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Dispositional Mindfulness as a Moderator of Electrocortical and Behavioral Responses to Affective Social Stimuli

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DISPOSITIONAL MINDFULNESS AS A MODERATOR OF ELECTROCORTICAL AND BEHAVIORAL RESPONSES TO AFFECTIVE SOCIAL STIMULI

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University.

by

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Abstract

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Numerous studies have linked dispositional mindfulness to enhanced emotion regulation. The present research examined dispositional mindfulness as a predictor of emotion regulation in social affective contexts. Participants completed passive viewing and Emotional Go/No-Go tasks involving social affective stimuli (happy, neutral, and fearful facial expressions). Event-related potentials (ERPs) and behavioral responses were examined to discern whether dispositional mindfulness predicted differential neural and behavioral responses indexing attention to, awareness of, and inhibitory control over automatic responses to affective social stimuli. Dispositional mindfulness predicted larger (more negative) N100, N200 and No-Go N200 amplitudes during the Emotional Go/No-Go task, but was not associated with amplitude of the Late Positive Potential during the passive viewing task. Dispositional mindfulness also predicted faster response times (RT) to target stimuli that were not attributable to a speed-accuracy tradeoff. No relations were found between mindfulness and RT variability nor accuracy.

Implications for understanding mindfulness and early processes of social emotion regulation are discussed.

Dispositional Mindfulness as a Moderator
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Background and Motivation

Nearly every day we come face-to-face with others' emotions. This may be truer for individuals in particular environments and professions (e.g., helping professionals), but exposure to others' emotions, including their distress, commonly occurs in everyday interactions and through various media (Olsson, Nearing, & Phelps, 2007). Because the emotions of others are such a ubiquitous part of our social lives, how we process and respond to them may have far-reaching intrapersonal and interpersonal consequences. A primary way we are exposed to others' emotions is through their facial expressions. Faces are social stimuli that serve to communicate motivationally salient information, and in a manner similar to unpleasant and pleasant nonsocial stimuli, unpleasant social stimuli have been shown to result in withdraw-oriented processing, whereas pleasant social stimuli result in approach-oriented processing (Hare, Tottenham, Davidson, Glover, & Casey, 2005). Evaluation of both social and nonsocial stimuli as, most basically, "good" or "bad" appears to occur automatically (Bargh & Ferguson, 2000), and this evaluation prepares the organism immediately to approach or avoid (Chen & Bargh, 1999).

Even in the context of such motivationally salient stimuli, facial expressions can be considered a unique kind of stimuli because of perceivers' tendency for automatic, subconscious mimicry of facial expression, a key mechanism underlying emotional contagion (Cacioppo & Hatfield, 1993). Through both automatic evaluation and mimicry, one function of facial expressions may be to orient others' behavioral systems to danger or safety (Darwin, 1878; Mineka & Cook, 1993; Sorce & Emde, 1981; Fox, 2002). Yet automatic responses to, and mimicry of, others' emotions may not always function as adaptive drivers of behavior in contemporary cultures.

There are likely many adaptive benefits, both personal and social, to greater emotion regulation and emotion-related behavior regulation (hereafter, behavior regulation) during exposure to affective social stimuli. Perhaps most relevant to the present study is that goal pursuit often necessitates behavior in opposition to our automatic approach/withdraw responses (Berkman & Lieberman, 2010), such as when a dieter passes up sweets (avoiding appetitive stimuli) or when a tired athlete runs one more lap (approaching aversive stimuli). The achievement of many goals is thus dependent on emotion and behavior regulation comprised of goal-directed monitoring and governance of automatic approach/withdraw responses (Berkman & Lieberman, 2010). In social contexts, this type of goal-directed regulation may be necessary to appropriately respond to others' emotions (Hare et al., 2005). For example, maintaining good relationships at work may require overriding innate tendencies to avoid an aversive encounter with an angry colleague. Indeed, decrements in self-regulation have been associated with reductions in the quality of social behavior (Kanske, Heissler, Schonfelder, Bongers, Wessa, 2011; Eisenberg, Spinrad, & Morris, 2002; Eisenberg, Fabes, Guthrie, & Reiser, 2000). For example, participants high in emotion regulation were rated higher in interpersonal sensitivity and prosocial tendencies by peers (Lopes, Salovey, Coté, & Beers, 2005). Successful social behavior and social goal achievement may thus depend on goal-relevant regulation of automatic approach- and withdraw-oriented responses to others' emotions, in a manner similar to regulating these responses in nonsocial contexts (Cacioppo, 2002).

Automatic mimicry of others' facial expressions is another process generally considered to have great adaptive value, helping one to establish social connections and understand others' perspectives (McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006). However, such automatic mimicry may have maladaptive consequences if one is constantly "catching" others' distress. Distress contagion, whereby the distress of others induces personal distress (Eisenberg & Eggum, 2009), is another compelling example of when automatic responses to others' emotions may inhibit emotion regulation and compromise autonomy. Evidence suggests that socially transmitted fear may influence behavior as strongly as direct personal experience, even once the fear has already been transmitted (Olsson et al., 2007). Catching others' distress could thus be detrimental when others' distress is not the most appropriate response to the environment. For example, emotion regulation has been identified as critical to empathic responding - that is, through helping one govern and manage intrapersonal emotions activated by perceiving others' distress (Eisenberg & Eggum, 2009). The capacity to regulate one's own emotions in the face of others' distress can be considered a key boundary separating empathy from simple distress contagion, the latter of which may lead to overarousal (Eisenberg & Eggum, 2009). As an illustration, imagine how a clinician's automatic (withdraw-oriented) response to and mimicry of his patient's fearful facial expression may interfere with his capacity to skillfully identify and treat his patient's anxiety.

Accurate discrimination of others' emotional expressions is a key component of successful social emotion regulation (Tottenham, Hare, & Casey, 2011), including control over automatic mimicry and behavioral response to others' emotions. In order to override one's impulse to approach a smiling petitioner vying for attention on one's walk to work, for example, explicit recognition of the happy expression affords greater conscious control over one's automatic response. Because basic discrimination processes depend on early deployment of attention (Vogel & Luck, 2000), social emotion regulation involves efficient attention to others' emotions in addition to cognitive control of emotional processing. Indeed, early attentional processing to emotional information is considered a critical component of emotion regulation (Todd, Cunningham, Anderson, & Thompson, 2012). From this perspective, initial attention to emotional stimuli influences “downstream” processing for better or worse. Over time, experience and goal-driven deployment of attention shapes habits of initial attention that inform subsequent emotional processing (Todd et al., 2012). Regular top-down deployment of attention to others’ emotions may therefore “tune” more bottom-up attention such that it becomes reflexively applied. For example, both normative and clinical anxiety are associated with heightened early attention to threat-relevant versus neutral or happy stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van IJzendoorn, 2007). On the other hand, such affect-biased attention to one category of stimuli over another is malleable, and can be attenuated through systematic cognitive training (Hakamata et al., 2010). This perspective suggests a complex interplay between voluntary and stimulus-driven attention to emotional information that highlights the importance of investigating factors that may influence early attention and emotion regulation in the presence of others’ emotions.

In summary, social situations provide unique challenges for emotion regulation, including noticing, discriminating between, and appropriately responding to others’ emotions and one’s automatic responses to them. Therefore, exploring factors which promote ongoing sensitivity to both intra- and inter-personal influences on emotional processing is important for understanding adaptive social emotion regulation. One such factor is dispositional mindfulness, defined as “an enhanced attention to and awareness of current experience or present reality” (Brown & Ryan, 2003, p. 822), and previously linked with enhanced intrapersonal emotional sensitivity (Hill & Updegraff, 2012) and emotion regulation (e.g., Way, Creswell, Eisenberger, & Lieberman, 2010; Brown, Weinstein, & Creswell, 2012). The present study examined whether mindfulness predicts improved emotion regulation in social emotional situations through investigating relations between self-reported mindfulness and neural/behavioral responses to affective facial expressions.

Relevance of Mindfulness to Social Emotion Regulation

Automatic approach/withdraw responses to emotional facial expressions have been shown to influence behavior regulation in normal populations (Hare et al., 2005). But studying how mindfulness influences emotional processing of affective social stimuli may not only inform our understanding of normative processes, it could also have clinical relevance. Cognitive-affective interactions may be critical for understanding disruptions in behavior regulation common to a variety of affective disorders (Schulz, Fan, Magidina, Marks, Hahn, & Halperin, 2007) as well as behavior problems more generally (Eisenberg et al., 2000). For example, both clinical and subclinical levels of anxiety have been associated with attention bias toward threat-related stimuli (Bar-Haim et al., 2007; Eldar, Yankelevitch, Lamy, & Bar-Haim, 2010). These differences reflect heightened sensitivity to both social and nonsocial threat-relevant affective stimuli, and are hypothesized to contribute to the etiology and preservation of anxiety (Beck, 1967; Vasey & MacLeod, 2001).

Indeed, it has been theorized that disruptions in emotion regulation may be a central mechanism underlying mood and anxiety disorders (Campbell-Sills & Barlow, 2007). Because mindfulness appears to promote adaptive emotion regulation (Chambers, Lo, & Allen, 2007; Wadlinger & Isaacowitz, 2011), the study of neural responses to affective social stimuli could contribute to an understanding of multiple mechanisms underlying more adaptive sensitivity to one’s own and others’ emotions. Moreover, because there is evidence that one’s level of dispositional mindfulness may increase with training (Shapiro, Brown, Thoresen, & Plante, 2011; Jensen, Vangkilde, Frokjaer, & Hasselbalch, 2011), understanding mechanisms of emotion regulation associated with mindfulness may inform clinical interventions targeting mood and anxiety disorders. For example, in patients with Social Anxiety Disorder, Goldin & Gross (2010) demonstrated that training mindfulness through an 8-week, Mindfulness-Based Stress Reduction program (Kabat-Zinn, 1990) decreased symptoms of depression and anxiety, as well as enhanced the efficacy of an adaptive emotion regulation strategy during the processing of negative self-beliefs.

Research on individual differences in mindfulness has also provided neuroscientific and behavioral evidence suggestive of adaptive emotion and behavior regulation. By definition, mindfulness involves less automatic emotional evaluation of stimuli through simple, non-evaluative observation of stimuli (Brown, Ryan, & Creswell, 2007). A number of studies have confirmed this at the level of neurophysiology, linking dispositional mindfulness to differential neural responses to unpleasant stimuli. Two studies have found that higher dispositional mindfulness is associated with less amygdala reactivity to negative emotional faces (fear and anger; Way et al., 2010; Creswell, Way, Eisenberger, & Lieberman, 2007). Furthermore, Creswell et al. (2007) found stronger negative associations between a number of regions of the prefrontal cortex (PFC) and amygdala activation among those scoring higher in trait mindfulness (using the Mindful Attention Awareness Scale [MAAS]; Brown & Ryan, 2003). This suggests that mindfulness promotes more efficient PFC down-regulation of amygdala responses to emotional information (Creswell et al., 2007). Conversely, greater amygdala reactivity to negative faces has been associated with depressive symptomalogy (Way et al., 2010) and both subclinical (Stein, Simmons, Feinstein, & Paulus, 2007) and clinical anxiety (Rauch, Shin, & Wright, 2003). Most recently, mindfulness was associated with attenuated neural reactivity between 500 and 900 ms after stimulus onset (the Late Positive Potential; LPP) to a mix of social and nonsocial, high arousal pleasant and unpleasant, motivationally salient stimuli (Brown et al., 2012). This indicates that dispositional mindfulness is associated with less "upstream" evaluative processing of high arousal emotional stimuli.

While a large number of studies have corroborated an association between mindfulness training and improvements in task performance across a wide variety of cognitive domains and functions (Grossenbacher & Quaglia, in preparation), there has been considerably less research linking dispositional mindfulness to differential task-based behavioral performance. However, task performance studies on this topic thus far show some support for a relation between dispositional mindfulness and factors that may promote greater emotion and behavior regulation. For example, studies have also associated dispositional mindfulness with greater capacity for sustained attention (Moore & Malinowski, 2009; Schmertz, Anderson, & Robins, 2009). Perhaps most relevant to the present study, studies have linked mindfulness to greater inhibitory control for both emotional and affect-neutral stimuli. In a sample of formerly depressed adults, higher trait mindfulness (MAAS) predicted greater inhibition of negative facial expressions when inhibition was counter to task goals (De Raedt, Baert, Demeyer, & Goeleven, 2012). In that study, MAAS scores also predicted less inhibition of positive facial expressions, suggesting an emotional sensitivity to which affective information necessitates inhibition, and overall less biases of attention (De Raedt et al., 2012). Regarding inhibitory control for affect-neutral stimuli, Josefsson & Broberg (2010) found that dispositional mindfulness was related to less behavioral response interference on a computerized Stroop task (Josefsson & Broberg, 2010). Similarly scores on the Five Factor Mindfulness Questionnaire (FFMQ; Baer et al., 2006) Act with Awareness subscale have been related to less interference on a measure of active inhibitory control, requiring intentional inhibition of distractors (Lee & Chao, 2012). Because inhibition of prepotent responses is an executive function central to self-regulatory processing generally (Hofman, Schmeichel, & Baddeley, 2012), dispositional mindfulness, as an attention-based marker of executive function, may also be related to greater emotion and behavior regulation. However, it important to note that evidence for the relation between inhibition of prepotent responses and dispositional mindfulness is mixed, as another study found no relation between FFMQ scores and Stroop interference (Galla et al., 2011). Making sense of mixed findings regarding mindfulness and inhibitory control may require an understanding of dispositional mindfulness as a propensity towards a mindful state (Brown & Ryan, 2003), rather than an enduring, static individual difference in attention and awareness. Indeed, it has been found that dispositional mindfulness scores predict states of mindfulness in everyday life, as measured by experience sampling methods (Brown & Ryan, 2003). From this view, one explanation for mixed findings may be that task performance measures are more sensitive to these fluctuations in state mindfulness than other kinds of dependent measures assessing chronic psychological propensities (e.g., self-report). There may also be considerable variation in individuals with high dispositional mindfulness regarding which contexts support versus hinder a mindful mode of processing. Consistent with this understanding, state mindfulness, initiated by 20 minutes of mindfulness meditation, has been linked to less Stroop interference compared to rest and learning control conditions (Wenk-Sormaz, 2005). Similarly self-reported state mindfulness was associated with less interference by unpleasant emotional information on ensuing behavior (Ortner, Kilner, & Zelazo, 2007). Thus both theory and evidence highlight the importance of accounting for states of mindfulness during an experimental procedure.

Mindfulness may facilitate behavioral responding not only through less evaluation of affective stimuli, but also through heightened open and receptive awareness of interoceptive and exteroceptive stimuli occurring the present moment. Consistent with theory that mindfulness promotes greater sensitivity to one's own processing, Brown & Ryan (2003) found that higher dispositional mindfulness positively moderated concordance between explicit and implicit state affect, with implicit state affect measured using an IAT with "me" and "not me" crossed with "pleasant" and "unpleasant" (Brown & Ryan, 2003). While no studies have corroborated these associations with the temporal precision that neural markers of attention can provide, studies have linked mindfulness to heightened attention and greater inhibitory control on measures of task-based behavior. Regarding heightened awareness of external present-moment occurrence, Jensen, Vangkilde, Frokjaer, & Hasselbalch (2012) found that MAAS scores predicted faster identification of target letters (faster discrimination threshold) and that MAAS changes from pre- to post-mindfulness training predicted decreases in the speed of identification. Importantly, discriminating between stimuli during a discrimination task differs from emotional evaluation (or appraisal) of stimuli as pleasant or unpleasant. Discrimination reflects discernment between stimuli, which can occur without an emotional response.

In short, dispositional mindfulness has been associated with less neural reactivity to aversive stimuli, greater inhibition of prepotent responses, and greater awareness of interoceptive and exteroceptive stimuli. It is also worth noting that two of the studies reviewed above related dispositional mindfulness directly to reduced neural reactivity to aversive affective facial expressions (Creswell et al., 2007; Way et al., 2010). Together these studies provide converging evidence to support further investigation of the relation between dispositional mindfulness and emotion and behavior regulation in the context of affective social stimuli. Specifically, considering the important role of early, automatic processing of others' emotions, the study of how individual differences influence the rapid processing of affective facial expressions may lend insight into mechanisms that support emotion regulation in social emotional contexts. Investigation of rapidly unfolding neural processes associated with attention, awareness, and appraisals offers an excellent opportunity to glean such insight.

Mindfulness and "Upstream" Emotion Regulation

Stages of early emotion regulation. Understanding cognitive-affective interactions is imperative for understanding the regulation of behavior (McClure, Botvinick, Yeung, Greene, & Cohen, 2007; Hare et al., 2005). Investigation of cognitive-affective interaction has generally focused on emotion regulation strategies, including cognitive reappraisal and the controlled modulation of emotional responses (Gross, 2007). Yet these are comparatively "downstream" responses, made after one or more appraisals or emotional responses have occurred. Recently, research has revealed that the nature of the "upstream" or early processing of emotion-relevant stimuli may also provide regulatory advantages (Todd et al., 2012). Regarding mindfulness, individual differences in self-reported mindfulness were shown to modulate neural responses associated with the early (<1 s) processing of motivationally salient, unpleasant and pleasant stimuli (Brown et al., 2012). In other words, one way dispositional mindfulness may facilitate emotion regulation is through modulation of the initial emotional reaction to affective stimuli. Further research is needed to examine whether differences in early neural response to motivationally salient stimuli, both before and during the early emotion generative process (< 1 s), are related to adaptive social emotion regulation. By examining dispositional mindfulness as a goal-sensitive moderator of (i) initial emotional response, (ii) conflict monitoring and inhibition of prepotent responses, and (iii) behavioral response selection, this study may facilitate understanding of how individual differences manifest at these three primary stages of emotion regulation (Campos, Mumme, Kermoian, & Campos, 1994). Moreover, because a core feature of mindfulness is heightened moment-by-moment attention (Grabovac, Lau, & Willett, 2011), it is also important to examine whether self-reported mindfulness is associated with differential neural response even earlier—at the level of initial attention to stimuli. Consistent with recent conceptualizations of emotion regulation (Gross & Thompson, 2007; Todd et al., 2012), an early stage of emotion regulation may occur at this level of initial attention to stimuli. According to the process-specific timing hypothesis (Sheppes & Gross, 2011), such early attention to emotional information may be less effortful and require fewer resources than emotion regulation occurring further "downstream" (e.g., reappraisal, response modulation).

The purpose of the present study was to leverage the temporal precision of both electroencephalogram (EEG)-based event-related potentials (ERPs) and task performance to examine these stages of processing others' emotional facial expressions. Regarding the former, ERPs have been used extensively to study the mental chronometry associated with early processing of both nonsocial and social stimuli. The temporal resolution of ERPs provides a means for investigating stages of information processing that begin immediately following stimulus exposure. Task-based behavioral measures afford a complementary window into the information processing occurring soon after stimulus exposure, through indexes such as response time (RT) and error rate. For the present study, distinct ERP components and behavioral outcomes were both used to index neural and behavioral indicators of discrete stages of early emotion regulation. Electrocortical responses were collected from participants while they performed a passive viewing task and an Emotional Go/No-Go Task (Hare et al., 2005), in which behavioral responses indexed speed and accuracy of discrimination of emotional facial expressions, as well as emotional biasing of approach and avoidance behaviors to these same facial expressions.

N100 and early allocation of attentional resources. The visual N100 is a negative-going waveform, occurring less than 200 ms after stimulus onset, which indexes deployment of attentional resources to stimuli (Vogel & Luck, 2000). More specifically, the N100 is found in tasks which require a discrimination process, including discriminating between complex stimuli (Vogel & Luck, 2000). Moreover, the N100 has been found to be sensitive to differences in top-down attention (e.g., Ruz, Madrid, & Tudela, 2012), and at least some studies indicate it is sensitive to valence of emotional facial expressions (Luo, Feng, He, Wang, & Luo, 2010). Together, these findings suggest the visual N100 may be an ideal index for examining the role of mindfulness on early allocation of attentional resources to emotional information.

No-Go N200 and conflict monitoring. Shortly following the N100, the N2 component of the ERP waveform (approximately 200 ms after stimuli onset), is thought to reflect conflict monitoring of the discrepancy between prepotent responses and task demands during a Go/No-Go task (Donkers & Van Boxtel, 2004). More specifically, the No-Go N2 reflects conflict monitoring of the prepotent Go response when faced with No-Go stimuli (Nieuwenhuis, Yeung, Van Den Wildenberg, & Ridderinkhof, 2003). The No-Go N2 has been related to individual differences in political orientation (Amodio, 2007), suggesting that it may also be sensitive to other individual differences.

Late Positive Potential and evaluative processing. While affective facial expressions have been shown to influence many well-known components of ERP-indexed stimulus processing (Luo et al., 2010), the late positive potential (LPP) is a component that has been associated with differential processing of both the valence and arousal of affective stimuli

(Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Olofsson, Nordin, Sequeira, & Polich, 2008; Weinberg & Hajcak, 2010). The LPP, a positive deflection occurring approximately 400-500 ms to 900-1000 ms after stimulus onset, has been shown to be larger to pleasant and unpleasant, compared to neutral, stimuli, and is larger for high arousal than low arousal visual images (Schupp, Cuthbert, Bradley, Cacioppo, Ito, & Lang, 2000). Affective social stimuli have been shown to evoke a similar neural response as to pleasant and unpleasant nonsocial stimuli (Schupp, Junghofer, Weike, Stockburger, & Hamm, 2004), and the LPP in particular has been shown to be sensitive to both implicit and explicit processing of facial expression valence (Van Strien, De Sonneville, & Franken, 2010).

The LPP may reflect unique individual differences in electrocortical responses to affective stimuli (Horan Wynn, Kring, Simons, & Green, 2010). Therefore, the study of how dispositions moderate the LPP is important for understanding the role of the LPP in emotional regulation more generally (Hajcak, MacNamara, & Olvet, 2010). Considering the evaluative function of the LPP (Cacioppo, Crites, & Gardner, 1996) and the non-evaluative nature of mindfulness, the LPP is one potential benchmark for understanding how mindfulness may influence reactivity to (or appraisal of) motivationally salient stimuli. Research is needed to examine whether dispositional mindfulness is related to an attenuation of the LPP to affective social stimuli, in a manner similar to the mindfulness-related attenuation of mixed, social and nonsocial stimuli (Brown et al., 2012).

Task-based behavior. In addition to ERPs, the present study examined behavioral responses during the Emotional Go/No-Go task. Typically, participants in this task respond via button press to targets presented on the majority of trials (e.g., happy faces), and are instructed to withhold button presses for less frequent nontarget trials (e.g., fearful faces). This task affords simultaneous investigation of speed and accuracy of facial expression discrimination as well as inhibition of prepotent responses (Tottenham et al., 2011). Further, the incorporation of affective social stimuli allows for analysis of emotion-related biases on cognition and behavior. Because the most effective emotion regulation is flexible and sensitive to individual goals and context (Eisenberg et al., 2000; Gross & Thompson, 2007), task parameters were varied to examine whether the hypothesized moderation of both neural (electrocortical) and behavioral responses by mindfulness during the task were goal-sensitive (i.e., facilitated performance across divergent task parameters). For example, responding quickly to emotional targets that evoke either avoid or approach behavioral tendencies may be facilitated by more or less inhibition, respectively. Assessment of ERPs alongside task performance has the added benefit of examining whether mindfulness-based differences in ERP responses to affective stimuli are related to overt behavior.

Primary Hypotheses

Past research suggests that dispositional mindfulness is associated with reduced ERP amplitudes to unpleasant images (Brown et al., 2012) and reduced amygdala reactivity to angry and fearful facial expressions (Way et al., 2010; Creswell et al., 2007). Therefore, participants completed a passive viewing task of happy, neutral, and fearful faces to examine the influence of dispositional mindfulness on early neural response to fearful faces. I hypothesized that LPP amplitude would be larger for fearful versus neutral faces, and dispositional mindfulness would be negatively correlated with LPP deflection to fearful facial expressions. Regarding the Emotional Go/No-Go task, I hypothesized higher self-reported dispositional mindfulness would predict faster discrimination (smaller RT) and less RT variability to all target stimulus types on the Emotional Go/No-Go Task, and dispositional mindfulness would be a stronger predictor of

RT to fearful faces, which is expected to be slower overall (Hare et al., 2005). I also predicted that dispositional mindfulness would be associated with greater accuracy, indexed by fewer false alarms (FAs) to all nontarget stimulus types. However, because it has been previously shown that it is harder to inhibit happy faces than neutral or fearful faces (Hare et al., 2005), due to happy faces evoking approach-oriented behavioral tendencies, I expected that dispositional mindfulness would most strongly predict FAs for happy nontargets.

Consistent with the hypothesis that dispositional mindfulness will promote discrimination between affective social stimuli, I also reasoned that mindfulness would be related to greater N100 amplitudes to all stimulus types during the Emotional Go/No-Go (Vogel & Luck, 2000). Additionally, I hypothesized that mindfulness would predict larger No-Go N2, reflecting greater conflict monitoring of prepotent Go responses (Donkers & Van Boxtel, 2004), and that No-Go N2 would be largest for happy nontargets, since approach oriented responses to happy faces are harder to inhibit (Hare et al., 2005). Regarding the relation between ERP components and task performance, it was hypothesized that more negative N100 would predict faster RT and fewer FAs, consistent with its role in visual discrimination (Vogel & Luck, 2000). It was also hypothesized that more negative No-Go N200 would predict fewer FAs. Further, these ERP components were expected to mediate any significant associations between mindfulness and respective behavioral outcomes.

State mindfulness was also tested as an independent predictor and as a moderator of dispositional mindfulness, to assess whether mindfulness during the tasks significantly predicted, or modified the predictive relation of trait mindfulness to the emotion and behavior regulation outcomes. Rigorous investigation of mindfulness on early neural responses and behavior to affective social stimuli should account for other variables which may heighten sensitivity and speed response time via different underlying mechanisms (e.g., attention bias to threat). As noted earlier, greater early sensitivity to emotion-related stimuli may also characterize a variety of mood and anxiety disorders (Beck, 1967; Vasey & MacLeod, 2001). In contrast to the heightened sensitivity to others' emotions hypothesized for dispositional mindfulness, the early sensitivity to others' emotions which characterizes mood and anxiety disorders has downstream consequences that disrupt one's own emotion regulation. Further, as a construct characterizing open and receptive attention, adaptive for emotion regulation, mindfulness should predict neural and behavioral responses distinct from constructs involving more concentrated attention (e.g., attentional control; Goodman, Quaglia, & Brown, in press). Therefore, it was hypothesized that the all significant relations between dispositional mindfulness and outcome measures would hold after accounting for two additional predictors that may predict similar results, but reflect divergent underlying processes, namely distress contagion and attentional control.

Methods

Participants

A sample of 62 undergraduate students, 18 years or older, were recruited from Virginia Commonwealth University and received course credit for their participation. Prospective participants were recruited though online research participation software (Sona Systems; Tallin, Estonia). Only Caucasian students were eligible to complete the online screening, in order to minimize variation in response to facial stimuli due to race/ethnicity. All prospective participants completed an initial online questionnaire to screen for right-handedness (because handedness has been shown to affect ERP measurement), serious medical or neurological conditions, prescription and recreational drug use, and recent psychiatric diagnoses. Subjects specified the presence/absence of these conditions and behaviors with a summary yes or no response to a longer list of conditions and behaviors, designed to reduce discomfort that may stem from reporting specific sensitive information. There were 21 male participants (33%) and 41 females (67%).

Two subjects were excluded from all analyses: one fell asleep during the experiment and the other experienced a power outage during the study session. In addition, one participant was excluded from LPP and N100 analyses because of irregularities during acquisition, and four additional participants were excluded from N200 analyses because a hardware malfunction prevented task performance data and ERPs from being merged. Thus, the final numbers of participants included in each analysis were: 60 for behavioral, 59 for LPP and N100, and 55 for N200.

Materials

Self-report. In addition to providing basic demographic information (age, sex), participants completed a battery of self-report psychological measures. Relevant to this study were the following scales:

Mindfulness. Dispositional mindfulness was measured using both the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) and the Five Factor Mindfulness Questionnaire (FFMQ; Baer et al., 2006). The MAAS has demonstrated high reliability and validity (Brown & Ryan, 2003), and has been used extensively in research on dispositional mindfulness. Participants endorse items on the MAAS such as, "It seems I am 'running on automatic,' without much awareness of what I'm doing," on a Likert Scale (1= 'Almost Always' to 6 = 'Almost Never'). Therefore, the MAAS operationalizes the presence of mindfulness via 15 items antithetical to mindful attention, such that higher scores reflect higher mindfulness. The Cronbach's alpha coefficient for the MAAS was .82 in this sample. The FFMQ is another wellvalidated measure of mindfulness, which assesses mindfulness on a 5-point scale from 1 ('never or very rarely true') to 5 ('very often or always true'). For the present analyses, only the FFMQ's Act with Awareness subscale was used, as other subscales may reflect skills associated with mindfulness, rather than mindfulness itself (Brown & Cordon, 2009). Cronbach's alpha for the FFMQ was .71 in this sample.

As noted earlier, previous research suggests that accounting for mindful states during the study may be important for understanding variation associating dispositional mindfulness with emotion and behavior regulation at neural and behavioral levels of analysis. Therefore, the state Mindful Attention Awareness Scale (State MAAS; Brown & Ryan, 2003) was used to capture self-reported mindfulness specifically during the experiment.

Personal Distress. The Interpersonal Reactivity Index (IRI; Davis, 1983) is a 28-item self-report scale that measures cognitive and emotional components of empathy. The four subscales of the IRI are intended to be analyzed separately, and of interest to the present study, the Personal Distress (PD) subscale indexes distress experienced in interpersonal situations that interferes with helping others (i.e., distress contagion). This subscale was chosen to represent a form of heightened sensitivity to others that is antithetical to the type of heightened attention to others' emotions theorized to characterize mindfulness in social contexts, and correlates positively with social anxiety (Davis, 1983). Sample Cronbach's alpha for PD was .81.

Attentional Control. There is some dispute regarding whether mindfulness is distinct from other sorts of attentional dispositions. In particular, establishing discriminant validity with individual differences in voluntary control of attention is important to understand the open, receptive quality of mindful attention. Therefore, the Attentional Control Scale (AC; Derryberry & Reed, 2002) was employed in the present study, which measures dispositional attentional control on 4-point scale (‘almost never’ to ‘almost always’). Cronbach’s alpha for the ACS was .81 in this sample.

Tasks and Stimulus Materials. The social stimuli were selected from the NimStim Face Stimulus Set, previously used in an Emotional Go/No-Go task to assess approach/avoidance tendencies to affective social stimuli (Hare et al., 2005). Images from twelve models total, including three African American or Caucasian males and three African American or Caucasian females, expressing happy, neutral, or fearful facial expressions were grayscaled and normalized for luminance.

Passive Viewing**.** The participant was asked to engage in a passive viewing task, viewing photographs of happy, neutral, and fearful faces on a 19’’ flat-screen LCD monitor at a distance of approximately 34”, with a vertical visual angle of 20°. The task included 150 trials, divided into 5 equal blocks, each separated by a 30-second break. The images were presented in a pre-arranged random order for 5 s each, with a random interstimulus interval of between 2 s and 4 s.

Emotional Go/No-Go. Following a procedure used in past research (Hare et al., 2005), a fixation cross was presented to participants on the same 19’’ flat-screen LCD monitor, at the same viewing angle, for 2000 ms, followed by a stimulus. Participants were instructed to press a response key using a button box to fearful, happy, or neutral faces only, depending on the condition. Condition A and Condition B were counterbalanced, such that half the participants completed Condition A first (randomly assigned). Condition A first responded to fearful targets, presented randomly on 70% of trials, while 30% of the stimuli were happy faces or neutral faces (alternating blocks). After eight blocks of 60 trials, Condition A participants switched to alternating blocks of happy targets/fearful non-targets and neutral targets/fearful non-targets. Condition B received the same conditions, but in reverse order. Participants completed twenty practice trials before beginning the experimental stage of each condition, the latter of which consisted of 480 trials divided into eight equal trial blocks, separated by short rest breaks. Behavioral responses were recorded via a dominant hand button press on a button box placed on a stable board on the lap. Performance was assessed by response time (RT), False Alarms (FA), and RT variability.

Procedure

Participants reported individually to a quiet laboratory in the Department of Psychology where the general outline and purpose of the study was described. Participants were then asked to review and sign an informed consent form. A questionnaire assessing the inclusion criterion (right-handed) and exclusion criteria for the study was completed and verified. Excluded participants received partial credit and were thanked for their time. A packet of questionnaires was then completed by those passing the screen. After packets were completed, each participant was directed to sign up for a time on a separate day to complete the EEG/task performance portion of the study.

Within two to three weeks of completing questionnaires, participants reported to the lab where cap placement occurred and EEG impedences were checked. In counterbalanced order, participants completed the passive viewing task and the Emotional Go/No-Go Task, with all participants viewing the same social stimulus set. Participants completed the state MAAS after the passive viewing task and following every four blocks of the Emotional Go/No-Go Task. Upon completion of a final state MAAS questionnaire, the experimenter removed the EEG cap, and participants were thanked for their efforts, debriefed, and dismissed. The complete EEG/task performance procedure took about 2 hours, including the intermittent breaks.

Electrophysiological recording, artifact rejection, and component specification. All electrophysiologic signals were acquired using a Neuroscan (El Paso, TX) SCAN NuAmps Express 40 channel system. The EEGs and the EOGs were acquired at a gain of 20K (3.75 μV/mm equivalent) for a frequency bandwidth of 0.3-100Hz (24dB/octave). The EMGs were acquired at a gain of 20K for an initial bandwidth of 30-1000Hz. The digital band-pass filter settings were as follows: EOGs at 0.3-4Hz, EEGs at 0.3-20Hz, and EMGs at 30-250Hz. The timing, presentation, and synchronization of stimulus presentation and the continuous EEG recording were controlled on a PC using Stim2 software (Neuroscan; El Paso, TX). During the tasks, continuous EEG signal was time-locked to the visual presentation of, and participant's behavioral response to, the social stimuli.

A semi-automatic artifact detection procedure in EEGLAB software was used to clean EEG signal data and prepare it for subsequent analyses (Viola et al., 2009). An epoched average waveform (all time points) was computed for each participant between -500 and 1500 ms pre- and post- stimulus, respectively. For the Emotional Go/No-Go task, average waveforms were computed separately for correct versus incorrect trials. Independent component analysis (ICA) was used to identify and partition artifact and brain-related signals. CORRMAP, an open-source EEGLAB plug-in, was then performed to enable visual inspection and statistical removal of exemplary artifacts (e.g., blinks). Waveforms were baseline corrected by averaging between -500 and 0 ms.

N100. Visual inspection of grand average waveforms for each task revealed an N100 peaking around 130 ms at electrode Cz, consistent with previous research (e.g., Campanella et al., 2002; Kubota & Ito, 2007; Rossignol, Philippot, Douilliez, Crommelinck, & Campanella, 2005). The N100 was indexed by averaging activation at Cz for each stimulus type in a 50 ms window (Vogel & Luck, 2000) between 100 and 150 ms. Further, because previous research has demonstrated that the N100 can be sensitive to top-down differences in executive control (Ruz et al., 2012), averages for Go and No-Go trials were computed separately.

No-Go N200. Visual inspection of the grand average waveform for no-go stimuli followed by correct omission of behavioral response revealed an N200 component peaking around 260 ms, and maximal at FCz. Following previous work (Zhang & Lu, 2012; Bruin & Wijers, 2002), the N200 ERP component was indexed as the amplitude between 200 and 350 ms post-stimulus for three different frontocentral sites (Fz, FCz, Cz). Though the N200 was computed for both go and no-go trials for comparison, only trials involving correct rejection to no-go stimuli constitutes the No-Go N2 (Nieuwenhuis et al., 2003; Amodio et al., 2008).

LPP. Consistent with the sustained positive deflection of the LPP in previous studies (Hajcak, MacNamara, & Olvet, 2010a), visual inspection revealed the start of LPP around 500 ms and extending beyond 1000 ms. Following previous work on mindfulness and the LPP (Brown et al., 2012), the LPP was indexed by the average amplitude at four different electrode sites in a 400 ms window following the presentation of happy, neutral, and fearful facial expressions. More specifically, the LPP was averaged across both an early (500-700 ms) and late (701-900 ms) window because previous research suggests the LPP should be assessed across multiple time windows (Hajcak et al., 2010a). LPP amplitudes during each window, and for each stimulus type, were averaged separately at four different electrode sites across midline central and posterior regions of the scalp (FCz, Cz, CPz, and Pz; Cuthbert et al., 2000; Schupp et al., 2004).

Behavioral data preparation. RT for incorrect trials introduces greater error in calculating average response times, so only RT for correct trials were included. To be certain that differences in RT variability were not due solely to differences in RT, the coefficient of variation (standard deviation/RT) was used to index RT variability (Hendricks & Robey 1936). RT, RT variability, and FAs were computed for each stimulus type. Before averaging, RTs reflecting anticipatory or delayed responding (< 200ms or >1500ms, respectively) were removed (Vago & Nakamura, 2011). Descriptive analyses revealed that the number of FAs for each stimulus type were highly skewed and kurtotic. Thus, natural log transformations were applied to each variable, resulting in normal distributions.

Results

Self-Report

Correlations between self-report scales were mostly as expected, and are reported in Table 1. Interestingly, dispositional mindfulness was only significantly related to state mindfulness during the Emotional Go/No-Go, and only as assessed by the MAAS.

Table 1.

Correlations between self-report scales

Observed Variable	**1**	**2**	**3**	**4**	**5**	**6**
1. MAAS	1	-	-	-	-	-
2. FFMQ Act with Awareness	.743**	1	-	-	-	-
3. AC	.438**	.480**	1	-	-	-
4. PD	-.228	-.292*	-.377*	1	-	-
5. State MAAS Passive Viewing	.175	.150	.188	-.087	1	-
6. State MAAS Go/No-Go	.274*	.227	.070	-.011	.511**	1

Note. * = p < .05; ** p < .001; FFMQ = Five Factor Mindfulness Questionnaire; MAAS = Mindful Attention Awareness Scale; SMAAS = State Mindful Attention Awareness Scale; PD = Personal Distress; AC = Attentional Control

Given that dispositional mindfulness has been considered as a tendency to engage in mindful states (Brown & Ryan, 2003), a lack of clear demonstration of association between trait and state mindfulness during the study indicates important variability in state mindfulness during the experiment unaccounted for by dispositional mindfulness.

ERP during Emotional Go/No-Go Task

N100. To test the hypotheses that dispositional and state mindfulness would predict larger average N100 amplitudes to social stimuli, repeated measures mixed (multilevel) model analyses, using restricted maximum likelihood estimation (REML; Bryk & Raudenbush, 1992) were run. At the level of repeated-measures, Condition (fearful, happy, or neutral facial expression) and Stimulus Type (Go vs. No-Go) were dummy coded (0, 1, 2; and 0, 1, respectively). Analyses were first conducted to see whether there was a main effect of these level one predictors. Initial analyses revealed no main effect of condition, type, or their interaction (ps $> .10$). Subsequently, these predictors were retained in the model, but no cross-level interactions between condition, type, and individual level predictors were tested.

Next, two multilevel models were run, each covarying one self-report dispositional mindfulness measure (MAAS, FFMQ Act with Awareness), together with state MAAS during the Emotional Go/No-Go Task. Additionally, because the order of the tasks (passive viewing and Emotional Go/No-Go) was counterbalanced, task order (hereafter, Order) was included at the individual level to control for variability due to task counterbalancing. Exemplary of models used throughout this paper, Table 2 presents equations for the repeated measures mixed models which covary MAAS:

Table 2.

Primary Repeated Measures Mixed Model Equations for Each Outcome Variable

Equations	**Variables**
	$Y_{ij} =$ Outcome variable
N100:	
	Repeated Measures Predictors:
$Y_{ij}= (\gamma_{00}+ \gamma_{01}Z_{1j} + \gamma_{02}Z_{2j} + \gamma_{03}(Z_{1j} \text{ x } Z_{2j}) + u_{0j}) + (\gamma_{10}+ u_{1j})X_{1ij}+ (\gamma_{20}+ u_{2j})X_{2ij} + r_{ij}$	$X_{1ij} =$ Stimulus Condition (happy, fearful, neutral) $X_{2ij} =$ Stimulus Type (Go vs. No-Go) $X_{3ij} =$ Signal Window (Early vs. Late)
N200:	
	Person Level Predictors:
$Y_{ij}= (\gamma_{00}+ \gamma_{01}Z_{1j} + \gamma_{02}Z_{2j} + \gamma_{03}(Z_{1j} \text{ x } Z_{2j}) + u_{0j}) + (\gamma_{10}+ u_{1j})X_{1ij}+ (\gamma_{20}+ \gamma_{21}Z_{1j} + \gamma_{22}Z_{2j} + \gamma_{23}(Z_{1j} \text{ x } Z_{2j}) + u_{2j})X_{2ij} + r_{ij}$	$Z_{1j} =$ MAAS score $Z_{2j} =$ State MAAS score
	Coefficients:
LPP:	$\gamma_{00} =$ Avg. intercept for individuals with mean scores on predictors
$Y_{ij}= (\gamma_{00}+ \gamma_{01}Z_{1j} + \gamma_{02}Z_{2j} + u_{0j}) + (\gamma_{10}+ u_{1j})X_{1ij} + (\gamma_{30}+ u_{3j})X_{3ij} + r_{ij}$	$\gamma_{01}, \gamma_{11}, \gamma_{21} =$ Avg. slope relating MAAS to outcome variable
RT, RT Variability:	$\gamma_{10}, \gamma_{20}, \gamma_{30} =$ Avg. slope relating Stimulus Condition, Type, or Signal Window (respectively) to outcome variable
$Y_{ij}= (\gamma_{00}+ \gamma_{01}Z_{1j} + \gamma_{02}Z_{2j} + u_{0j}) + (\gamma_{10}+ u_{1j})X_{1ij} + r_{ij}$	$\gamma_{02}, \gamma_{12}, \gamma_{22} =$ Avg. slope relating state MAAS to outcome
FA:	$\gamma_{03}, \gamma_{13}, \gamma_{23} =$ Avg. slope relating MAAS x state MAAS to outcome variable
$Y_{ij}= (\gamma_{00}+ \gamma_{01}Z_{1j} + \gamma_{02}Z_{2j} + u_{0j}) + (\gamma_{10}+ \gamma_{11}Z_{1j} + \gamma_{12}Z_{2j} + u_{1j})X_{1ij} + r_{ij}$	
	Residual Variances:
	$u_{0j} =$ Variance of participant's intercept around the mean intercept
	$u_{1j}, u_{2j}, u_{3j} =$ Variance of participant's slope around mean slope
	$r_{ij} =$ Variance of participant's outcome around mean

Note. To simplify presentation, Task Order (a control variable) is omitted from equations.

Regarding dispositional mindfulness, both MAAS [$F(1, 49) = 6.21$, $p = .016$] and FFMQ Act with Awareness [$F(1, 49) = 5.78$, $p = .020$] significantly predicted more negative N100 amplitude. For illustrative purposes, Figure 1 presents topographic maps and grand average waveforms highlighting these associations between mindfulness and the N100. Interestingly, the N100 with low FFMQ Act with Awareness appears lateralized to the left. In neither model was state MAAS a significant predictor of N100 amplitude (ps > .07), however, the interaction between FFMQ Act with Awareness and state MAAS was marginally significant [$F(1, 49) = 3.89$, $p = .054$]. Consistent with the hypothesized unique influence of mindfulness, these significant associations remained significant even after controlling either attentional control or personal distress (ps < .03). Table 3 summarizes results for each primary analysis at the electrode where the N100 component was maximal (Cz).

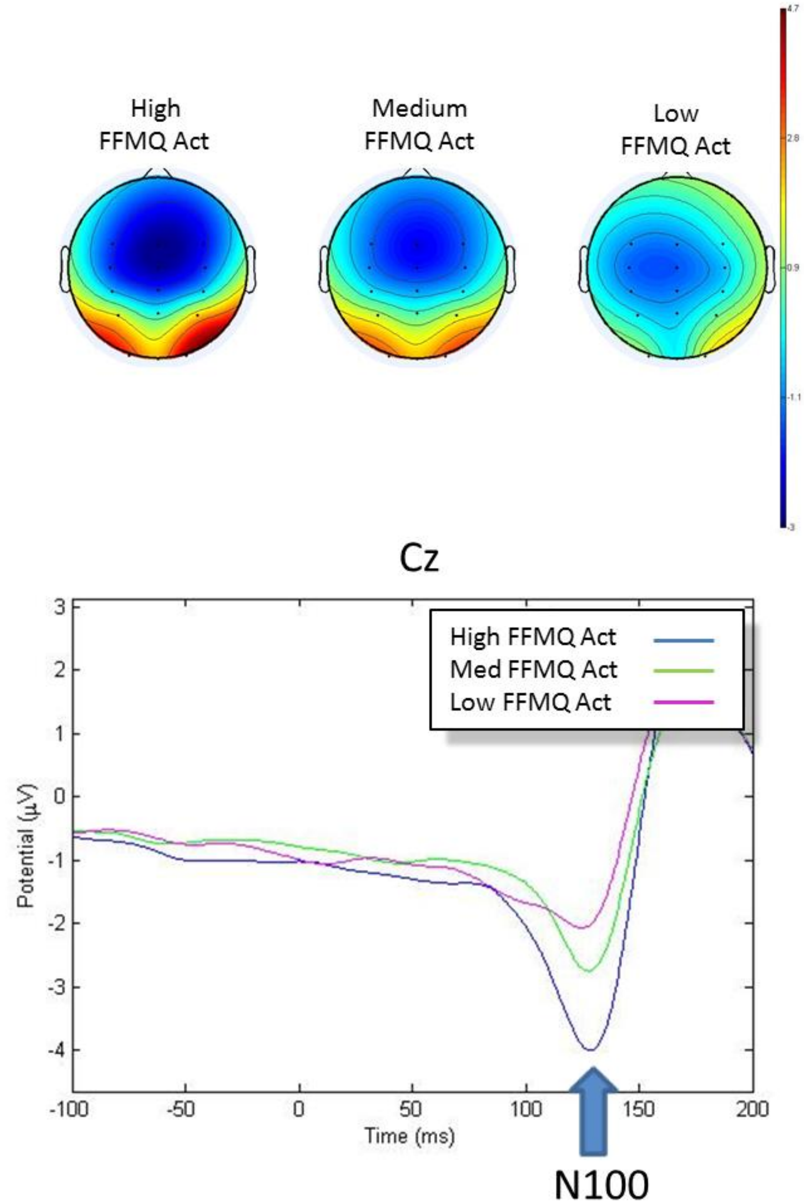

Figure 1. Top: Scalp topographies based on tertiary split of FFMQ Act with Awareness (high, medium, low from left to right) for 100-150 ms following stimulus onset during the Emotional Go/No-Go Task. Darker blue indicates more negative activation. Bottom: Grand average waveform at Cz for same tertiary split between -100 and 200 ms following all conditions and stimulus types.

Table 3.

Summary of N100 Results at Cz

	Model		
	Base Model	Controlling for PD	Controlling for AC
	b (SE)	b (SE)	b (SE)
FFMQ Act with Awareness Model			
FFMQ Act	-13.93* (5.79)	-13.36* (5.83)	-14.33* (5.78)
SMAAS	-10.62 (5.87)	-9.54 (5.94)	-10.76 (5.85)
FFMQ Act*SMAAS	3.52 (1.79)	3.19 (1.81)	3.55 (1.78)
PD		-.35 (.31)	
AC			-.48 (.34)
MAAS Model			
MAAS	-12.33* (4.95)	-12.27* (4.93)	-12.04* (5.01)
SMAAS	-6.17 (5.56)	-5.49 (5.54)	-6.00 (5.60)
MAAS*SMAAS	2.06 (1.48)	1.87 (1.48)	1.99 (1.49)
PD		-.41 (.28)	
AC			-.18 (.32)

Note. * $p < .05$, ** $p < .01$, *** $p < .001$; FFMQ = Five Factor Mindfulness Questionnaire; MAAS = Mindful Attention Awareness Scale; SMAAS = State Mindful Attention Awareness Scale; PD = Personal Distress; AC = Attentional Control

No-Go N200. To test the hypothesis that higher mindfulness would predict greater No-Go N2 amplitude, repeated measures mixed models examined two repeated measures factors: condition (fearful, happy, neutral) and Type (go vs. no-go). The following details analysis at FCz, where the N200 was maximal, and summarizes findings at Fz and Cz. An initial model tested the main effect of condition and Type on the N200 amplitude. Type was a significant predictor of the N200 [$F(1, 52) = 11.29$, $p < .001$], but Condition was not ($p > .10$). Tukey-Kramer post-hoc tests revealed that the amplitude of the N200 was more negative for No-Go than Go stimuli [$t(1, 52) = 3.36$, $p < .001$]. This is consistent with previous research suggesting that the N200 reflects conflict monitoring of the prepotent response for No-Go stimuli. Similar results were found at sites Fz and Cz (*p*s < .02).

Next, two multilevel models were run to test the effects of each dispositional mindfulness scale (MAAS, FFMQ Act with Awareness), together with state MAAS during the Emotional Go/No-Go task, on N200 amplitude. It was hypothesized that mindfulness would predict more negative No-Go N200 across conditions. As with the N100, task order (passive viewing vs. Emotional Go/No-Go first) was included at the individual level to control for variability due to task counterbalancing.

Regarding dispositional mindfulness, FFMQ Act with Awareness [$F(1, 45) = 5.14$, $p = .028$] and the MAAS [$F(1, 45) = 13.87$, $p < .001$] significantly predicted more negative N200 amplitude at FCz. For illustrative purposes, Figure 2 presents a median split of MAAS and its relation to N200 for No-Go stimuli, and Table 4 summarizes the results at FCz. Further, state MAAS was negatively associated with N200 amplitude in both models [MAAS model: $F(1, 45) = 9.24$, $p = .004$], and the interaction between state and dispositional mindfulness was significant for the MAAS [$F(1, 45) = 9.77$, $p = .003$], and marginally significant for FFMQ Act with

Awareness [$F(1, 45) = 3.92$, $p = .054$]. Interestingly, plotting these interactions revealed that the relation between dispositional mindfulness and more negative N200 was stronger for those lower in state mindfulness. There were no significant interactions with Type in either model at FCz.

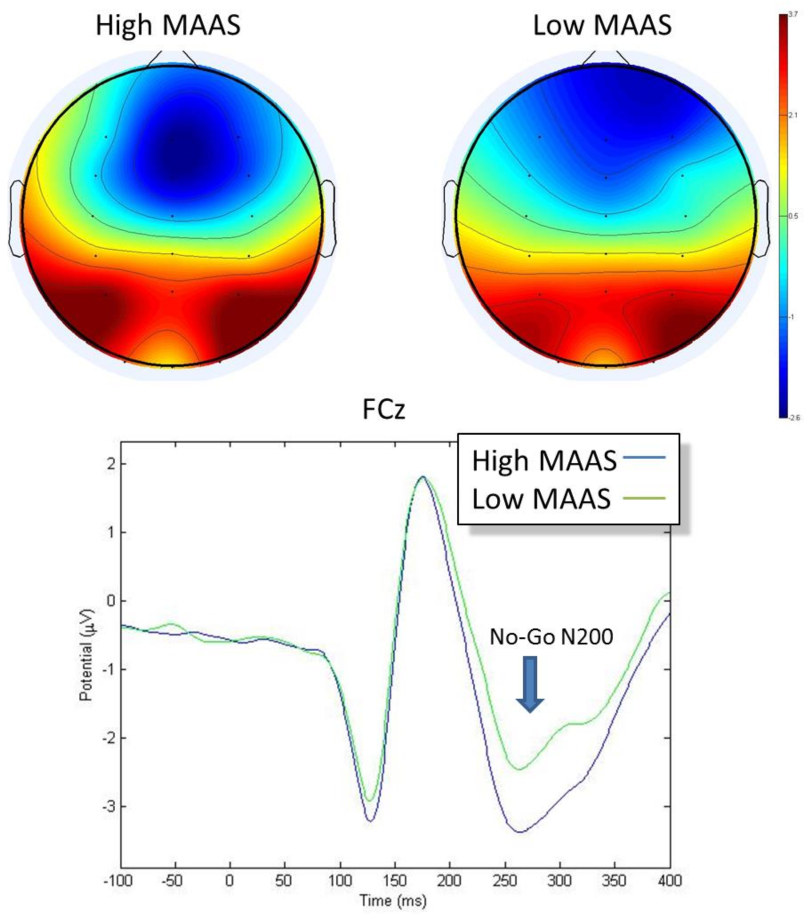

Figure 2. Top: Topographic maps based on a median split of the MAAS (high MAAS on left) for 200-350 ms following stimulus onset for all No-Go trials during the Emotional Go/No-Go Task. Darker blue indicates more negative activation. Bottom: Grand average waveform for high (blue) vs. low (green) MAAS between -100 and 400 ms, based on median split for No-Go trials during the Emotional Go/No-Go.

Table 4.

Summary of N200 Results at FCz

	Model		
	Base Model	Controlling for PD	Controlling for AC
	b (SE)	b (SE)	b (SE)
FFMQ Act with Awareness Model			
FFMQ Act	-10.87* (5.76)	-11.16* (5.84)	-10.88* (5.79)
SMAAS	-7.74 (5.47)	-10.02 (5.86)	-9.72 (5.78)
FFMQ Act*SMAAS	2.92 (1.76)	3.03 (1.79)	2.92 (1.77)
PD		.09 (.31)	
AC			-.11 (.34)
MAAS Model			
MAAS	-17.99** (5.23)	-18.21*** (5.31)	-18.39*** (5.30)
SMAAS	-16.19** (5.82)	-16.49** (5.93)	-16.47** (5.89)
MAAS*SMAAS	4.47** (1.58)	4.56** (1.62)	4.57** (1.60)
PD		.09 (.29)	
AC			.18 (.33)

Note. * $p < .05$, ** $p < .01$, *** $p < .001$; FFMQ = Five Factor Mindfulness Questionnaire; MAAS = Mindful Attention Awareness Scale; SMAAS = State Mindful Attention Awareness Scale; PD = Personal Distress; AC = Attentional Control

A very similar pattern of significant associations were found at electrodes Fz and Cz, except that there were also significant interactions between state mindfulness and Type [MAAS model: F(1, 250) = 4.35, p = .038], MAAS and Type [F(1, 250) = 5.22, p = .023], as well as a marginally significant interaction between FFMQ Act and Type [F(1, 250) = 3.55, p = .060] at electrode Cz. Further, there were significant three-way interactions between state mindfulness, Type, and each dispositional mindfulness scale: MAAS [F(1, 250) = 5.32, p = .022], and FFMQ Act with Awareness [F(1, 250) = 3.94, p = .048] at Cz. For each two-way interaction, dispositional mindfulness was a stronger predictor of more negative N200 amplitude for No-Go versus Go stimuli. Each three-way interaction revealed that the relation between dispositional mindfulness and more negative No-Go N200 (relative to Go N200) depended on state mindfulness, such that this relation was stronger for those higher in state mindfulness. In summary, mindfulness was related to larger (more negative) N200 generally, and was an even stronger predictor of No-Go N200 at Cz. A simple slopes analysis revealed that the relation between mindfulness and N200 for Go stimuli was also significant at Cz. For models controlling either personal distress or attentional control, a similar pattern of significant associations between mindfulness and N200 amplitude was found across sites of interest.

ERP during Passive Viewing

LPP. To test the hypotheses that dispositional and state mindfulness would predict smaller average LPP amplitudes to fearful faces, repeated measures mixed (multilevel) model analyses were conducted with signal window (early versus late) and the three stimulus conditions (happy, neutral, fearful) as condition-level repeated measures factors. Dispositional (MAAS or FFMQ Act with Awareness) and state mindfulness (State MAAS) was included as individual-level predictors. The following LPP analyses detail findings at site CPz (c.f., Brown et al., 2012), where the LPP was maximal, and summarize findings from other sites (FCz, Cz, Pz).

Preliminary analysis revealed no main effect of signal window, stimulus condition, or task order on LPP amplitude at any electrode site (*p*s > .05). Next, each dispositional mindfulness scale was included in a separate model, together with state mindfulness. Regarding dispositional mindfulness, neither the MAAS [$F(1, 55) = 0.02$, $p = .889$], nor the FFMQ Act with Awareness subscale [$F(1, 55) = .38$, $p = .541$], were significant predictors of LPP amplitude. Additionally, there were no significant interactions between dispositional mindfulness, window, or condition (*p*s > .10). Regarding state mindfulness, state MAAS was a significant predictor of LPP [FFMQ Act Model: $F(1, 55) = 7.64$, $p = .008$], but importantly, this relationship was in the direction opposite to what was expected. Higher state mindfulness was associated with larger LPP amplitudes generally. However, there were no significant interactions between state mindfulness, window, or condition (*p*s > .30). The primary results at site CPz are presented in Appendix A. Analyses at FCz, Cz, and Pz were consistent with those found at CPz.

Behavioral Responses

Response Time and Response Time Variability. To test the hypotheses that mindfulness would predict faster RT and less RT variability, repeated measures mixed models were run with condition (fearful, happy, and neutral) as the repeated measures factor and each self-report mindfulness scale as individual level predictors (MAAS or FFMQ Act with Awareness), including state MAAS. Additionally, Order was included in the model to control for task order effects. Regarding RT, an initial model found no main effect of condition [$F(2, 57) = .32$, $p = .728$]. This indicates that there was no emotional modulation of RT. However, there was an effect of Order such that those who completed the Emotional Go/No-Go after the passive viewing task had significant faster RT [F(1, 57) = 5.12, p = .028]. Next, two models were tested to assess whether mindfulness predicted significantly faster RT. Consistent with the hypothesis, both MAAS [F(1, 56) = 7.61, p = .007] and FFMQ Act with Awareness predicted significantly faster RT [F(1, 56) = 4.37, p = .041]. State mindfulness, on the other hand, did not significantly predict RT [F(1, 56) = .23, p = .634]. After controlling for attentional control, which was not a significant predictor of RT (p > .10), the relation between each dispositional mindfulness scale and RT remained significant (p < .05). Further, after controlling for personal distress, which itself predicted faster RT [MAAS model: F(1, 55) = 5.40, p = .024], both the MAAS [F(1, 55) = 10.16, p = .002] and the FFMQ Act with Awareness subscale [F(1, 55) = 7.00, p = .011] remained significant predictors of faster RT. These results, summarized in Table 5, indicate a distinct relation between mindfulness and faster RT.

Table 5.

Summary of Response Time Results

	Model		
	Base Model	Controlling for PD	Controlling for AC
	b (SE)	b (SE)	b (SE)
FFMQ Act with Awareness Model			
FFMQ Act	-.44* (.21)	-.57** (.21)	-.55* (.24)
SMAAS	-.01 (.09)	.01 (.08)	.33 (.53)
PD		-.26* (.11)	
AC			-.13 (.13)
MAAS Model			
MAAS	-.52** (.18)	-.60 (.18)**	-.62** (.20)
SMAAS	.02 (.09)	-.03 (.08)	-.02 (.08)
PD		-.24* (.11)	
AC			-.15 (.12)

Note. * $p < .05$, ** $p < .01$; FFMQ = Five Factor Mindfulness Questionnaire; MAAS = Mindful Attention Awareness Scale; SMAAS = State Mindful Attention Awareness Scale; PD = Personal Distress; AC = Attentional Control

Regarding RT variability, indexed by the coefficient of variation (standard deviation/RT), none of the self-reported mindfulness scales predicted less RT variability (*p*s > .10). These results for RT variability are presented in Appendix A. Together these results do not support a relation between mindfulness and RT variability.

Accuracy. The hypothesis that mindfulness would predict greater accuracy (fewer FAs), was also tested with a repeated measures mixed model. An initial model found that condition was a significant predictor of the number of FAs [$F(2, 57) = 35.32$, $p < .001$]. Tukey-Kramer post-hoc tests revealed that, compared to fearful No-Go stimuli, the number of FAs were higher for both neutral [$t(1, 57) = 5.84$, $p < .001$] and happy faces [$t(1, 57) = 8.00$, $p < .001$]. There was no significant difference between neutral and happy faces ($p > .10$). This is consistent with previous research suggesting that it is easier to inhibit a Go response to fearful No-Go stimuli, presumably because it is consistent with approach/withdraw tendencies (Hare et al., 2005). Regarding mindfulness, none of the mindfulness scales predicted fewer FAs for any no-go stimulus type (*p*s > .10). Appendix A presents results for FA analyses.

Speed-Accuracy Tradeoff? As described above, both dispositional mindfulness scales were related to faster RT but neither was significantly associated with fewer FAs. In contrast to hypotheses, a nonsignificant, positive correlation to FAs was found for the FFMQ Act with Awareness subscale. To account for a possible speed-accuracy tradeoff, an additional model was run to test the association between dispositional mindfulness and RT, controlling for the number of FAs. Both the MAAS and the FFMQ Act with Awareness subscale remained significant predictors (*p*s < .05), indicating that the relation between mindfulness and faster RT is not explained by a speed-accuracy tradeoff.

ERP – Behavior Relations

To test the hypotheses that ERP components would predict behavioral outcomes, repeated measures mixed models were run with condition (fearful, happy, and neutral) and ERP components of interest as repeated measures factors. Additionally, Order was included as an individual level predictor to control for task order effects. Two models were run to assess whether N100 amplitude at Cz predicted RT and FA. While N100 at Cz did not significantly predict RT [$F(1, 55) = .02$, $p = .897$], higher N100 did predict significantly fewer FAs [$F(1, 55) = 4.67$, $p = .035$]. However, because self-reported mindfulness did not significantly predict FAs, mediation was not tested. Regarding the hypothesis that more negative No-Go N200 would predict fewer FAs, models were run to test this relation at each germane electrode site (Fz, FCz, and Cz). In contrast to expectations, No-Go N200 was not a significant predictor of FAs [at FCz: $F(1, 51) = .04$, $p = .837$]. Similar results were found at electrodes Fz and Cz.

Discussion

Mindfulness has been previously linked to differential processing of emotional information (e.g., De Raedt, Baert, Demeyer, & Goeleven, 2012; Farb et al., 2010; Ortner, Kilner, & Zelazo, 2007), and more recently with attenuated early neural reactivity to affective imagery (Brown et al., 2012). The present study investigated the role of mindfulness on three components of "upstream" processing of social affective information. Specifically, this research examined self-reported dispositional and state mindfulness as predictors of neural and behavioral responses across passive viewing and Emotional Go/No-Go tasks involving happy, neutral, and fearful facial expressions. Consistent with hypotheses for the Emotional Go/No-Go Task, associations were found between higher mindfulness and more negative N100, N200, and No-Go N200 amplitudes, as well as faster discrimination of facial expressions. However, in contrast to expectation, there were no significant associations between mindfulness and RT variability or accuracy (number of FAs). Further, ERP components did not mediate the predicated associations between self-reported mindfulness and behavior. Finally, the hypothesized relation between self-reported mindfulness and LPP amplitudes to fearful facial expressions during the passive viewing task was not found. Though not all hypotheses were supported, these findings extend research on the neural correlates of mindfulness and promote our understanding of how individual differences in mindfulness contribute to social emotion regulation.

Summary of Results

The present study is the first to my knowledge that demonstrates a relation between dispositional mindfulness and the N100. Assessment of ERPs during the Emotional Go/No-Go task revealed that mindfulness predicted more negative N100, an ERP component previously linked to early top-down deployment of attentional resources (Ruz et al., 2012). Though some research has found an emotional modulation of the N100 component (Luo et al., 2010), emotional facial expression did not modulate the N100 in the present study. Additionally, there were no differences in N100 amplitude for Go versus No-Go stimuli across the sample. Dispositional mindfulness moderated N100 amplitude for all conditions and stimulus types, suggesting greater allocation of attention to the task generally. Further, this relation between dispositional mindfulness and the N100 remained significant after controlling for either attentional control or personal distress, suggesting mindfulness distinctively impacts early attentional allocation. The fact that mindfulness remained significant after controlling for the tendency to reactively “catch” others’ distress in social situations (personal distress), together with empirical support that dispositional mindfulness promotes enhanced emotion regulation (e.g., Hill & Updegraff, 2012), indicates it is unlikely that this enhanced early attention is maladaptive to emotion regulation. It is important to address why dispositional mindfulness may have been a stronger predictor of N100 amplitude for those lower in state mindfulness during the task. One explanation for this finding is simply that there was less variability in attention to be explained by dispositional mindfulness for participants high in state mindfulness during the task. Together, these findings suggest that heightened mindful attention influences processing very early (< 200 ms post-stimulus onset), and provide empirical support for theoretical accounts of mindfulness as a process involving heightened attention to moment-by-moment experience (Brown & Ryan, 2003; Kabat-Zinn, 1990). Perhaps the N100 serves as one neurophysiological mechanism for such present-oriented, heightened attention.

Individual differences in mindfulness were also evident slightly further "downstream", in the N200, between 200 and 350 ms post-stimulus. Though I hypothesized a relation between mindfulness and No-Go N200 in particular, mindfulness was a significant predictor of both the No-Go N200 (at Cz) and the N200 (Fz, FCz, and Cz) more generally. The N200 may be an index of early deployment of attention generally and, in the context of social stimuli, more negative N200 may reflect more individuated processing of faces (e.g., Kubota & Ito, 2007). Thus, these findings provide further support that dispositional mindfulness is related to greater selective attention, and may also promote more individuated processing of facial expressions. Regarding the No-Go N200, the association between dispositional mindfulness and more negative amplitudes indicates that mindfulness involves greater conflict monitoring of the prepotent Go response (Donkers & Van Boxtel, 2004; Nieuwenhuis et al., 2003). As with the N100, this is the first study to demonstrate an association between dispositional mindfulness and the amplitude of this early ERP component. Moreover, these relations held after controlling for attentional control and personal distress. That mindfulness is related to greater conflict monitoring provides support for theories that mindfulness promotes ongoing monitoring of internal and external stimuli (Brown et al., 2007), including one's own cognitive processing.

Following Brown et al.'s (2012) findings of an attenuated LPP for high arousal unpleasant stimuli, I expected to find an association between self-reported dispositional and state mindfulness and unpleasant social stimuli (fearful facial expressions). However, there was no main effect of stimulus condition in the present study, indicating that the LPP was not sensitive to the valence of social stimuli. This stands in contrast to a previous study that found greater LPP for fearful facial expressions selected from the same stimulus set used in the present research (Smith, Weinberg, Moran, & Hajcak, 2012), as well as other studies which have found the LPP to be sensitive to valence of facial expressions (for a review, see Hajcak et al., 2010). Further, and in contrast to expectations, the only significant association was a relation between state mindfulness and *greater* LPP amplitudes to all stimulus types. On one hand, heightened LPP amplitudes with state mindfulness might suggest greater evaluation to facial expressions. However, since state mindfulness was assessed immediately following the passive viewing task, a task involving limited demands on attention, LPP may instead reflect gross differences in spatial attention to the facial expressions (e.g., Keil, Moratti, Sabatinelli, Bradley, & Lang, 2005). In other words, individuals lower in state mindfulness may not be selectively attending to the facial expressions adequately to evoke a larger LPP. Perhaps insufficient spatial attention to stimuli in the passive viewing task also explains why there was no emotional modulation of LPP in the present study.

The task behavioral results demonstrated that dispositional mindfulness predicted faster discrimination of facial expressions. Mindfulness remained significant after controlling for personal distress, suggesting that mindfulness promotes faster RT in a manner distinct from factors involving maladaptive heightened sensitivity to others facial expressions (e.g., social anxiety). Moreover, faster RT associated with mindfulness was not explained by tradeoffs in accuracy. Together these results suggest that mindfulness facilitates discrimination of others' emotional facial expressions in a manner likely to support adaptive social behavior that is timely, but not at the expense of accuracy or one's own level of distress. In contrast to expected findings, mindfulness was not linked to greater inhibition of prepotent responses on the Emotional Go/No-Go task. This lack of association is inconsistent with some previous research (e.g., Josefsson & Broberg, 2011) demonstrating a relation between dispositional mindfulness and executive control, but consistent with a different study that did not find such a relation (Galla et al., 2011). Nonetheless, mindfulness was linked to higher conflict monitoring of prepotent Go responses, as indexed by higher No-Go N200 (Nieuwenhuis et al., 2003). Though a relation between No-Go N200 and FAs was expected, failure to find this association is consistent with another study that examined individual differences in No-Go N200 amplitude (Amodio, Jost, Master, & Yee, 2007). This indicates that individual differences in No-Go N200 may not be related to actual inhibition of prepotent behavioral responses, but instead reflect detection of conflict between behavioral tendency and task demand more generally (Nieuwenhuis et al., 2003).

Towards an Understanding of Mindful Emotion Regulation in Social Contexts

Recent models of emotion regulation emphasize the importance of allocation of attention shortly following stimulus onset. More specifically, early attention biases to emotional stimuli have been construed as part of emotion regulation, underscoring the relevance of differential early attentional processing to emotion regulation broadly (Todd et al., 2012). Further, the process-specific timing hypothesis of emotion regulation (Sheppes & Gross, 2011) highlights the interplay between emotion and attention occurring early (< 1 sec.) following an emotional event. This theory suggests that more “upstream” deployment of top-down attention may be less effortful and thus more adaptive than regulatory strategies occurring later. Thus far, the process-specific timing hypothesis has focused on early strategies of distraction or attentional avoidance (Sheppes & Gross, 2011). However, data from this study contributes to a growing body of literature (e.g., Brown et al., 2012; Vago & Nakamura, 2011) that suggests a third early regulation strategy, markedly different from distraction and avoidance. Specifically, the present study suggests an emotion regulation "strategy" involving greater, rather than less, allocation of attentional resources to affective stimuli. Critically, this early heightened attention appears distinct from the vigilance of personal distress, a variable characterized by distress contagion in social contexts. Nonetheless, future research should develop more precise understanding of ways that mindfulness promotes early attention to social stimuli in a manner distinct from the heightened early attention that characterizes anxiety (Bar-Haim et al., 2007).

Though N100 amplitudes did not predict RT on Go trials, previous research suggests that N100 may reflect a discrimination process within the focal point of attention (Vogel & Luck, 2000). More negative N100 amplitude did predict fewer FAs, consistent with its role in discrimination between different types of facial expressions. While dispositional mindfulness did not predict fewer FAs, it did predict faster discrimination (RT) without comparable decreases in accuracy (i.e., no speed-accuracy tradeoff). Perhaps faster discrimination among more mindful individuals was due in part to less interference by nontargets on RT. How might such faster discrimination of others' emotional facial expressions support social emotion regulation? Discrimination awareness makes information flexibly available to serve as input for a broad range of processes (Grossenbacher & Quaglia, in preparation). More specifically, discrimination of others' emotional facial expressions may contribute to improved emotion regulation in social contexts, through making another's emotions available to inform behavior that is both timely and appropriate (Tottenham et al., 2011). Indeed, differing patterns in speed and/or accuracy for discriminating emotional facial expressions have been related to distinct patterns of behavior in social situations (Tottenham et al., 2011). For example, on an Emotional Go/No-Go task, adolescence has been linked to more rapid discrimination of target stimuli but less ability to withhold task-inappropriate responses to affective facial expressions (Tottenham et al., 2011). The rapidity of discrimination (RT) for emotional facial expressions is therefore an important index for understanding the speed at which information becomes available to inform and guide conscious social behavior in the presence of others' emotions. The pattern of results in the present study suggest that more mindful individuals are faster to discriminate others' emotions while maintaining a normative level of withholding task-inappropriate responses.

Limitations and Future Directions

The present study had several limitations that are important to address. First, emotional modulation of ERP components (LPP) and behavior (RT) found in similar previous research (e.g., Hajcak et al., 2010; Hare et al., 2005; Smith et al., 2012) were not found in the present study. This constrained analysis of mindfulness as a moderator of automatic response tendencies (e.g., approach vs. withdrawal orientation). An influence of emotion consistent with previous research was evident in number of FAs, such that there were less errors of commission for fearful nontargets (Hare et al., 2005). The exact reason for the lack of typical emotional responses to emotional facial expressions is unknown, since stimuli from the same stimulus set (NimStim; Tottenham et al., 2009) produced reliable responses in previous research (Hare et al., 2005; Smith et al., 2012). Second, findings from this study are correlational, and although I controlled for attentional control and personal distress, results could be due to a variable correlated with mindfulness that was not assessed. Future research should experimentally manipulate mindfulness (e.g., mindfulness training) to better discern whether mindfulness causes these differences in neural and behavioral responses. A third limitation of the present study is that all participants were Caucasian. Though this homogeneity of participants facilitates investigation of some questions related to mindfulness (e.g., mindfulness as a moderator of neural and behavioral responses to racial outgroups), it does limit generalizability of the present findings. Investigating neural and behavioral responses across a more diverse sample should be a goal of future research on mindfulness and social emotion regulation.

Conclusion

Previous research has demonstrated that dispositional mindfulness is related to differential neural response to high arousal pleasant and unpleasant imagery less than 1 s after stimulus onset. The present research found that dispositional mindfulness predicted neural activity even earlier, evident in distinct ERP components (N100, N200, No-Go N200) less than 300 ms after stimulus onset. Further, dispositional mindfulness predicted faster discrimination of emotional facial expressions without decrements in accuracy. These findings highlight the importance of individual differences in mindfulness to understanding basic processes of social emotion regulation, including the potential adaptive role of early attentional allocation to others' emotions. This knowledge may inform basic and applied questions in social, cognitive, and clinical psychology and neuroscience pertaining to mindfulness, emotion regulation in social contexts, and the contributions of social emotion regulation to mental health.

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Appendix A

Table 6.

Summary of LPP at CPz, Response Time Variability, and False Alarm Results

	Outcome		
	LPP	RT Variability	FAs
	b (SE)	b (SE)	b (SE)
FFMQ Act with Awareness Model			
FFMQ Act	.80 (.57)	-.16 (.18)	.20 (.49)
SMAAS	1.64* (.80)	-.10 (.08)	-.07 (.53)
MAAS Model			
MAAS	.41 (.43)	-.14 (.33)	-.13 (.37)
SMAAS	.86 (.74)	-.26 (.47)	-.45 (.53)

Note. * $p < .05$; FFMQ = Five Factor Mindfulness Questionnaire; MAAS = Mindful Attention Awareness Scale; SMAAS = State Mindful Attention Awareness Scale

Vita

Jordan T. Quaglia was born in Victoria, TX on October 5, 1985. He earned his B.A. from the University of Richmond in 2008 (Magna Cum Laude), with an interdisciplinary major in Positive Organizational Leadership. In 2011, he graduated with an M.A. from Naropa University where he studied counseling psychology. In 2010 and 2011, Jordan was invited to present at the United Nations Day of Vesak Conference on scholarly work pertaining to contemplative training, psychology, and neuroscience. He is currently pursuing his PhD in Social Psychology at Virginia Commonwealth University, under the direction of Dr. Kirk Warren Brown. His research examines relationships between attention, emotion regulation, and social cognition, with a particular focus on mindfulness and contemplative mental training. In 2012, Jordan received a Francisco J. Varela Award from the Mind and Life Institute to investigate the effect of mindfulness training on neural, behavioral, and real-world indicators of emotion regulation in social contexts.