$.

RT. There was a significant main effect of Response, $F(1,99) = 604.58$, $p < .001$, $\eta^2_p = .86$, and Time, $F(1,99) = 15.05$, $p < .001$, $\eta^2_p = .13$. Correct trials ($M = 396.75$, $SD = 43.39$) took longer to respond than error trials ($M = 360.45$, $SD = 48.02$), and mean RT was reduced at Time 2. No group or other interaction effects emerged.

Error rate. There was no Time effect or Group effect.
PES. There was a significant main effect of Trial Type, $F(1,99) = 176.35, p < .001, \eta^2_p = .63$, and Time, $F(1,99) = 49.1, p < .001, \eta^2_p = .33$. Mean RT on post error trials was longer than post correct trials ($p < .001$) and mean RT were faster at post-intervention than pre-intervention, $p < .001$. No group or other interaction effects emerged (Mean PES is shown in Figure 9).

ERPs

ERN (10-110 ms). There was a significant main effect of Response, $F(1,85) = 141.43, p < .001, \eta^2_p = .62$. As expected, ERN on error trials were more negative than on correct trials. No group effect or other interaction effects emerged (Grand Average ERPs were displayed in Figure 10).

Pe (200-300 ms). There was a significant main effect of Response, $F(1,85) = 144.69, p < .001, \eta^2_p = .63$. As expected, Pe on error trials were more positive than on correct trials. There was a Time × Response interaction, $F(1,85) = 26.58, p < .001, \eta^2_p = .24$. The Pe was more positive on error trials and less positive on correct trials at Time 2, compared to Time 1. No group effect or other interaction effects emerged (Mean Pe amplitude was shown in Figure 11).

Moderation by ADHD Symptoms

No significant Group × ASRS-v1.1 score interaction effect emerged for the ERN or the Pe, $p > .05$. 

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Study 2 Discussion

Study 2 examined that a brief mindfulness invention increased acceptance measured by self-reported decentering scale and reduced affective response to erroneous responses measured by behavioral and electrophysiological indices, PES and the ERN, respectively.

As hypothesized, a brief MI increased self-reported acceptance relative to the control condition (H2a). This result is consistent with existing findings that a brief MI could improve self-reported acceptance including a 5-minute computer-based MI (Mahmood, Hopthrow, & De Moura, 2016) and a 12-minute audio-guided mindful-of-breath (Alberts & Thewissen, 2011). Contrary to the hypothesis that increased acceptance would lead to smaller PES and reduced ERN (H2b), the two groups did not differ in these two measures. One reason for the absence of group effect in these measures could be that the affective experience in response to erroneous responses was too weak. Erroneous responses may not be perceived as negative experiences by the participants because there was no consequence or punishment upon error commission. Participants received full credit points for participation regardless of their performance despite that accuracy was emphasized in the task instruction. This explanation is evident by the findings from a recent review with 65 studies that the effects of MI on reducing negative affectivity were more pronounced in studies with distress induction than studies without (Schumer, Lindsay, Creswell, & Creswell, 2018). However, we could not verify this explanation as we did not measure participants’ affective state immediately following an error commission due to the nature of the speeded task (stimuli should be presented consecutively without interruption). Alternatively, the effect of the brief MI on acceptance might not be immediately available to alter behavioral and psychophysiological indices of affective response. Most studies that reported mindfulness meditation reduced affective response have attributed the cause to trait mindfulness
instead of state mindfulness (Brown, Goodman, & Inzlicht, 2013; Creswell et al., 2007; Teper & Inzlicht, 2014). Studies that reported reduced affective reactivity have used more intense mindfulness training. One study found 7-week MI reduced skin conductance responses to unpleasant pictures and emotional interference from unpleasant pictures relative to a relaxation group and a wait-list control group (Ortner, Kilner, & Zelazo, 2007). Another study found a 8-week of MBSR showed less amygdala reactivity to positive pictures when compared to controls who completed an 8-week Health Enhancement Program (Kral et al., 2018). In particular, a cross-sectional study including mindfulness mediators with an average 3.19 years of practice found that increased self-reported emotional acceptance was correlated with years of meditation practice and practice frequency (Teper & Inzlicht, 2013). Thus, a brief session of mindfulness could be insufficient to alter the behavioral and neural indices of acceptance. To see a change in these measures may require more intense mindfulness training (Larson et al., 2013).

Despite that there was no change in the ERN amplitude, both groups showed an increase in the Pe amplitude, indexing awareness of error processing (Hajcak, McDonald, & Simons, 2004; Overbeek, Nieuwenhuis, & Ridderinkhof, 2005). Larger Pe suggested improved error awareness/conscious recognition of making an error following the intervention (Hewig, Coles, Trippe, Hecht, & Miltner, 2011; Steinhauser & Yeung, 2010). However, the control group did not report an increase in acceptance but also showed a larger Pe, indicating that the increase in Pe was not a result of increased acceptance. A general practice effect of the task might explain the present observations because both groups responded faster in the Flanker task at Time 2 but the accuracy remained the same. Moreover, both groups also showed reduced interference of making an error indexed by reduced PES at Time 2. This might indicate that participants were getting used to or able to better cope with the erroneous responses in the Flanker task as an effect
of practice. Similarly, a recent pre-post study also reported improved error awareness (larger post-intervention Pe) but not reduced ERN in two groups of participants who completed either 4-week mindfulness meditation or 4-week progressive muscle relaxation (Eichel & Stahl, 2020). The ERN and Pe were measured in a modified Simon task, which presented two boxes side by side on the screen and an arrow pointing either left or right appeared randomly in one of the boxes. In one condition, participants had to respond to the direction of arrow regardless of its position; while in another condition, participants responded to the position of the arrow and ignored its direction. The authors attributed the increase in Pe to training effect of the task.

Interestingly, error perception also changed on correct trials showing a reduced Pe. The Pe amplitude on correct trials is thought to be impacted by evaluation of response that larger Pe amplitudes were found in correct responses being perceived as incorrect than if they were perceived as correct (Endrass, Klawohn, Preuss, & Kathmann, 2012). Therefore, the reduced Pe may index increased certainty in perceiving the correct response as correct. Similarly, this increased certainty about performance may benefit from practice. Thus, Pe for both correct and error trials were enhanced at the post-intervention task that increased error awareness made the Pe more positive to error trials and improved certainty about correct trials made the Pe more negative to correct trials.

Taken together, our findings primarily indicate that a brief mindfulness intervention improved self-reported acceptance, but did not influence performance or neural indices of acceptance of erroneous responses, the PES and the ERN. Furthermore, both groups benefited from task practice that they were able to maintain the same accuracy with faster RT, shortened PES, and improved certainty about responses indexed by enhanced Pe for both correct and error trials in the Flanker at the second attempt.
GENERAL DISCUSSION

The present studies investigated two core components of MP, attention and acceptance, by comparing a mindfulness group that underwent a brief 10-minute MI to a control group that involved listening to a 10-minute talk about green living. Study 1 examined the effect of a brief MI on executive attention in a novelty oddball task that involves frequent standards, rare task-relevant targets, and unique task-irrelevant novels. The results highlighted the efficacy of a brief MI on improving executive attention in participants who had no prior experience with MI, and participants high in ADHD symptoms group benefited equally form MI as participants low in ADHD symptoms. Despite that the control intervention also improved executive attention, this effect was more robust in individuals with low ADHD symptoms. Study 2 examined the effect of a brief MI on acceptance of erroneous responses. The results showed an effect of MI on increasing self-reported acceptance but not on behavioral measure or neural measure of acceptance to erroneous responses.

These findings suggest that attention can be improved rather immediately even through a brief MI, while the cultivation of acceptance may require more intense mindfulness training, which is in accordance with the opinion that attention skills may improve before acceptance skills (Baer, Carmody, & Hunsinger, 2012; Gaëlle Desbordes et al., 2015). One within-subjects study has illustrated this opinion elegantly by examining the effect of a mindfulness condition (15-minute audio guided MI) on the processing of emotional images relative to a mind wandering condition (15-minute) through the measurement of ERP indices of both attentional
process (P3b) and emotional process (Eddy et al., 2015), the late positive potential (LPP), a component that reflects subjective evaluation of the stimuli’s motivational significance, with more arousing positive and negative stimuli producing larger LPPs than neutral stimuli (Hajcak, MacNamara, & Olvet, 2010). The study did not find a condition effect on LPP, but in the mindfulness condition, participants who scored higher on decentering had reduced P3b to negative versus neutral images, suggesting reduced attention allocated to negative images following MI. Note that reduced attention to emotional stimuli may not mean the same as increased acceptance of emotional experience. Rather, these findings suggest that a brief MI modified attentional, but not emotional processing to emotional stimuli. It is worth noting that the finding in P3b is consistent with the pattern in long-term meditators (Brown et al., 2013; Sobolewski, Holt, Kublik, & Wróbel, 2011; Teper & Inzlicht, 2014), further supports that attention can be immediately altered by a brief MI. This project also raises several points for consideration:

**Is Too Much Attention A Good Thing?**

Existing research has largely focus on the problem of being lack of attention and approaches to improve attention (see reviews, Dunn & Kronenberger, 2005; Polderman, Boomsma, Bartels, Verhulst, & Huizink, 2010; Rapport, Orban, Kofler, & Friedman, 2013), but too much attention may not always be ideal. In study 1, the mindfulness group showed increased processing to task-irrelevant stimuli, which is not a desired outcome despite that the task performance did not decline. The characteristic of MP “being attentive to and aware of what is taking place in the present” (Brown & Ryan, 2003, p. 822) emphasizes a type of attention that broadly captures current experience but lack of selectivity. This lack of selectivity could
potentially be harmful as it may impair people’s intention to avoid noticing aversive stimuli, which might increase anxiety (Giron & de Almeida, 2010).

Despite that “mindfulness…is now suggested as a cure for essentially every ailment” (North, 2014, p. 1; see also Grant, 2015, Joiner, 2017), MP may have adverse effects. One study assigned participants to engage in a mindful breathing or a mind-wandering exercise, then told them the next task was to complete difficult word puzzles. Relative to the mind-wandering group, the mindfulness group reported that they were not as motivated (Hafenbrack & Vohs, 2018). This is another undesired outcome since motivation is important for workplace performance (Ryan and Deci, 2000, Hackman and Oldham, 1976, Herzberg, 1966). It is worth noting that mind-wandering is considered the opposite state to mindfulness (Mrazek, Franklin, Phillips, Baird, & Schooler, 2013; Mrazek et al., 2012), thus mind-wandering induction might not be a strong control intervention; solving word puzzles is not an enjoyable task but workplace tasks can also be tedious. Besides, MP may cause relaxation-induced anxiety (Heide & Borkovec, 1984). One study found that mantra meditation increased tension in over half participants (53.8%) in a group of 14 adults, versus 30.8% of the same participants reported increased tension following a progressive relaxation (Heide & Borkovec, 1983); the mantra meditation also produced anxiety in people with panic disorder (Craske, Lang, Aikins, & Mystkowski, 2005; Craske, Lang, Tsao, Mystkowski, & Rowe, 2001).

Although only limited research reported adverse effects related to MP, and these adverse effects do not occur in everyone who practice mindfulness, people should still be aware of these adverse effects when choosing to practice mindfulness, especially those without prior training or are more vulnerable to relaxation-induced anxiety (Arch & Craske, 2010).
Importance of Including an Active Control in Mindfulness Studies

The failure of MI to produce differential outcomes than our control group demonstrates the importance of including an active control in mindfulness research. Mindfulness studies that adopt a waiting list or no-intervention control condition are more likely to report significant findings than studies adopting an active control condition (Davidson & Dahl, 2018; Eisenbeck, Luciano, & Valdivia-Salas, 2018). For example, one study that reported that a brief 12-minute mindfulness increased acceptance (reduced memory for negative words) has adopted a no-intervention group as control (Alberts & Thewissen, 2011). Regrettably, a passive control condition has been widely adopted in mindfulness research that clinical trials has commonly evaluated MBI to a no-intervention group (Vøllestad, Nielsen, & Nielsen, 2012). Findings from these studies ascribe effects to mindfulness can lead to exaggerated outcome of MI, misleading the general public and clinicians about the efficacy of mindfulness (Davidson & Dahl, 2018; Van Dam et al., 2018).

Limitations and Future Directions

Several limitations should be noted. First, we only measured state mindfulness after but not before each intervention, thus we were not able to examine the change of state mindfulness with intervention. Despite that two groups did not differ in trait mindfulness, it is still possible that the groups might differ in baseline state mindfulness since trait mindfulness is not necessarily correlated with state mindfulness (Bravo, Pearson, Wilson, & Witkiewitz, 2018; Tanay & Bernstein, 2013; B. L. Thompson & Waltz, 2007). Second, state mindfulness was measured at the end of the experiment rather than after the brief mindfulness induction/control condition exercises and therefore the state mindfulness measure was probably lower than
reported. Despite this, state mindfulness was higher in mindfulness group than the control. Third, we did not measure affect regarding error commission, thus unable to assess subjective affect toward erroneous responses. Third, the generalizability of the improved executive attention in high ADHD group is limited by the current participants, who were not clinically diagnosed with ADHD. To what extent these findings can be transferred to a population with clinically diagnosed ADHD requires further investigation.

A brief MI improved executive attention but it is unclear this effect may last; future studies should conduct follow up sessions to evaluate the duration of the effects generated from a brief MI. To evaluate low-level orienting attention, both task demand and the deviance of the novels should be increased in order to elicit an orienting response. Future studies should also include a sample of individuals who are clinically diagnosed with ADHD to determine to what extent this population can benefit from MI. To determine to what extent attention to distractors might affect performance, future studies should employ a difficult task. To further examine practice effect as reported in Study 2, future studies should include an additional control group that does not receive any type of intervention. To study acceptance, future studies should adopt more intense mindfulness training and employ a task to elicit stronger affective experience. Studies that adopt a brief MI should carefully evaluate whether the dose of MP is sufficient to impact the measure of interest because some measures may not be altered through a brief MI.
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APPENDIX A. THE BIFURCATION OF ATTENTION

Table 1. The bifurcation of attention (Anderson, 2011)

<table>
<thead>
<tr>
<th>Top-down</th>
<th>Bottom-up</th>
</tr>
</thead>
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<tr>
<td>Exogenous</td>
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<tr>
<td>Divided</td>
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<td>Object</td>
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<td>Global</td>
</tr>
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<td>Controlled</td>
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<tr>
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<td>Involuntary</td>
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<td>Conscious</td>
</tr>
<tr>
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<td>Central</td>
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<td>Intraperceptual</td>
<td>Extraperceptual</td>
</tr>
<tr>
<td>Passive</td>
<td>Active</td>
</tr>
<tr>
<td>Pre-attentive</td>
<td>Attentive</td>
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</tbody>
</table>


APPENDIX B. TRANSCRIPT FOR INTERVENTIONS

Mindfulness Intervention

(Start: 00:01) This is the sitting meditation on the breath. While sitting down in your chair, begin by placing your feet flat on the floor. Try to sit up straight and relax your shoulders, your neck, and place your hands in your lap or on your knees. Now as you settle into a comfortable position, commit yourself to simply being fully awake, fully present for these next few moments. And if you feel comfortable with it, gently close your eyes. Otherwise, just look down toward the floor.

(00:43) 6 second silent period

(00:49) Begin by bringing your attention to your breath. Noticing the breath as it moves in and out of your body.

(00:58) 5 second silent period

(01:03) Perhaps focusing on the sensation of the breath that moves in and out of your nose. Noticing the air moving here and any temperatures that come with the in breath and the out breath.

(01:16) 5 second silent period

(01:21) Or perhaps pay attention to the rise and fall of the chest and abdomen as you breathe in and out. Just allow your attention to fall wherever it naturally does when you notice the breath.

(01:35) 21 second silent period

(01:56) And naturally your mind may wander off to something else during this exercise. You may start to listen to sounds that you’re hearing or on some other type of physical sensation. And whenever this happens just bringing your attention back to the breath, back to your breathing.

(02:17) 24 second silent period

(02:41) You may notice thoughts come up about something that you’re planning to do in the future or even something that’s already happened earlier today. Just notice what’s on your mind and how your body is feeling when this happens. Acknowledging that these thoughts have come up, whatever they are, without judging or evaluating them. And then just gently let them go. Bringing your attention back to the breath. Focusing on the sensation of the breath moving in and out of the body. Again, wherever you notice that the most.
(03:17) 32 second silent period

(03:49) Noticing where the mind is right now. And bringing your attention back to the breath if it’s gone elsewhere. Just breathing in and breathing out.

(04:01) 36 second silent period

(04:37) And each time that you notice that your mind has gone somewhere else, wherever that may be, just bring your attention back to the breath. And if the mind wanders of a thousand times, you simply bring it back a thousand times. Intentionally cultivating an attitude of patience and gentleness towards yourself. This means choosing, as best as you can, to not react to or judge any of your thoughts, or feelings, or perceptions. Instead, just reminding yourself that absolutely anything that comes into the field of awareness is okay. Noticing when this happens. Bringing attention to it. And then slowly bringing your attention and focus back to the breath.

(05:32) 30 second silent period

(06:02) We simply sit and breathe and observe it. Staying open and awake in the present moment right here, right now. And this may be a continual process of seeing and letting be, seeing and letting go. Rejecting nothing. Pursuing nothing. Just dwelling in the stillness and calmness as the breath moves in and out.

(06:30) 43 second silent period

(07:13) Where is the mind right now?

(07:15) 34 second silent period

(07:49) If you’d like, commit yourself to bringing this attitude of attention and acceptance with you throughout your day. Being fully aware of the present moment. Noticing any thoughts or feeling that may arise without judging them. Just being right here, right now. Accepting the present moment and accepting yourself no matter what happens. And remember that you can always bring your focus back to your breath, back to the sensations of the present moment, to help cultivate the sense of attention and acceptance.

(08:25) 11 second silent period

(08:36) Continuing to focus on the breath. Just noticing the breath. Breathing in and breathing out. Breathing in and breathing out.

(08:52) 40 second silent period

(09:32) Go ahead and take just a few more breathes. Being fully present and fully aware in this moment.

(09:40) 9 second silent period
And then, whenever you’re ready, go ahead and open your eyes.

(End: 09:54)

Control Intervention

I live a zero waste lifestyle, and I have for the past three years. Now, zero waste, that's a pretty big idea. Right? So let me define it for you. To me living zero waste means that I don't make any trash. So no sending anything to landfill, no sending anything in a garbage can, and no spitting gum on the ground, and walking away. Right? No trash. This is a big concept, and this all started when I was an environmental study student at NYU. My senior year, I was taking a course called: “The Environmental Studies Capstone course”, which is essentially the culminating course that all environmental study students need to take in order to go out into the world, and make it a more sustainable place. Well, there was a girl in this class, and every class she would have this big plastic bag, with a plastic clamshell full of food, a plastic fork and knife, a plastic water bottle, and a plastic bag a chips, and she would eat all of this, and then class after class, would just throw it in the trash. This was really frustrating, because here we were these environmental study students trying to make the world a better place, and there she was, throwing all this stuff into the garbage. One day after class, feeling still particularly upset about watching her throw everything away, I went home to make dinner, and I opened my fridge, and noticed something that I had never seen before. Every single thing in my fridge was in one way or another packaged in plastic, and I couldn't believe it. You know I was getting so mad at this girl for making so much plastic trash, and it turns out that I was just as bad. I was that girl, and so I made a decision in that moment. I was going to stop using plastic. Well, quitting plastic, not so easy of a thing. Right? When you think about your everyday life, you wake up in the morning, you go into the bathroom, and you brush your teeth. What is your toothbrush made out of? Plastic. What is your toothpaste probably packaged in? Plastic. Your face wash, your moisturizer, your contact solution. So many things that are in our everyday lives come packaged in plastic, and so I realized that if I was going to move away from plastic, the only way that I was going to do that was to learn how to make my products myself. Well, I don't know about you, but I certainly didn't know how to make deodorant. I didn't have the recipe just hanging out in my back pocket, and so I realized that I had to do some research, and while I was doing research online, I came across a blog called the "Zero Waste Home" started by a woman named Bea Johnson who is a wife, and mother of two kids, out in Mill Valley, California, and the four of them live a completely zero waste life. When I learned about Bea, and her family, my mind was completely blown. I thought that I was doing the best thing for the planet by not using any plastic. But the idea that I didn't have to produce any trash, was so empowering, and so inspiring, and it made perfect sense. Right? Because I was this Environmental Studies student, I cared about the environment, studied sustainability, talked about sustainability, protested for sustainability. But I realized, that I wasn't actually implementing any of those values into my day-to-day life, and so I made the decision to go zero waste. So let me break it down for you, and tell you some of the things that I did in order to make this transition a little easier. The first thing that I did was I stopped buying packaged food. So instead of going to the store, and buying
things packaged in paper, and glass, and plastic, I started bringing my own jars, and bags to the store to fill with bulk, or package-free items. I also started buying my fruit, and vegetables from the farmer's market. So, package-free. The second thing that I started doing was I started making all of my own products. Before I started living this lifestyle, my boyfriend at the time, used to brush his teeth using baking soda, and I thought he was probably the grossest person in the entire world. Right? There’s no way that you can possibly get your teeth clean using something like baking soda, it's gross. Well fast-forward, and it turns out that the first product that I made was toothpaste, made with baking soda. So overtime I started making all of my own products. When I would run out of something, instead of going to the store, and buying a new one, I would learn how to make it myself. So when I would run out of lotion, I learned how to make it myself. Run out of deodorant, learn how to make it myself. Over time, all of the things I had previously purchased, were now, ones that I made myself. The third thing that I started doing, was shopping second-hand. So instead of buying new clothing, and putting new waste into the waste cycle, I would buy things that were totally recycled, second-hand. So not making any new trash. The fourth thing that I did was I downsized. So I focused on having only the things that were truly necessary, and that I really needed. Well this was really, really hard because I'm the kind of person who's really sentimental, and I can tell you as to why a toothpick needs to be in my life. But after I really got through that process, and I completely downsized, I realized that I had so many fewer things in my life, my home was less cluttered, and everything was easier to clean. And when you have fewer things you realize that you take better care of them. Right? When you take better care of your things you don't have this mentality like: "If I don't want this anymore I'll just throw it out and I'll get a new thing later. “No, I only had a few things and so I took care of them, and wasn't sending anything to the landfill. All this must sound pretty difficult. Right? I assure you, it's not that hard. I'm just an average, lazy person, and I wouldn't live this lifestyle if it was difficult. In fact the benefits of living this lifestyle far outweigh any of the negatives that you can imagine. The first benefit is that I save money. So I save money when I buy my food, and the products, and when I make my own products, because I'm not paying for the embedded cost of packaging, so things are cheaper. I'm also saving money by shopping completely second-hand, because second-hand clothing is usually less expensive than new clothing. I'm also saving money because I've downsized. I don't go shopping all the time now and you know just buy things on impulse. I only have what I really need. The second benefit is that I eat better. When I go shopping now I don't have the option to buy processed food products, package-free, and so now my diet consists of things like fresh fruit and vegetables, or bulk you know, greens, and nuts that I buy with my jars and my bags. And so when you eat better, you feel better. Over these past few years, I've noticed that my weight has stabilized, I have more energy, I need less sleep, and when you're eating better, and you feel better, and you save money, you're happier. But besides those things I'm happier, because for the first time in my life, I’m living in direct alignment with my values. And why is this important? Right? Waste. Well, waste is a really big problem. In fact the average American person produces approximately 4.4 pounds of trash per person per day. Over the course of a year, that's like taking 8.5 of your best friends, and throwing them in the trash. Don't do that, it's not nice. So, if you care about your friends, and you don't want to throw them away, and you think that it's possible for you to reduce how much trash you're producing, I have three simple steps for you. The first step is to actually look at your trash, and understand what it is. Because you can't solve a problem of having a lot of waste until you know what it is. So when I did this exercise, I realized that I had three main sources of trash. The first was food packaging, and so I learned
how to shop in bulk or package-free. The second was product packaging, and so I learned how to make all of my own products. And the third was organic food waste, and so I learned how to compost. And just by identifying those three sources of waste and eliminating them, I have reduced my trash by about 90%. The second thing that I'd like to suggest is picking at the low-hanging fruit. So doing little things, one-time changes in your everyday life that have a large-scale, and long-term positive impact. This includes things like using a reusable bag instead of a plastic or paper bag. Or using a stainless steel, or glass water bottle, instead of buying plastic water bottles. Over the course of, you know, however long, you realize that these little changes actually add up, and make a big difference. The third thing that I'd like to suggest is the DIY or actually learning how to make your products yourself. Now I absolutely love doing this because when you go to a store, and you have to buy products you kind of have to settle, and accept them as they are. Right? If you don't like the way they smell, too bad. If you don't like the way they feel, sorry. If you don't like what they're packaged in, you don't have a choice. But for me, since I make all my own products, if I don't like the way they smell, I change the scent. If I don't like the ingredients in them, I change it. If I don't like the packaging, it's my choice. And so by making my own products I have complete control over what I'm putting in my body.
APPENDIX C. SPATIAL-TEMPORAL PRINCIPAL COMPONENT ANALYSIS (PCA)

Figure 1. Factors from Spatial-temporal Principal Component Analysis (PCA)
Table 2. Sample Demographic Information.

<table>
<thead>
<tr>
<th>Item</th>
<th>Category</th>
<th>Control group (n = 59, %)</th>
<th>Mindfulness group (n=62, %)</th>
<th>$\chi^2$ or t</th>
<th>p</th>
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<tbody>
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<td>.25</td>
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<tr>
<td></td>
<td>Female</td>
<td>72</td>
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<td>22-31</td>
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Table 3. Descriptive Statistics of Physiological Data.

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<td></td>
<td>C</td>
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<td>11.07</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>71.21</td>
<td>10.72</td>
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</tbody>
</table>

Note. M = Mindfulness; C = Control; Pre = Pre-intervention; Post = Post- intervention; End = End of task.
Table 4. Descriptive Statistics of Reaction Times and Error Rate in Novelty Oddball

<table>
<thead>
<tr>
<th></th>
<th>Pre-intervention</th>
<th>Post-intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mindfulness</td>
<td>Control</td>
</tr>
<tr>
<td>Mean RT</td>
<td>360.59</td>
<td>375.30</td>
</tr>
<tr>
<td>SD</td>
<td>48.02</td>
<td>42.83</td>
</tr>
<tr>
<td>Mean Error rate</td>
<td>.006</td>
<td>.003</td>
</tr>
<tr>
<td>SD</td>
<td>.01</td>
<td>.01</td>
</tr>
</tbody>
</table>
Figure 2. A Sample Trial in the Novelty Oddball Task and The Novels
Figure 3. A Sample Trial in the Flanker Task.
Figure 4. Grand Average ERPs in the Novelty Oddball Task
Frontal Electrode Site
(Mindfulness: n=56; Control: n=45)
Figure 5. Grand Average ERPs in the Novelty Oddball Task Parietal Electrode Site (Mindfulness: n=56; Control: n=45)
Figure 6. Mean P3b Amplitude for Group × Time × Stimuli Interactions 
(Mindfulness: n=56; Control: n=45)
Figure 7. Distribution of the ASRS-v1.1 Score (n=121)
Figure 8. ADHD symptoms moderated the relationship between Group and $\Delta P3b$ to target ($p = .08$)

(Mindfulness: $n=56$; Control: $n=45$)
Figure 9. Mean PES in the Flanker Task
(Mindfulness: n=56; Control: n=45)
Figure 10. Grand Average ERPs in the Flanker at Frontal and Central Electrode Site
(Mindfulness: n=46; Control: n=41)
Figure 11. Mean Pe amplitude for Correct and Error Trials in the Flanker
(Mindfulness: n=46; Control: n=41)