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A Neural Correlate of Mindful Acceptance? Relating Individual Differences in Dispositional Acceptance to Error Processing

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Abstract

Mindfulness is a multi-faceted construct that can be defined with more precision via a two-component model that includes self-regulated attention and an accepting orientation towards one's experiences. Many of the observed benefits of mindfulness are associated with the orientation of acceptance, which is characterized by having less reactivity and judgment of one's experiences and may be particularly relevant to the processing of errors, as errors often enlist cognitive and affective responses. Error processing is a system that involves detecting errors and adjusting behavior adaptively to prevent future errors. Error processing can be measured in the brain and thus could be a potential neuromarker related to acceptance. The present study examined the relation between individual differences in dispositional mindful acceptance and error processing as measured by the amplitude of Error-Related Negativity (ERN), in a nonclinical population. Adults completed a Go/No-Go (GNG) task while their performance was monitored with an electroencephalogram (EEG) in order to capture the ERN, a measure of error processing, as well as the co-occurring behavioral responses of response inhibition. Dispositional mindful acceptance was measured by the nonreactivity and nonjudging subscales of the Five Facet Mindfulness Questionnaire (FFMQ). EEG results indicate that nonreactivity correlated with a smaller ERN, and behavioral results indicate that higher acceptance correlated with faster reaction time, without any trade-offs in accuracy. Overall, these findings suggest that individuals who are higher in dispositional mindful acceptance may be able to process errors and competing responses with less neural activity while still reaching the same behavioral response. Given that there are minimal ways of assessing acceptance and the benefits associated with acceptance, the presence of these neural and behavioral correlates of acceptance may be critical in informing the clinical research of mindfulness interventions.

A NEURAL CORRELATE OF MINDFUL ACCEPTANCE? RELATING INDIVIDUAL
DIFFERENCES IN DISPOSITIONAL MINDFUL ACCEPTANCE TO ERROR PROCESSING

by

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B.A., College of Wooster, 2013

Thesis

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Table of Contents

Abstract	i
Title Page	ii
Copyright Notice	iii
Table of Contents	iv
Body of Text	1
Appendix	36
References	38
Vita	50

A Neural Correlate of Mindful Acceptance?

Relating Individual Differences in Dispositional mindful acceptance to Error Processing

Mindfulness

Since the 1990s mindfulness has increasingly been adopted by Western health service professionals with a core intention of integrating secular meditation practices with modern therapy. Empirical evidence suggests that practicing mindfulness may result in a myriad of benefits, including improved attention and quality of life, and reduced stress, pain, unpleasant affect, racing thoughts, rumination, anxiety, depression, and ADHD symptoms (De Vibe et al., 2017; Andreu et al., 2017; Hofmann, Sawyer, Witt, & Oh, 2010). Although empirical evidence supports the claim that mindfulness-based interventions may lead to benefits in multiple domains, several outstanding research questions regarding the empirical study of mindfulness remain unanswered. One of the areas that is in need of further scientific inquiry involves defining the very construct of mindfulness, and more specifically, identifying objective fundamental measurable components of this multifaceted construct (Dimidjian & Linehan, 2003; Grabovac, Lau, & Willett, 2011). Approaching mindfulness in this way may also help identify the very mechanisms by which benefits are achieved in clinical contexts.

Mindfulness as a whole can be succinctly defined as “the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment” (Kabat-Zinn, 2003, p.145). This broad definition of mindfulness can be specified via a two-component model that includes self-regulated attention and an accepting orientation towards one’s experiences (Bishop, 2004). While self-regulated attention has been studied extensively in the literature and has biomarkers such as working memory, acceptance has not been examined as closely and there are currently limited modes of

assessing acceptance. An accepting orientation can be described as an attitudinal quality of acceptance that consists of responding deliberately rather than automatically, and without judging experiences as being “good” or “bad.” This ability to accept experiences without judgement and reactivity is an integral piece of mindfulness training and is theorized to be a critical element that, in turn, leads to observable health benefits. For example, the significant role of acceptance has been highlighted by Lindsay and Creswell (2019) in their Monitor and Acceptance Theory (MAT), which posits that attentional monitoring is only associated with therapeutic benefits when accompanied by acceptance (Lindsay, Young, Smyth, Brown, & Creswell, 2018).

The role of acceptance in mindfulness can be further understood by analyzing correlates of attention in the presence and absence of acceptance. Heightened attention to emotions without acceptance is associated with increased psychological distress, while heightened attention with high acceptance leads to better recognition and management of thoughts and emotions (Desrosiers, Klemanski, & Nolen-Hoeksema, 2013; Coffey, Hartman, & Fredrickson, 2010; Mor & Winquist, 2002). Furthermore, acceptance alone is correlated with lower rumination and higher emotion regulation, whereas attention is not correlated with these (Coffey et al., 2010; Evans & Segerstrom, 2011). In addition, substance use is higher in individuals with heightened observations of internal experiences, but acceptance moderates this relation such that higher levels of acceptance reverse the direction of this relation (Eisenlohr-Moul, Walsh, Charnigo, Lynam, & Baer, 2012). In sum, although attention monitoring alone reduces psychological well-being, attention monitoring with an attitudinal quality of acceptance is associated with better psychological well-being and reduced maladaptive behavior.

Given that acceptance appears to play an important role in attention and well-being, it is important to understand the specific neural mechanisms of acceptance that may be directly related to other observed benefits. This might allow for the identification of neurological markers of individual differences that are implicated in the relation between acceptance and the benefits of mindfulness practices. To this end, it is therefore important to first operationalize the construct of acceptance. Acceptance can be measured at both the state and the trait, or dispositional, level, with state representing a temporary characteristic of an individual in the moment that is expected to fluctuate, and dispositional representing a person's mindfulness as an enduring personal attribute over time (Kiken, Garland, Bluth, Palsson, & Gaylord, 2015). Here the focus is on dispositional measures as the goal is identifying an intrinsic, stable marker of acceptance. Dispositions of acceptance can be measured by the Five Facet Mindfulness Questionnaire (FFMQ) (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006), a self-report questionnaire, in which mindfulness is defined by five distinct subordinate components. These 5 facets include: observing, describing, acting with awareness, nonjudging, and nonreactivity. Acceptance, as defined in this widely utilized scale, is operationalized as a combination of the nonjudging and nonreactivity facets of the FFMQ (Baer et al., 2006; Lindsay & Creswell, 2019), such that acceptance involves letting experiences be as they are without judging or criticizing (i.e., nonjudging facet), and without impulsive reactions (i.e., nonreactivity facet).

Acceptance is characterized by lessened reactions and judgments to internal and external stimuli at both the affective and cognitive levels. This ability to be fully aware of one's present moment experience with equanimity and letting experiences unfold without reacting or judging may be especially important in the context of error monitoring (Teper & Inzlicht, 2013; Andreu et al., 2017). Error processing is a system that involves detecting errors and adjusting behavior

adaptively to prevent future errors (Holroyd & Coles, 2002). For example, errors often enlist affective responses, including negative evaluation, anxiety, frustration, and negative affect (Inzlicht, Bartholow, & Hirsh, 2015). Nonreactivity, a key facet of acceptance, can lead to a “non-grasping” state, and this reduced attachment may be significantly related to reduced emotional reactivity (Lutz, Slagter, Dunne, & Davidson, 2008). This ability to accept one’s self from emotions as transient, nonthreatening psychological events (e.g., “I feel frustrated. I made a mistake, which is ok, and I will continue on with the task”) should play an important role in the process of monitoring and reacting to errors.

Error Processing

Currently, methods for testing dispositional mindful acceptance are limited to self-report measures. While these measures have good reliability and validity (Baer et al., 2006), they also have limitations, including potentially biased responding, age and cognitive restraints, items that can be misinterpreted, and item structures that do not replicate across all cultures (Bergomi, Tschacher, & Kupper, 2013). Additional significant shortcomings include diversity among scales, such that measures of acceptance include varying items depending on how the developer of the scale conceptualizes mindfulness and acceptance, and as such scales are variable and do not always strongly correlate (Grossman, 2011). Without a singular conceptualization of acceptance, the ability to correctly detect individual levels of acceptance as well as compare findings across acceptance studies is limited. Furthermore, mindful acceptance inherently includes a component of self-awareness and perception, and this may alter the essence of how questions are responded to on such scales. As people become more self-aware they sometimes rate themselves lower on mindfulness scales (Grossman, 2011).

Given the benefits associated with acceptance and the limitations of self-report forms, it would advance the field of contemplative science to find a neuromarker that is related to acceptance, and error processing may be one such component. This process may be uniquely related to one's dispositional mindful acceptance and could consequently be a useful clinical tool that could aid in measuring changes in dispositional mindful acceptance following mindfulness interventions. Unlike self-regulated attention, there are no biomarkers for acceptance yet.

Electrophysiology

Neurological activity related to error processing can be directly studied by having individuals engage with a computerized task that elicits errors, and simultaneously recording neural activity using an electroencephalogram (EEG). EEG is a noninvasive test that involves placing electrodes on an individual's scalp. The electrodes measure the summations of postsynaptic potentials of groups of cortical pyramidal neurons in superficial brain structures (Kirschstein & Köhling, 2009). While fMRI can also capture neural activity during error processing, EEG is the best tool for capturing electrical activity in the temporal domain because of the speed at which electric signals occur (Luck, 2014). This temporal precision is critical for capturing Event-Related Potentials (ERPs), which measure the electrophysiological responses to a specific event. ERPs are waves that are specifically time-locked to an event, such as the event of making an error. Oftentimes electrical activity unrelated to the ERN (i.e., "noise") contaminates the EEG signal in the form of non-physiological artifacts such as electronic equipment nearby, and physiological artifacts such as blinking and other motor movements. Given that these artifacts are likely to occur during EEG acquisition, each participant typically completes at least 50 to 100 trials, or repetitions, of each task, which are then averaged to form an ERP wavelength

for each participant. These wavelengths are then averaged across participants to form the Grand Average ERP wave.

The ERN

Components are specific ERP waves that have been identified to be related to a specific function, over years of confirmatory research. One ERP component that may be particularly important to understanding the role that acceptance plays in the benefits of mindfulness is the Error-Related Negativity (ERN). The ERN is measured in cognitive tasks where participants make errors (Gehring, Coles, Meyer, & Donchin, 1990). Researchers have consistently found that about 100ms after people make errors on cognitive tasks, they exhibit an ERN. The ERN component is a negative-going wave (i.e., a negative deflection) that directly reflects the brain's signal of error processing. The ERN is hypothesized to be predominately generated by the dorsal Anterior Cingulate Cortex (ACC), and lesions in this region lead to inconsistent error processing (Gehring, Liu, Orr, & Carp, 2011; Stemmer, Segalowitz, Witzke, & Schönle, 2004; Bush, Luu, & Posner, 2000).

There are multiple computerized tasks that can be used to elicit the ERN, and one such task is the Go/No-go (GNG). In a typical GNG paradigm, there are frequent Go trials of easy responses (e.g., press a button when you see an "X" on the screen) and less frequent, No-go trials that require inhibiting responses (e.g., withhold pressing buttons when seeing an infrequently presented "O" on the screen). Mistakes of commission (i.e., incorrectly pressing the button when the behavioral response should have been inhibited) result in an ERN (Luck, 2014). More negative ERN amplitudes are often associated with fewer errors on such tasks, and consequently a more negative deflection is presumed to reflect heightened neural activity related to performance monitoring. Individual differences in the negative deflection of the ERN have been

observed in correspondence with different traits. For example, a more negative ERN corresponds with an improved ability to cope with stress via reduced cortisol reactivity (Compton, Hofheimer, & Kazinka, 2013).

Response Inhibition

In addition to electrophysiological data, the behavioral responses on the GNG task can be analyzed as measures of response inhibition. Errors of commission on No-go trials are thought to represent response inhibition, errors of omission on Go trials are thought to represent behavioral execution as well as lapses in attention, and reaction time on Go trials have been conceived as a factor of vigilance, decision making, and response initiation (Schulz, Bédard, Czarnecki, & Fan, 2011; Torpey, Hajcak, Kim, Kujawa, & Klein, 2012; Wright, Lipszyc, Dupuis, Thayapararajah, & Schachar, 2014; Hughes, Velmans, & De Fockert, 2009). While all three measures can be used, the most common behavioral measure extracted from the GNG task is the rate of commission errors (i.e., response inhibition).

Response inhibition is a component of executive functioning that involves the ability to deliberately withhold a response. This type of response inhibition has been shown to mediate the relation between mindfulness training and adaptive socioemotional functioning (Sahdra et al., 2011) and mindfulness is generally associated with better inhibitory control (Gallant, 2016). Higher dispositional mindful acceptance may be associated with enhanced inhibition, such that people higher in mindful acceptance are less likely to have automatic reactions than those who report relatively less trait mindfulness. This may consequently lead to more efficient error processing, meaning that one is attentive to errors, and behavior is consequently adapted with less internal distractions, such that there are fewer overall errors and the speed of one's response is quicker. Paul and colleagues (2013) found that participants higher on the nonreactivity

subscale of the FFMQ had less overall rumination and stress, slower respiration during stress tasks, and better inhibition accuracy, especially for negative images on a GNG task consisting of faces with a range of valenced expressions (Paul, Stanton, Greeson, Smoski, & Wang, 2013). Furthermore, researchers have found that after mindfulness training, individuals exhibit enhanced inhibitory performance as measured by better accuracy on a Stroop task (Teper & Inzlicht, 2013; Moore & Malinowski, 2009), Response Inhibition Test (RIT) (Sahdra et al., 2011), and Hayling task (Heeren, Van Broeck, & Philippot, 2009; Gallant, 2016). These three tasks measure response inhibition in paradigms that contrast easy, automatic responding (i.e., label the color of a blue word; complete a sentence; press a button when seeing a frequently presented long line) with more difficult inhibitory responding (i.e., label the color when the word “blue” is presented in red letters; complete a sentence nonsensically; inhibit pressing a button when seeing a rarely presented short line). In sum, a GNG task allows for the study of both error processing at the neural level, measured via the ERN, as well as behavioral measures (e.g., task accuracy and reaction time) of response inhibition, and it’s expected that both the neural and behavioral indices may relate to dispositional mindful acceptance.

Mindfulness and the ERN

Multiple studies have looked at the ability to actively change the ERN in clinical and nonclinical populations via forms of mindfulness training. A few studies measured the ERN immediately before and after participants participated in a brief 14-minute mindfulness induction as compared with a control, such as listening to a psychoeducation recording (Saunders, Rodrigo, & Inzlicht, 2016; Larson, Steffen, & Primosch, 2013). Extant literature indicates that this dosage of mindfulness is not powerful enough to alter the ERN (Larson, Steffen, & Primosch, 2013; Bing-Canar, Pizzuto, & Compton, 2016), except when the meditation is emotion-focused

(Saunders, Rodrigo, & Inzlicht, 2016). Saunders and colleagues found that the ERN was significantly more negative after a 14-minute emotion-focused meditation, while a thought-focused meditation did not change the ERN. In their study, both groups did breathing exercises and sensory awareness, and were then instructed to focus on internal emotions or thoughts and then describe an affective picture with an emphasis on either emotions or thoughts, depending on condition. Other clinical trials implemented a higher dosage of 3-12 week interventions, of which two studies (Fissler et al., 2017; Smart & Segalowitz, 2017) demonstrated enhanced error processing as indicated by a more negative ERN, whereas another study (Schoenberg et al., 2014) did not find this link. These studies covered a broad range of targeted clinical populations and varied dramatically in their dosage and type of mindfulness training. The inability to consistently find changes in the ERN with mindfulness training may also be attributed to the use of different scales to measure mindfulness, of which the emphasis on acceptance varies, and awareness and acceptance facets of mindfulness may affect error monitoring differentially. Additionally, extant studies have not defined the interventions with reference to the amount of activities that were more acceptance versus awareness based, but rather describe interventions in general terms.

Other studies have begun to specifically research associations between neural signals of error processing and the acceptance qualities of dispositional mindfulness using cross-sectional designs. Teper and Inzlicht (2013) and Andreu et al. (2017) compared meditators with a control sample on the ERN during cognitive tasks. Both research teams found that the ERN was more negative for meditators, and meditators had significantly higher scores on self-reported acceptance than a comparison group but did not differ on any other facets of mindfulness, including their awareness of their experiences, their tendency to observe their sensations, and

their ability describe their current experience in words. Acceptance in these studies was measured by Andreu and colleagues (2017) via the nonreactivity and nonjudging facets of the FFMQ and by Teper and Inzlicht (2013) by the acceptance facet of the Philadelphia Mindfulness Scale (Cardaciotto, Herbert, Forman, Moitra, & Farrow, 2008). The results suggest that the change in ERN amplitude (i.e., a more negative ERN reflecting enhanced performance monitoring) is driven by increases in the ability to monitor affective states with nonjudgment and nonreactivity. Emotional acceptance mediated the relation between meditation experience and ERN amplitude (Teper & Inzlicht, 2013), indicating that the link between meditation and the ERN can be partially explained by acceptance. Across all participants (e.g., both mindful and controls), higher acceptance was correlated with a more negative ERN (Teper & Inzlicht, 2013). Bailey and colleagues (2018) attempted to replicate these findings but found no differences in the ERN between meditators of 2 or more years with a comparative control group. In order to determine whether subjective perceptions of errors correlated with the ERN, they specifically looked at two error-related items from the Freiburg mindfulness inventory (FMI) (Walach, Buchheld, Buttenmüller, Kleinknecht, & Schmidt, 2006), “I see my mistakes and difficulties without judging them” and “I am friendly to myself when things Go wrong.” They found that meditators scored significantly higher on both of these items, indicating a more accepting orientation toward error commissions, but this was not reflected in the ERN.

Research suggests that dispositional mindful acceptance may be related to neurological indices of error processing, and specifically a more negative ERN. However, these results are not unanimous, and one factor that may work to explain this is that there may be individual differences in dispositional mindful acceptance and ERN activity, irrespective of mindfulness training, which has not yet been researched. Therefore, an important next step is to understand

how individual differences in acceptance relate to error processing in a non-clinical population irrespective of mindfulness training. Understanding the individual differences in acceptance will help inform our current understanding of how acceptance may uniquely alter neurological indices of performance monitoring. Previous researchers that looked at acceptance were unable to randomize groups due to recruiting half of their participants from mindfulness centers and half control participants without meditation experience. While they did perform correlational analyses, correlational approaches within this context cannot distinguish between individual differences in those who actively choose to meditate, with those who don't meditate. In other words, they may have found that acceptance is higher in meditators because those gravitating towards contemplative practices are naturally more open and accepting (i.e., higher dispositional mindful acceptance) and consequently have a larger ERN. This correlation might further be characterized by acceptance that has been 'trained' via mindfulness, which may look different from acceptance that is 'innate' to an individual at the dispositional level. Therefore, while Teper and Inzlicht (2013) and Andreu and Colleagues (2017) found higher acceptance and a more negative ERN in meditators, and Teper and Inzlicht (2013) found a correlation between acceptance and the ERN, it is also important to examine what acceptance and the ERN look like in a non-clinical population that isn't a split sample of trained meditators and control participants.

Not all previous studies on the ERN and mindfulness controlled for psychopathology (Saunders et al., 2016; Teper & Inzlicht, 2013). This is important because psychopathology, especially along the internalizing and externalizing dimensions, has been shown to alter the ERN (Olvet & Hajcak, 2008). For example, substance use disorder (SUD) and ADHD (Herrmann et al., 2010; Schoenberg et al., 2014) tend to correspond with a less negative ERN, whereas

Obsessive Compulsive Disorder (OCD) (Gehring, Himle, & Nisenson, 2000) and anxiety (Hajcak, McDonald, & Simons, 2003; Ladouceur, Dahl, Birmaher, Axelson, & Ryan, 2006) are known to be associated with a more negative ERN. Taken as a whole, different forms of psychopathology may alter ERN amplitudes, and as such it is important to control for psychopathology when studying the ERN.

Current Study

Due to the confounding nature of psychopathology and the ERN, participants with high levels of general psychopathology were screened out from analyses. To this end, participants filled out the Adult Self-Report (ASR), a measure of psychopathology, and those falling within the clinical range on the total problems scale, internalizing scale, and externalizing scale were removed from analyses. These three scales should account for psychopathology that may alter the ERN, as they include subscales that query about substance abuse, ADHD, depression, and anxiety.

The current study examined error processing via the ERN on a GNG task, as well as the co-occurring inhibitory behavioral responses. Dispositional mindful acceptance was measured by self-reported nonreactivity and nonjudging subscales of the FFMQ, along with the standardized sum of these two subscales, which form a third variable that represents a broader acceptance disposition. The FFMQ was chosen because it is a psychometrically valid and reliable form of measuring dispositional mindfulness and its ubiquity in mindfulness research makes it easy to compare with other research results in this field (Felder et al., 2018). Furthermore, while it consists of questions that may be interpreted differently by meditators and nonmeditators, when comparing young adult meditators with nonmeditators, FFMQ scores are negatively correlated with dissimilar constructs such as worry, rumination, and thought suppression, indicating that the

FFMQ is a reliable indicator of mindfulness even in people with minimal mindfulness exposure (de Bruin, Topper, Muskens, Bögels, & Kamphuis, 2012; Baer et al., 2008; Baer, Samuel, & Lykins, 2011). Thus, it is anticipated that the FFMQ is an adequate measure of dispositional mindful acceptance in a normative non-clinical population. Previous research has commonly used the FFMQ to qualify the acceptance component of mindfulness via the nonreacting and nonjudging facets (Smart & Segalowitz, 2017; Andreu et al., 2017). There are other measures of acceptance that are commonly used outside of the context of literature that seeks to define and operationalize facets of mindfulness but given that the goal here is to identify a measure of acceptance as a component of mindfulness, the FFMQ is appropriate.

The aim of the current study is to identify whether error processing is a neurophysiological and/or behavioral marker of dispositional mindful acceptance. To this end, the relation between individual differences in dispositional mindful acceptance was assessed in a non-clinical population in relation to the amplitude of the ERN. Two research questions were addressed in the current study. First, do individuals higher in dispositional mindful acceptance, a) commit less errors on the GNG task, indicating enhanced response inhibition, and b) have a more negative ERN amplitude, reflecting differences in neural performance monitoring?

Method

Participants

Data for this study were collected as part of a larger study examining the relation between ERP marker of attention and early psychopathic symptoms (Racer et al., 2011). Adult participants were recruited from the University of Oregon, and children recruited from the community in Eugene, Oregon. Participants completed five different computerized tasks, the Attention Network Task, Choose a Door, Go/No-Go, Oddball, and Picture Learning, in a

counterbalanced order, in addition to a battery of self-report forms. All procedures were reviewed and approved by the Institutional Review Board (IRB) at University of Oregon. The data with adults has not previously been reported on, and none of the present study's variables of interest, namely self-reported mindfulness and ERP amplitude and behavioral performance on the GNG task, have been previously analyzed or reported on. Participants were recruited through the psychology department research credit pool at the University of Oregon. Participants earned 1 class credit per hour of participation in the study. The sole inclusion criteria to sign up for the study was that the individual was 18 years of age or older at the time of the study. There were 44 undergraduate students that took part in the study.

To ensure that the majority of participants were in the nonclinical range for clinical disorders, the distribution of scores on the Adult Self-Report (ASR) were analyzed (Achenbach, Dumenci, & Rescorla, 2013). Externalizing problems, internalizing problems, and total problems scores can range from 50 to 100, with *T* scores below 60 classified as falling within the normal range, 60 to 63 classified as borderline clinical range, and 64 and above falling in the clinical range (Achenbach & Rescorla, 2003). In the current sample, *T* scores for externalizing problems ranged from 30 to 72 ($M = 51.82$, $SD = 9.01$), internalizing problems ranged from 32 to 73 ($M = 52.27$, $SD = 9.86$), and total problems ranged from 26 to 69 ($M = 51.80$, $SD = 7.88$). The majority of participants fell within the normal range. However, 2 participants scored in the clinical range for total problems ($T = 64$; 69), 2 participants scored in the clinical range for externalizing problems ($T = 65$; 72), 2 participants scored in the clinical range for internalizing problems ($T = 64$; 73), and 1 participant scored in the clinical range for both internalizing ($T = 65$) and externalizing problems ($T = 64$).

While scores on the ASR are not sufficient to indicate the presence of a disorder, internalizing and externalizing scales represent clusters of syndrome scales, and the total problems score is thought of as a global index of psychopathology (Achenbach & Rescorla, 2003). Therefore, the scores for these 7 participants suggest that they may be more likely to meet diagnostic criteria for a clinical disorder and consequently these 7 participants were screened out and removed from statistical analyses. The resulting 37 participants were 48.6% female, ages 18-47 years ($M = 21.92$, $SD = 5.79$), and 89.2% ($n = 33$) White, 2.7% ($n = 1$) Latino, 2.7% ($n = 1$) Black, and 5.4% ($n = 2$) Asian. Participants were all undergraduate or graduate students at the University of Oregon, 27% ($n = 10$) freshman, 37.8% ($n = 14$) sophomore, 18.9% ($n = 7$) junior, and 10.8% ($n = 4$) senior, and 5.4% ($n = 2$) graduate students. Six participants were left-handed and 31 were right-handed.

Measures

Five Facet Mindfulness Questionnaire (FFMQ). The FFMQ (Baer et al., 2006) was used to assess dispositional mindful acceptance. The FFMQ is a five-factor model of mindfulness developed from 613 participants' responses to current mindfulness measures, including the Mindful Attention Awareness Scale (MAAS), Freiburg Mindfulness Inventory (FMI), Kentucky Inventory of Mindfulness Skills (KIMS), Cognitive and Affective Mindfulness Scale (CAMS), and Mindfulness Questionnaire (MQ). The resulting full 39-item self-report questionnaire was used in the present study, with scores ranging from 1, "never or very rarely true" to 5, "very often or always true". The five domains include observing (e.g., "When I'm walking, I deliberately notice the sensations of my body moving"), describing (e.g., "I can usually describe how I feel at the moment in considerable detail"), acting with awareness (e.g., reverse scored item "I don't pay attention to what I'm doing because I'm daydreaming,

worrying, or otherwise distracted”), nonjudging (e.g., reverse scored item “I make judgments about whether my thoughts are good or bad”), and nonreactivity (e.g., “I watch my feelings without getting lost in them”).

Each factor score ranges from 8 to 40, with the exception of the nonreactivity factor, which ranges from 7 to 35. The total FFMQ score ranges from 39 to 195. FFMQ subsets have adequate to good internal consistency, with the following alpha values: nonreactivity = .75, observing = .83, acting with awareness = .87, describing = .91, and nonjudging = .87 (Baer et al., 2006). The FFMQ subsets have good convergent validity with similar constructs including openness to experience (.19-.42, $p < .001$), emotional intelligence (.21-.60, $p < .001$), and self-compassion (.14-.53, $p < .001$). Furthermore, it has good divergent validity with Alexithymia (-.19--.68, $p < .001$), Dissociation (-.27--.62, $p < .001$), Absent-mindedness (.16--.61, $p < .001$), Neuroticism (-.23--.55, $p < .001$), Thought suppression (-.16--.56, $p < .001$), Difficulties with emotion regulation (-.36--.52, $p < .001$), and Experiential avoidance (-.23--.49, $p < .001$) (Baer et al., 2006). The FFMQ has been demonstrated to have good predictive validity for general severity of psychological symptoms based on the *Brief Symptom Inventory* (BSI) (Derogatis, 1992) and the Depression Anxiety Stress Scales; correlations between FFMQ facets and psychological symptoms range from -.22 to -.63, $p < .01$ (Baer et al., 2008). Construct validity has been tested by comparing scores from meditators with non-meditators. Meditators scored significantly higher on nonreactivity ($t = 14.24$, $p < .0001$), observing ($t = 10.27$, $p < .0001$), describing ($t = 3.21$, $p < .001$), and nonjudging ($t = 5.62$, $p < .0001$), but not acting with awareness (Baer et al., 2008). Overall, the FFMQ has good psychometric properties, and is unique in its development of five factors that can be used to tap into different domains of mindfulness.

Go/No-go task (GNG). The go/No-go paradigm is a computerized task designed to juxtapose manual responses for one stimulus (go) and inhibited responses for another (No-go), which creates conflict when No-go stimuli are presented (Luck, 2014). This paradigm can be used to measure Error Related Negativity (ERN). In this task, a fixation cross appears at the center of the screen, followed by a series of Go (X) and No-go (O) stimuli presented for a duration of 200ms. Post-presentation of the stimulus, participants see a blank screen for 300ms, during which they can respond by pressing a key. Participants were instructed to press the “4” key when they saw the Go cue (X) and were instructed to withhold responding, or not press any key, when they saw the No-go cue (O). There were 3 blocks, with each block composed of 100 trials, for a total of 300 trials. Each block presented 80 X’s and 20 O’s. Participants were able to take breaks between each block.

Adult Self-Report (ASR). Participants completed the ASR (Achenbach & Rescorla, 2003), which is a 126-item self-report form that is used to help identify symptoms of psychopathology in adults ages 18-59. Participants responded to questions on a 3-point Likert scale, which included the options 0, “not true”, 1, “somewhat or sometimes true”, and 2, “very true or often true”). While the ASR assesses multiple domains of psychopathology, the scores utilized in the current study were internalizing problems, externalizing problems, and total problems. Internalizing problems includes the subscales: anxious/depressed, withdrawn, and somatic complaints. Externalizing problems includes the subscales: aggressive behavior, rule-breaking behavior, and intrusive. The total problems scale is the total of the internalizing and externalizing problems, in addition to thought problems, and attention problems, and substance use (i.e., tobacco, alcohol, and drugs).

Procedure

After informed consent was obtained, students completed the questionnaires and then were brought to the EEG laboratory. The GNG was one of several computerized tasks administered in counterbalanced order during the testing session. Participants were instructed to keep their gaze focused on the central fixation point throughout the task and to respond as quickly and accurately as possible.

EEG Data Processing and Analysis

Electroencephalographic (EEG) data were acquired using a 256-channel HydroCel Geodesic Sensor Net (GSN) (Electrical Geodesics Inc. [EGI], Eugene, OR). Data were analog filtered with a 0.01–100-Hz bandpass and then digitized at 250 Hz with a 16-bit A/D converter. Electrodes were referenced to the vertex (Cz) during acquisition. A 60-Hz notch filter was applied prior to the analysis of the EEG data. Using Net Station Software, EEG data were segmented into 800ms epochs from 200ms before to 600ms after the response, binned by correct and incorrect responses. Epochs were screened for eye blinks, eye movements, bad channels, and other noncephalic artifacts. Trials were then averaged to create the individual subject waveforms, which were then averaged across participants to determine the total grand-average waveforms for correct and incorrect responses. Grand-average waveforms were then exported from Net Station as a Tab Delimited Text file, and converted to a CSV UTF-8 Comma Delimited file in Microsoft Excel for graphing and analysis.

Based on previous research that the ERN typically occurs about 100ms or earlier, following a response, the time window used to extract the ERN component from the individual-subject waveforms was -50ms to 150ms, with the response locked at 0ms. The early window allowing the ERN to include data prior to 0ms was chosen because it is common for the ERN to begin slightly before the response is registered (Fissler et al., 2017). In addition to the ERN, the

Correct Response Negativity (CRN) and the change in ERN (Δ ERN) can also be extracted during this timeframe. Whereas the ERN is negativity in response to error commission, the CRN is a smaller negativity that occurs during correct trials (Gehring et al., 2011), and the Δ ERN is the difference between the ERN and CRN waveforms. The Δ ERN method is advantageous because it may reduce electrical activity unrelated to the ERN (Luck, 2014) whereas separately analyzing correct and error trials may include noise unrelated to the ERN.

The adaptive mean, a common extraction method used for the extraction of ERP amplitude (Clayson, Baldwin, & Larson, 2013), was used to measure the ERN, CRN, and Δ ERN. The adaptive mean gathers the mean amplitude centered around the peak latency per individual subject. The adaptive mean is more sensitive to variability in peak latency between subjects, thus representing the best estimate of the true ERP signal when there is wide variability in latency, however it may be more biased in capturing a peak that may not exist or capturing the wrong peak (Clayson et al., 2013). This said, most subjects only had one negative peak from -50 to 150ms. Given that there was considerable variability in latency, such that average latency at the FCz site ranged from -24 to 140ms ($M = 60.67$, $SD = 37.03$) for the ERN, and from -48 to 144ms ($M = 26.70$, $SD = 46.32$) for the CRN, the adaptive mean should be best suited for this dataset. Furthermore, when using a simulated model, Clayson et al. (2013) found the adaptive mean to be better than peak amplitude when considering biases of noise. The ERN was measured as the adaptive mean of the EEG amplitude between -50 and 150ms, for a 50ms window centered on the peak.

Electrodes in medial-frontal sites Fz, FCz, and Cz were selected for the quantification of the ERN component based on previous studies that consistently find that the ERN occurs in the medial-frontal scalp sites (Gehring et al., 2011). Both the adaptive mean amplitude from -50 to

150ms and the overall mean amplitude from 0 to 150ms were extracted at the Fz, FCz, and Cz sites for No-go trials. The average of each were calculated, and the most negative method and location was chosen. In this dataset, the adaptive mean at the FCz site was most negative, suggesting it is the best estimate of the ERN. The FCz was consequently used to quantify the ERN in all analyses, as defined by channel 8 on the 256-channel Sensor Net.

Data Analyses

Data were analyzed using IBM SPSS Statistics for Windows, version 23 (IBM Corp, 2015) and graphed using the ggplot2 package (Wickham, 2016) in R Studio (R Core Team, 2012). A one-way ANOVA was conducted between the adaptive mean for the CRN and ERN at the FCz location to ensure that the experimental manipulation was effective.

While multiple correlations were conducted, the overarching research question is to determine a behavioral and neurological neuromarker related to acceptance. My specific hypotheses are that trait acceptance will correlate with accuracy, reaction time, and the ERN. As such, family wise comparisons adjusted for these three hypotheses is 0.02 based on Bonferroni correction (i.e., .05 divided by 3, which is 0.017). Pearson's correlation coefficients were thus conducted with all analyses performed with significance at the 0.02 level.

Results

Behavioral Results

GNG performance. There were 300 total trials per participant on the GNG task, of which 240 (80%) were Go trials and 60 (20%) were No-go trials. Two participants did not complete all trials (i.e., one completed 165 Go trials and 41 No-go trials and the other completed 152 Go trials and 36 No-go trials) but were still included in analyses since they completed over half of each set of trials. Participants correctly inhibited responding on 19–56 out of 60 No-go

trials ($M = 41.67$, $SD = 9.48$), which corresponds to 32-93% ($M = 70.81\%$, $SD = 14.48$), and participants correctly pressed the button on 151-239 out of 240 Go trials ($M = 221.67$, $SD = 22.77$), which corresponds to 76-100% ($M = 94.14\%$, $SD = 6.30$). Stable estimates of the ERN require at least 4-6 commission errors and at least 30 participants, and the current study employed 37 participants with a commission error rate of 4-42 errors, which falls in this recommended range (Steele et al., 2016). Participants incorrectly withheld responding when they should have pressed the specified button (i.e., omission errors occurred) on 1-58 out of 240 trials ($M = 13.81$, $SD = 15.29$).

Mean reaction times for correctly pressing the button on Go trials ranged from 236.68-346.63ms ($M = 287.20$, $SD = 28.28$). Typically, trials are removed from analyses if they fall outside of the 200-1300ms range, but all of the data fell within this range. Reaction time on correct Go trials significantly correlated with accuracy on Go trials ($r = -0.43$, $p = 0.01$) and accuracy on No-go trials ($r = 0.42$, $p = 0.01$), indicating that quicker response times to Go trials were associated with better accuracy on Go trials, but worse accuracy on No-go trials.

Mindfulness scores. FFMQ total scores can range from 39 to 195. FFMQ total scores in the present study ranged from 112-164 ($M = 136.95$, $SD = 13.62$). The maximum range for the nonjudging factor is 8 to 40, and nonreactivity is 7 to 35. In the current sample, nonjudging ranged from 17-40 ($M = 31.35$, $SD = 6.19$), and nonreactivity ranged from 8-32 ($M = 21.36$, $SD = 5.42$). The total FFMQ score was statistically significantly correlated with nonreactivity ($r = 0.52$, $p < 0.001$) and trended towards a positive correlation with nonjudging ($r = 0.31$, $p = 0.07$), both subscales of the FFMQ. Nonjudging was not correlated with Nonreactivity ($r = -0.26$, $p = 0.13$). The acceptance variable was created by summing the standardized nonjudging and nonreactivity scores. Given that nonjudging and nonreactivity factors have different ranges, these

variables were first standardized by transforming them into z-scores in SPSS. Therefore, the following analyses include 3 variables that characterize dispositional mindful acceptance: nonjudging, nonreactivity, and acceptance.

Mindfulness and GNG performance. First, dispositional mindful acceptance as a whole and the corresponding subscales (nonjudging and nonreactivity) were correlated with behavioral performance on the GNG task. On the GNG task, reaction time can only be extracted from correct Go trials, as correct No-go trials are indicated by response omission. There was not a significant correlation between the reaction times in milliseconds on correct Go responses and nonreactivity ($r = -0.24, p = 0.17$). However, the correlation between reaction time and nonjudging trended toward significance ($r = -0.33, p = 0.05$), and reaction time was significantly correlated with acceptance ($r = -0.48, p = 0.003$), indicating that individuals higher in acceptance were significantly faster in their correct responses to Go trials, as presented in Figure 1. There were no statistically significant correlations between accuracy on the No-go trials or Go trials and nonreactivity, nonjudging, and acceptance. However, the correlation between accuracy on Go trials and acceptance trended toward significance ($r = 0.34, p = 0.05$).

ERP Results

ERN extraction. The ERN was defined as the grand average ERP waveform locked to error responses on No-go trials, and correct response negativity (CRN) defined as the ERP waveform locked to correct responses on Go trials. Correct and incorrect commissions are used here because a temporal behavioral response needs to be present to lock the waveforms to, whereas correct and incorrect omissions cannot be time-locked since they reflect a response that is withheld. Difference waves were computed between errors on No-go trials and correct

responses on Go trials to create the Δ ERN. All of the following analyses are based on the adaptive mean, which is the mean amplitude in the 50ms window around the most negative peak from -50 to 150ms in relation to the stimulus presentation, per participant. Figure 2 presents the amplitude on correct and incorrect trials on the GNG task, and the adaptive mean of the ERN is outlined in a black rectangle. The boxed section in Figure 2 includes two negative peaks, which occurred due to variability in latency of the ERN across participants. Since the adaptive mean was extracted per individual participant, only the single largest negative peak per participant was extracted for use in the following correlations.

ERN confirmation. In order to confirm that the ERN was significantly more negative than the CRN as expected based on the task manipulations, a one-way RM ANOVA was conducted between the adaptive mean for the CRN and ERN at the FCz location. The adaptive mean of the ERN was -4.39 and the CRN was -1.29 and these were significantly different, $F(1, 71) = 28.89, p < 0.001$, indicating that the ERN was significantly more negative than the CRN. The ERN was statistically significantly correlated with the CRN ($r = 0.67, p < .001$) and the Δ ERN ($r = 0.92, p < .001$). The latency of the ERN was statistically significantly correlated with the amplitude of the ERN ($r = -0.56, p < .001$), CRN ($r = -0.57, p < .001$), and the Δ ERN ($r = -0.41, p = .01$).

ERN and mindfulness. There were no statistically significant correlations between the ERN at the FCz site and the nonjudging FFMQ facet and the standardized sum acceptance variable. There was a statistically significant correlation between nonreactivity and the ERN ($r = 0.43, p = 0.01$), and the CRN ($r = 0.34, p = 0.04$) and Δ ERN ($r = 0.36, p = 0.03$) trended towards significance after alpha correction, indicating that higher mindful nonreactivity was associated with a less negative ERN, and trended towards a less negative CRN and Δ ERN (see Figure 3 and

Table 1). The latency of the ERN was not statistically significantly correlated with acceptance. However, the correlations between the ERN latency and nonjudging ($r = 0.28, p = 0.09$) and nonreacting ($r = -0.30, p = 0.08$) trended toward significance, indicating a trend towards an earlier ERN for those higher in nonreactivity and later ERN for those lower in nonreactivity, and a later ERN for those higher in nonjudging and earlier ERN for those lower in nonjudging.

ERN and behavioral performance on the GNG task. The ERN amplitude was neither statistically significantly correlated with reaction time on correct Go trials ($r = 0.03, p = 0.86$), accuracy on Go trials ($r = -0.13, p = 0.44$), nor accuracy on No-go trials ($r = 0.06, p = 0.75$). The latency of the ERN amplitude was not significantly correlated with reaction time on correct Go trials ($r = -0.18, p = 0.31$).

Partial Correlations. There is typically a reduction in the amplitude of the ERN in older adults relative to younger adults, though research is mixed (Friedman, Nessler, Cycowicz, & Horton, 2009; Gehring et al., 2011; Nieuwenhuis et al., 2002). In the present study, older participants have a less negative ERN ($r = 0.39, p = 0.02$). When controlling for age, the relation between nonreactivity and the ERN is still statistically significant, as indicated by the partial correlation, $r = 0.42, p = 0.02$. At the behavioral level, when controlling for age, the relations between acceptance and reaction time ($r = -0.49, p = 0.003$) is still statistically significant.

In addition to age, partial correlations were conducted to control for psychopathology in neurological and behavioral domains. While individuals who scored in the clinical range for internalizing, externalizing, and total problems on the ASR were removed from analyses, it is still possible that different levels of psychopathology in the nonclinical range may influence the relation between acceptance and the ERN as well as behavioral responses to the GNG task. As such partial correlations were run between nonreactivity and the ERN, controlling for

internalizing, externalizing, and total problems, $r = 0.42$, $p = 0.02$. When controlling for psychopathology in this same way, the partial correlation between acceptance and reaction time is $r = -0.47$, $p = 0.007$, which is still significant.

Discussion

Previous research has indicated that the ERN is more negative after participants engage in mindfulness interventions, and some studies have suggested that this change reflects an improvement in performance monitoring that may be best attributed to an enhanced ability to be nonreactive to one's emotions and nonjudgmental of one's present experience (Teper and Inzlicht, 2013; Andreu et al., 2017). In other words, mindfulness may lead to a more negative amplitude in the frontocentral region of the brain, signaling error monitoring, via being present without valenced attachment to one's experiences (Teper & Inzlicht, 2013). While research has demonstrated that acceptance is associated with a more negative amplitude of the ERN, this has only been studied in within-subject pre-post designs in the context of mindfulness trainings, and between subject analyses of meditators with a comparison group. The findings from these studies suggest the ERN may be naturally higher in people drawn to meditation, or there may be something about meditation training that uniquely alters the ERN, perhaps with participants learning techniques that closely mirror error monitoring processes. If the ERN is to be used as a measure of dispositional mindful acceptance in clinical trials, then it is important to first understand how the ERN relates to acceptance at the dispositional level, outside of the context of mindfulness training. Then we can more accurately understand differences before and after training. Thus, the present study sought to investigate whether individual differences in dispositional mindful acceptance are associated with a more negative ERN when investigated outside the context of mindfulness training.

Whereas previous studies involving meditators have found that nonreacting to current experiences is associated with a more negative ERN amplitude, the results of the present study suggest the opposite, that nonreactivity, as measured by the FFMQ, is correlated with a less negative ERN amplitude during a GNG task. There are several plausible explanations for why the neural activity of error processing is more negative in nonreactive meditators and post-mindfulness trainings (i.e., previous research), yet less negative in individuals with nonreactive dispositions outside of the context of mindfulness training (i.e., the current research). Operating under the assumption that a more negative ERN corresponds to better performance monitoring, one explanation is that meditation training uniquely alters acceptance in a way that is not occurring for those who do not engage in meditation. For example, meditation builds skills of self-monitoring one's thoughts, feelings, actions, and reactions that are similar skills to that of monitoring errors. As such, practicing self-monitoring skills may contribute to both higher acceptance and more neural activity of performance monitoring. Frequently monitoring one's experience in each moment, without judging or reacting to whatever happens (whether correct or erroneous) may uniquely alter the ERN in a way that's different from those high in acceptance who do not engage in mindfulness training. It has been previously hypothesized that meditation leads to acceptance which then leads to benefits in executive functioning (Teper, Segal, & Inzlicht, 2013), but it may also be that mindfulness leads to benefits in executive functioning which then lead to higher acceptance. Mindfulness training involves heightened awareness to internal and external stimuli and noticing one's natural tendencies to inhibit or respond impulsively, which may at first enhance inhibition and deliberation, enhancing executive control, and over time one learns to notice these tendencies openly without acting on them or judging them, ultimately encouraging tendencies of acceptance.

Participants in previous research were actively learning mindfulness or were meditators of a couple years, and therefore the quality of mindfulness may be differentiated from mindfulness at the enduring dispositional level. Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson (2007) found that the ACC might be activated when learning mindfulness and while in the early stages of mindfulness training. However, they found that ACC activation may decrease with considerable mindfulness experience, as one no longer has to put significant effort towards attention and focus, and rather has this implicit disposition. Thus, looking at dispositional mindful acceptance, we may find a decrease in neural activity. Applying this to reactivity, if one is early on in mindfulness training or frequently engaging in mindfulness exercises, then the ACC may be more activated because the individual is, a) focusing on attending to stimuli, and b) working hard to maintain a steady disposition on refocusing on the breath, and effortfully not reacting to external or internal stimuli, such as emotions. In other words, these processes may be more effortless at the dispositional level outside of meditation practice, which may manifest in a larger ERN in the context of training, but a smaller ERN at the dispositional level.

Results may be alternatively understood through reviewing theories of the functional significance of the ERN. Overall the amplitude of the ERN is conceived as a performance monitoring system, but it is still unclear whether the ERN amplitude reflects attentional components, affective components, or a particular combination of these two components. According to Luck (2014), the ERN component monitors responses, is sensitive to the conflict between intended and actual responses, and generates emotional reactions depending on responses. The results of the present study indicate that the ERN response during a GNG task is less negative for individuals who observe feelings without getting lost in them or immediately reacting to them. These results are most consistent with the affective/ motivational theory of the

ERN, which posits that the ERN can be likened to the “oops!” response to errors and is related to the affective qualities of error processing (Gehring, Liu, Orr, & Carp, 2012).

Support for the affective hypothesis of the ERN includes research that the ERN is more negative in people who find errors to be aversive and salient, OCD (Gehring et al., 2000), anxiety (Hajcak et al., 2003), and high sensitivity to punishment (Boksem, Tops, Wester, Meijman, & Lorist, 2006). Weinberg, Riesel, and Hajcak (2012) suggest that the motivational and affective component of the ERN may be best summarized as defensive reactivity, which is the negative emotional reactions when a threat is present. Higher defensive reactivity results in a larger ERN, and less defensive reactivity results in a smaller ERN. The present findings are that mindful nonreactivity is associated with a less negative amplitude, whereas more reactivity is associated with more negative amplitude, which might be explained by the emotional reaction to making mistakes. Similarly, previous research has indicated that higher emotional stability is correlated with a less negative ERN (Eichel & Stahl, 2017), which may in part account for our findings. In other words, individuals who are naturally more able to create a space between themselves and their emotions are less reactive to emotions and experience less distress in response to errors, which is reflected in the less negative ERN amplitude post error commission.

Previous research found that long-time meditators have a greater ERN response, and these meditators tend to be higher in nonjudgement and nonreactivity. While it was hypothesized that these factors are associated with a more negative ERN, the current study does not replicate this in a normative sample. Alternatively, it appears that nonreactivity has the opposite effect, as it is associated with a less negative ERN amplitude, but this amplitude is not associated with poorer behavioral performance on the task. An alternative explanation is that higher nonreactivity allows individuals to process errors and competing responses with less neural

activity, while still reaching the same behavioral response, potentially saving cognitive resources.

If it is the case that those higher in acceptance are able to process errors with more efficiency, we would expect better performance in the behavioral domain. In the current study acceptance correlated with reaction time on Go trials of the GNG task, such that higher acceptance correlated with quicker reaction time, without any trade-offs in accuracy. In other words, individuals higher in acceptance were able to respond more quickly when a behavioral response was warranted, and yet even with this increase speed, they were able to correctly inhibit responses to No-go trials just as well as those with lower acceptance who were taking more time. Given the correlational design it could also plausibly be the case that being able to respond quickly to tasks without tradeoffs in accuracy is what leads to a higher disposition of acceptance because those individuals may be more confident in their abilities and may find it easier to then accept their inner states at an enduring level. Alternatively, there might be another variable (e.g., emotion regulation) that corresponds with both reaction time and acceptance, leading to this perceived association.

Paul and colleagues (2013) found that participants higher on the nonreactivity subscale of the FFMQ had less overall rumination and stress, slower respiration during stress tasks, and better inhibition accuracy, especially for negative images on a GNG task consisting of faces with a range of valenced expressions (Paul et al., 2013). While the current study did not include an emotional task, it may be that higher nonreactivity to errors is attributed to less rumination and stress, and consequently faster reaction time. Nonreactivity is characterized by an ability to be equanimous and deliberately pause in the presence of stressors, whereas reactivity often includes acting impulsively and becoming more easily overwhelmed by thoughts and emotions.

Participants higher in nonreactivity may have been less stressed by errors and more present without ruminative thoughts about, or emotional reactions to, prior mistakes. This would then enhance their ability to respond to the present questions with less competing cognitions and thus reduced cognitive load.

It is noteworthy that in the current study the only measure of executive functioning was response inhibition, which is correlated with other measures of executive functioning, including working memory, and there may be more explanatory power when analyzing multiple areas of executive functioning (Daucourt, Schatschneider, Connor, Al Otaiba, & Hart, 2018). In fact, previous research has indicated that response speed variability and working memory may map onto the acceptance and awareness facets of mindfulness, such that response speed variability correlates with present moment awareness, and working memory correlates with acceptance, even after controlling for intelligence (Ruocco & Wonders, 2013). It may be that the ability to actively allow current thoughts and feelings rather than automatically avoid them, relies in part on working memory abilities. Alternatively, at the trait level, it may be that embracing the moment without altering internal events free up working memory. Future studies may benefit from the studying the mutual role of both response inhibition and working memory in acceptance.

In this study, it is important to note that while nonreactivity was significantly correlated with the ERN, nonjudgement, the other subcomponent that when combined with nonreactivity is hypothesized to form acceptance, was not. While behavioral responses to the GNG task occur later temporally, the ERN occurs very quickly post response. It may be that not reacting is encoded at this stage of time, as the ERN is thought to reflect the comparison between the correct and error response, and one's reactivity may be integral to this process, whereas judging one's

behaviors as good or bad may occur in later processing stages. In the current study, nonjudging and nonreactivity trended towards a significant correlation with the latency of the ERN, such that higher nonreactivity was associated with a slightly earlier ERN and higher nonjudging was associated with a slightly later ERN. In addition to ERN latency, it would be interested to study how nonjudging is related to later temporal components. For example, judging may be uniquely related to feedback-related negativity (FRN), which is negativity that is time-locked to feedback to errors, rather than time-locked to the act of error commission itself.

Limitations and Future Directions

Our understanding of the ERN is fluid and there is currently no sole conceptualization of the ERN that can be agreed upon at this point in time (Gehring et al., 2000; Greg Hajcak & Dan Foti, 2008; Luck, 2014; Weinberg et al., 2016). Much of the work in this field is highly exploratory, meaning that neural activity is studied with the necessity of working backwards to determine what this activity means. While the results of the present study suggest that neural activity time-locked to errors is related to the reactivity component of dispositional mindful acceptance at the dispositional level, the underlying mechanisms are still up for debate.

Extant data was utilized in the current work, and there was no record of whether any participants had exposure to mindfulness, and participants were not asked about their meditation experience. While participants were not recruited from meditation centers and were not doing any mindfulness trainings as part of the study, it is possible that there may have been some participants in the study who have an experience meditating and/or currently meditate. Therefore, we cannot distinguish between those who practice mindfulness and those who naturally possess more mindful qualities, and future studies may want to control for this. Additionally, the extant data did not include the reaction times at the individual level, and as

such the reaction time variability could not be analyzed. Reaction time variability measures the intra-individual variations in response time from trial to trial. This measure has been posed as an index of mind wandering and could consequently be an interesting avenue for future research that may seek to continue to differentially operationalize present moment awareness and acceptance, and the intersections between these two constructs (Mrazek, Smallwood, & Schooler, 2012).

The current study used the nonreactivity and nonjudging facets of the FFMQ to operationalize acceptance, relying on this measure as the exclusive proxy for mindfulness. While operationalizing acceptance in this way has benefits, including the ability to differentiate between two areas of acceptance, and the developer of this scale suggests these are good qualifiers of acceptance, there are differing opinions as to whether nonreactivity truly operationalizes acceptance. For example, Coffey and colleagues (2010) indicate that while the FFMQ nonjudging represents acceptance, nonreactivity may be better categorized as negative emotion regulation.

Other questionnaires that are used to measure acceptance include the Acceptance and Action Questionnaire-II (AAQ-II; Fledderus, Oude Voshaar, ten Klooster, & Bohlmeijer, 2012) and the acceptance facet of the Philadelphia Mindfulness Scale (Cardaciotto et al., 2008). While these scales are moderately positively correlated with the nonreactive and nonjudging subsets of the FFMQ (Cardaciotto et al., 2008), indicating that they are related, there are also differences between scales. Using multiple theoretically convergent measures of acceptance in future studies may help to determine how the operationalization of acceptance changes its relation to the ERN, and this can help to determine what the actual mechanisms are. For example, acceptance as measured in the current study includes pausing when encountering difficult situations, and not

evaluating thoughts as good or bad, with some broad statements that include accepting both positive and negative emotions. The AAQ on the other hand is more specific to worry and fear interfering with living in the present, experiential avoidance and cognitive inflexibility, and asks questions pertaining more to negative rather than positive emotions. The AAQ may be more likely of the different measures of acceptance to confound low acceptance with distress (Wolgast, 2014). Thus, if the study was replicated with the AAQ and findings were different, this might suggest that emotion processing and specifically distress may be key to the relation between acceptance and error processing.

Future research may benefit from distinguishing between the emotional and cognitive aspects of acceptance and teasing apart their relation with the ERN. Accepting emotions (I feel frustrated, but it is not good or bad, and I won't grasp onto this feeling) and accepting cognitions (this is difficult and that's curious, but not good or bad, and I won't grasp onto this thought) may have differential influences on behavioral and neurological indices of performance monitoring. Furthermore, the task in the current study was not emotionally charged, and future studies may benefit from using two versions of an ERP task, one emotionally neutral and one emotionally charged to test the differential effect of mindfulness on performance monitoring in the context of neutral and emotional tasks. Paul and colleagues (2012) found that only the participants higher on the nonreactivity subscale of the FFMQ had better accuracy for negative but not neutral images on an emotion inhibition task. It may be that acceptance is most helpful for emotional experiences and manipulating task valence would clarify this. Similarly, future studies may choose to simultaneously record physiological responses to emotion in accordance with an ERN task such as an emotional GNG in relation to dispositional mindful acceptance. By doing this, we can discern the role of physiological responses to mistakes (e.g., an "oops!" response to errors

may manifest in elevated blood pressure, elevated pupils, frowning, etc.) (Inzlicht et al., 2015), with the role of the ACC as measured by ERP.

Understanding the implications of dispositional mindful acceptance in adolescence and beyond in their influence on benefits using ERP components is very useful. However, it is important to note the implications of the correlational design utilized. It is unclear whether dispositional nonreactivity leads to a less negative ERN, a less negative ERN leads an individual to be higher in nonreactive mindfulness, or whether a third factor is responsible for the relation between the two. In other words, people may be nonreactive because of their innately lower ACC activity and thus it could be that their biology is driving their mindful behavior. Alternately, it could be that the dispositional orientation of nonreactive mindfulness is causing the changes in their neural activity. Plausibly, it could also be bidirectional, such that baseline neural structures increase the proclivity for certain behaviors that cyclically continue to alter the neural activity over time. Research has found that short mindfulness trainings do alter the ERN, so it is likely that the ERN can be trained to an extent (Smart & Segalowitz, 2017), but no studies have studied this longitudinally to determine whether changes in the ERN after mindfulness training ensues over time, and that may be a fruitful avenue for further research.

There is a growing body of work supporting the importance of acceptance, and this research contributes to the field by advancing our understanding of a potential measurement tool that may help qualify dimensions of acceptance. Future research might consider recording the ERN pre- and post- acceptance-based programs such as Acceptance and Commitment Therapy (ACT; Hayes, Strosahl, Bunting, Twohig, & Wilson, 2004) to determine how acceptance-specific components of mindfulness training may alter the ERN. Another avenue for study would be to study the ERN in the context of a manipulation that would involve telling half the

participants to not push away thoughts, just notice feelings and thoughts and let them go, and know that during the task no feelings are right or wrong and to try to pause without reacting impulsively, comparing this with a group that is explicitly told to push away bad thoughts and focus on emotions, attempting to keep them close, and these groups would practice this for a few minutes with feedback prior to the behavioral task. This could then be compared to a more standard mindfulness induction. While this has been done in the pain literature, indicating that acceptance coping strategies are more effective than other strategies when faced with physical pain (Keogh, Bond, Hanmer, & Tilston, 2005; Jackson et al., 2012), this has not been done in the ERN literature.

Finally, future directions may include studying how acceptance contributes to the adaptivity of the ERN. Error processing is defined as a system that involves detecting errors and adjusting behavior adaptively to prevent future errors (Holroyd & Coles, 2002). Response inhibition has been shown to mediate the relation between mindfulness training and adaptive socioemotional functioning (Sahdra et al., 2011). In many ways, adaptive behavior is the outcome measure that is both relevant to error processing and acceptance and represents a key outcome measure of mindfulness training. Given that adaptive behavior is what is ultimately important from the perspective of studying behavior after mindfulness training, it is important to also study how changes in the ERN may reflect adaptive functioning. Future studies could specifically study the adaptivity of acceptance by slightly changing the task or task instructions a few times throughout the experiment and measuring performance right after each shift in the task or task instructions.

Appendix

Table 1

Correlations of the FFMQ with the ERN, CRN, and Δ ERN

Mindfulness Facet	Electrode	ERN	CRN	Δ ERN
Nonreactivity	FCz	0.43*	0.34*	0.36*
Nonjudging	FCz	-0.15	-0.17	-0.09
Acceptance	FCz	0.28	0.16	0.27

† $p < 0.1$, * $p < 0.05$ significance

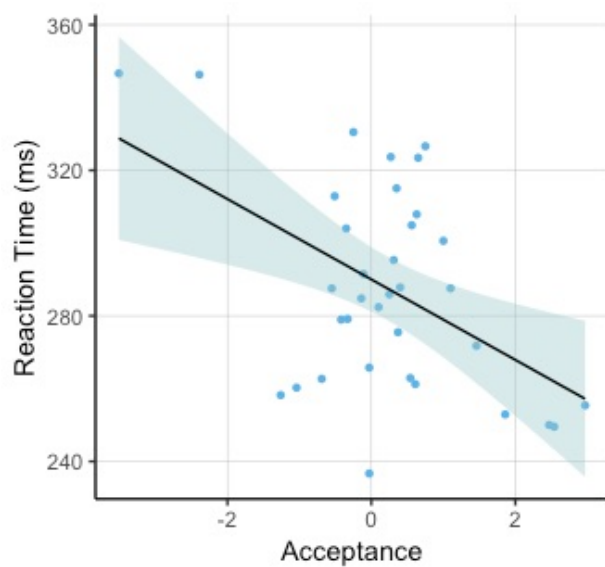


Figure 1. Correlation between reaction times on correct Go trials on the GNG task and acceptance as measured by the sum of the standardized scores on the nonreactivity and nonjudging facets of the FFMQ.

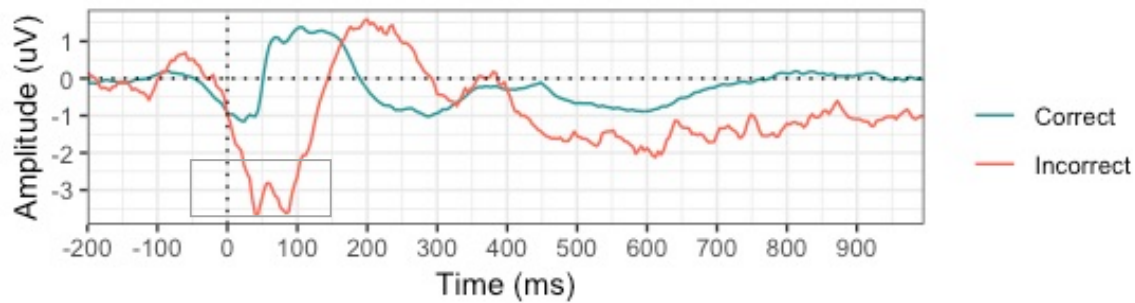


Figure 2. Response-locked ERP waveforms at the FCz electrode site corresponding to correct Go trials and incorrect No-go trials during the GNG task.

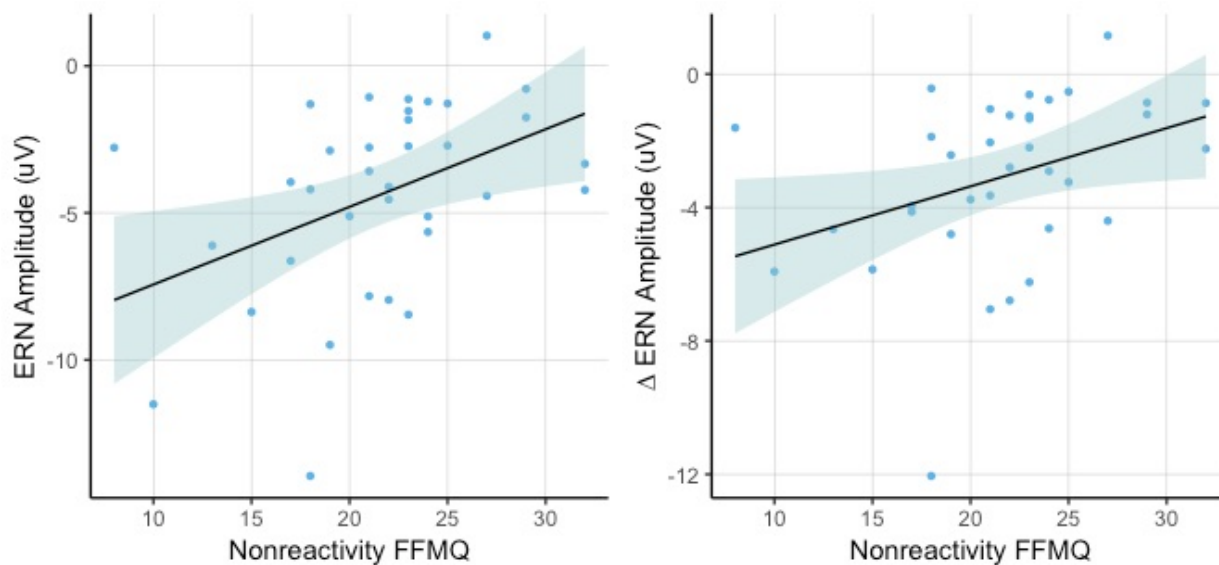


Figure 3. Correlations between the nonreactivity facet of the FFMQ and the ERN and Δ ERN, as measured by the adaptive mean at the FCz electrode site.

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Curriculum Vitae
 Emily Lynne Cary
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EDUCATION

Graduate Student, Syracuse University, Syracuse, NY GPA: 3.9
 School Psychology Ph.D. Program (APA, CAEP accredited, NASP approved)
 Advisors: Natalie Russo, Ph.D., Licensed Psychologist & Joshua Felver, Ph.D., Licensed Psychologist

The College of Wooster, Wooster, OH GPA: 3.7
 Bachelor of Arts 2013, Psychology and Studio Art Double Major
Cum Laude, Departmental Honors in both Psychology and Art, and 2 Honors Undergraduate Theses

RESEARCH EXPERIENCE

Graduate Researcher, Mind Body Lab, Syracuse University, *Fall 2017 – present*

- Co-interventionist for Learning to Breathe, a mindfulness intervention conducted at Henninger high school
- Interventionist for Soles of the Feet, teaching mindfulness coping skills to elementary students with aggressive or maladaptive behaviors
- Perform treatment fidelity for Mindfulness Based Stress Reduction with college students
- Conduct neuropsychological assessments and cognition batteries with students at local schools pre- and post- largescale mindfulness interventions

Graduate Researcher, Center for Autism Research and Electrophysiology, Syracuse University, *Fall 2017 - present*

- Administer Modules 2, 3, and 4 of the ADOS-2 to children and adults with and without ASD
- Administer and score WASI-II and PPVT-IV
- Edit tasks via Matlab, collect data using EEG, and clean and analyze data in Matlab
- EEG cap repairs
- Train and oversee undergraduate lab members in EEG protocols and analysis, administering and scoring assessment forms, professional development, and research projects

Research Assistant, University of Washington Rehabilitation Medicine, *2015-2016*

- Work on multiple studies that implement therapeutic techniques for mental health, including ACT, mindfulness, hypnosis, cognitive therapy, and education training
- Recruit patients at the Rehab clinic via EPIC chart review, provider referrals, and patient contact
- Study start up including writing IRB applications, study design, and writing study protocol
- Conduct neuropsychological assessments with adults with Multiple Sclerosis including the symbol digit modality test, Paced Auditory Serial Addition Test, and the WASI
- Perform EEGs and pain assessments with veterans at the Veterans Affairs

Team Leader & Research Associate, Pacific Institute for Research and Evaluation, *2014-2015*

- Oversee data collection for a randomized control study on smoking and public health policy, a study that is currently published in JAMA internal medicine and referenced in the NY Times

- Supervise a team of 5 Research Assistants, including scheduling and assigning work duties
- Audit research files and shadow participant interviews
- Create and maintain databases, take inventory of supplies, write agendas and minutes for team meetings

Social Anxiety, Stress, and Spatial Perception, Honors Senior Thesis, 2012-2013

- Under the aid of faculty advisor, Dr. John Neuhoff, developed and completed a thesis on the interaction between stress, social anxiety, and the spatial perception of threatening social stimuli
- Administered the Trier Social Stress Test and the State-Trait Anxiety Inventory
- Organized survey data and analyzed interactions using SPSS
- Completed an oral defense and received honors status

NYU Social Perception Action and Motivation (SPAM) Lab, Intern, 2012

- Selected for a competitive summer research position with Dr. Emily Balcetis
- Designed, conducted, coded, and analyzed data for experiments on cultural biases influencing legal verdicts, and the influence of cognitive style and other internal states on distance perception

PROFESSIONAL EXPERIENCE

Therapist Trainee, Syracuse University Counseling Center, *Fall 2019 – Spring 2020*

Supervisors: Heather Cosgrove, Ph.D.

- Individual counseling within a brief therapy model for 8 hours a week
- Conduct initial consultations with clients seeking services twice a week
- Conduct weekly drop-in appointments for clients seeking immediate services
- Engage in a social justice project in alliance with Inclusive U, the Disability Cultural Center, and the Autism Self-Advocacy Network
- Co-lead a weekly expressive arts counseling group
- Attend weekly seminars, engage in case presentations, and receive case supervision

Psychological Evaluator, ARC of Onondaga Horizon's Clinic, *Fall 2018 – Summer 2019*

Supervisors: Joseph Himmelsbach, Ph.D. & Christine Sweeney, LMSW

- Complete assessments to determine OPWDD eligibility for children and adults with disabilities using the WAIS-IV, WISC-V, WPPSI-IV, TONI-4, ABAS-3, and Vineland-3
- Complete Sexuality assessments using the SSKAAT-R to determine the ability for adults with disabilities to consent, for use within the OPWDD system, and/or for cases of sexual assault
- Teach a monthly class for new employees on consent, sexuality, and abuse, in individuals with developmental disabilities and how to best protect and support them

Behavior Therapy Practicum, ARC of Onondaga IRA and Parkside Preschool, *Spring 2019*

Adult Supervisors: Brian Martens, Ph.D. & Ruth Ann Riposa, LMSW

Child Supervisors: Brian Martens, Ph.D., Jedidiah Kissane, M.Ed. & Lauren Merola, M.Ed.

- Complete a case conceptualization and case report for one adult and one preschool student
- Administer the QABF, and complete an FA and FBA to determine functions of behavior
- Design and implement function-matched treatments for challenging behavior
- Direct caregivers and teachers on site to implement the treatment protocols

Senior Behavioral Therapist, Center for Autism and Related Disorders, Berkeley, CA, 2013-2014

Supervisors: Emily Keough, BCBA & Heather Brown, BCBA

- Provide ABA therapy in homes, schools, and clinics to children with ASD

- Work with families to enhance child's skills and shape difficult behaviors
- Record and graph behaviors for analysis, and adjust behavior plans accordingly
- Train, shadow, and conduct performance evaluations for new therapists

Classroom Support, Ida Sue School, Wooster, OH, *Spring 2013*

- Volunteer at a special needs elementary school assisting with activities and class management

Special Needs Counselor, Ramapo for Children, Rhinebeck, NY, *Summers of 2010 & 2011*

- Work at an immersive residential camp for special needs populations including Autism Spectrum Disorders, Asperger's, Fragile x Syndrome, Selective Mutism, behavioral cases, and hearing-impaired children and adolescents ages 6-16

Teacher's Assistant, Parkview Elementary School, Wooster, OH, *spring 2010*

- Teach lessons to a second-grade class
- Facilitate group lessons and one-on-one support

TEACHING EXPERIENCE

Graduate Teaching Assistant, Syracuse University, *Fall 2017 & Spring 2018*

- Psyc 205 Foundations of Human Behavior
- Teach 4, 80-minute, weekly sections of 25 students
- Lecture and lead interactive discussions and activities
- Hold office hours, write quizzes, grade papers and quizzes, and proctor exams

PUBLICATIONS

Cary, E. L. & Felver, J. C. (forthcoming). Susan M. Pollak: Self-compassion for parents: Nurture your child by caring for yourself. *Mindfulness*.

Molton, I., **Koelmel [Cary], E.**, Curran, M., Von Geldern, G., Ordway, A., & Alschuler, K. N. (2019). Pilot intervention to promote tolerance for uncertainty in early multiple sclerosis. *Rehabilitation Psychology, 64*(3), 339.

Felver, J. C., Clawson, A. J., Helminen, E. C., **Koelmel [Cary], E. L.**, Morton, M. L., & Sinagar, S. E. (2018). Reconceptualizing the measurement of mindfulness. In D. Grimes, H. Lin, & Q. Wang (Eds.), *Empirical Studies of Contemplative Practices* (pp.19-42). New York, NY: Nova Science Publishers.

Koelmel [Cary], E., Hughes, A., Alschuler, K., & Ehde, D. (2017). Resilience mediates the longitudinal relationships between social support and mental health outcomes in multiple sclerosis. *Archives of Physical Medicine and Rehabilitation, 98*(6), 1139-1148.

CONFERENCES & POSTERS

**indicates mentorship of undergraduate student(s)*

*Garber, M., **Cary, E.**, & Russo, N. (August 2019). *Neurological Indicator of Traits Associated with Autism Spectrum Disorder*. Poster presented at the Syracuse University College of Arts and Sciences Conference and the Syracuse University College of Engineering and Computer Science Conference, Syracuse, New York.

*Garber, M., **Cary, E.**, & Russo, N. (May 2019). *Neurological Indicator of Traits Associated with Autism Spectrum Disorder*. Poster presented at the McNair Spring 2019 Research Symposium, Syracuse, New York.

Kaplan, E. A., Russo, N., McKernan, E. P., Kopec, J., **Koelmel [Cary], E. L.**, & Masters, E. (2019). *This is a Question? Prosody, Social Communication, and the N400 Effect*. Poster presented at the International Society for Autism Research, Montreal, Canada.

Kopec, J., Prawl, A. M., McKernan, E.P., Kaplan, E. A., **Koelmel [Cary], E.L.**, & Russo, N. (2018). *Children and Adults with Autism Detect Rapidly Presented Temporal Information More Accurately Than Typically Developing Individuals*. Poster presented at the International Society for Autism Research, Rotterdam, Netherlands.

McKernan, E. P., Kopec, J., Kaplan, E. A. **Koelmel [Cary], E. L.**, & Russo, N. (2018). *The Relationship of Sensory Overresponsivity to Amplitude Discrimination*. Poster presented at the International Society for Autism Research, Rotterdam, Netherlands.

Kaplan, E. A., Russo, N., Kopec, J., McKernan, E.P., **Koelmel [Cary], E. L.** & Prawl, A. M. (2018). *EEG Correlates of the Attentional Blink: Relationship to Autism Symptoms*. Poster presented at the International Society for Autism Research, Rotterdam, Netherlands.

*Allawh, C., *Wherry, M., **Koelmel [Cary], E.L.**, & Felver, J., A. (2018). *Evaluating the Effects of a Learning to BREATHE Mindfulness Intervention on Emotion Regulation in At-Risk Adolescents*. Poster presented at the SU Psychology Undergraduate Poster Session, Syracuse, NY.

Clawson, A., **Koelmel [Cary], E.L.**, & Felver, J., A. (2018). *School-based Mindfulness Intervention Supports Adolescent Resiliency*. Oral presentation at the NASP Conference, Chicago, IL.

Koelmel [Cary], E. L. (2013). *The Interaction between the Physical Environment and Metaphysical States: the Role of Social Anxiety and Stress in Informing Spatial Perception*. Poster presented at the College of Wooster Independent Study Symposium, Wooster, OH.

Koelmel [Cary], E. L., & Mian, M. (2012). *The Dieter's Dilemma: A Struggle between Self Control and Temptation*. Oral presentation at the NYU Social Perception Action and Motivation Summer Conference, New York, NY.

PROFESSIONAL AFFILIATIONS

National Association of School Psychology (NASP) Member, *Nov 2017-Present*
International Society for Autism Research (INSAR) Member, *Feb 2018-Present*

EDITORIAL EXPERIENCE

Ad hoc reviewer, *Journal of School Psychology*, *April 2018*
Ad hoc reviewer, *Brain and Cognition*, *October 2018*

SERVICE

National Alliance on Mental Illness (NAMI), *Spring 2018*
Diversifying Psychology Weekend Graduate Student Liaison, *Spring 2018*
Graduate Admissions Committee, *Spring 2018 – Fall 2019*
Professional Development Committee, *Fall 2019*

PAC Peer Mentor, *Fall 2019*

TRAININGS & CERTIFICATIONS

Learning to Breathe Mindfulness Clinical Training, three days at Trinity Retreat Center, *August 2018*

Introductory Clinical Training for the Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2), two days at Weill Cornell Medicine Center for Autism & the Developing Brain, *October 2018*

Trauma-Focused Cognitive Behavioral Therapy Online Training, 11 CEU hours through The Medical University of South Carolina, *November 2018*

Advanced Research Training for the ADOS-2, three days at Weill Cornell Medicine Center for Autism & the Developing Brain, *October 2019*

GRANTS & AWARDS

Syracuse University Psychology Department Travel Award, *2018 & 2019*

Syracuse University Graduate Student Organization Travel Award, *2019*

Henry J. Copeland Independent Study Fund Grant Award, *2013*

Netta Strain Scott Prize in Art for Outstanding Creativity, *2013*

Deans Award, *2009-2013*