Present with an Uncertain Future: Dispositional Mindfulness, Covariation Bias, and Event-Related Potential Responses to Emotional Stimuli in Uncertain Contexts

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PRESENT WITH AN UNCERTAIN FUTURE: DISPOSITIONAL MINDFULNESS, COVARIATION BIAS, AND EVENT-RELATED POTENTIAL RESPONSES TO EMOTIONAL STIMULI IN UNCERTAIN CONTEXTS

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

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Abstract

PRESENT WITH AN UNCERTAIN FUTURE: DISPOSITIONAL MINDFULNESS, COVARIATION BIAS, AND EVENT-RELATED POTENTIAL RESPONSES TO EMOTIONAL STIMULI IN UNCERTAIN CONTEXTS

By: Robert J. Goodman, M.A.

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

Virginia Commonwealth University, 2014

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Uncertainty represents a robust threat that can amplify aversive experiences and exaggerate negative expectations about uncertain future outcomes. Mindfulness – an open and receptive attention to present moment experiences -- has been shown to facilitate adaptive regulation when faced with a variety of distinct emotional threats. Reduced experiential avoidance and equanimity in the face of unpleasant emotional experiences have been theorized as central to these emotional regulatory benefits. The present study explored whether dispositional mindfulness would promote adaptive responses to uncertainty during the anticipation of, and after exposure to emotional stimuli, as indicated by self-reports and neural (event-related potential) markers of anticipation and appraisal. Participants were exposed to stimulus cues that informed them about the valence of a subsequent emotional picture as neutral, aversive, or uncertain. Consistent with past research, uncertainty during the anticipation of an
emotional stimulus amplified unpleasant stimulus appraisals, and participants demonstrated biased expectations to associate uncertainty with aversiveness. Dispositional mindfulness was associated with lower expectations for unpleasant stimuli, and was found to amplify the effect of uncertainty on a cortical marker of stimulus appraisal called the late positive potential (LPP). Traits that contrasted with mindfulness predicted opposite patterns of association with these measures. However, these findings were directly the opposite of findings from past research. A theoretically defensible explanation is discussed for these findings and suggestions were made for future research on the role of mindfulness on ERP variability.

The results from the present study contribute to a growing body of evidence that suggests that uncertainty during the anticipation of potentially negative future outcomes can exert a potent downstream influence on emotional anticipation and appraisal processes. Further research is needed to clarify the role of dispositional mindfulness during emotional stimulus anticipation and appraisal following uncertainty.
Present with an Uncertain Future: Dispositional Mindfulness, Covariation Bias, and Event-Related Potential Responses to Emotional Stimuli in Uncertain Contexts

We live in a world that is constantly changing and difficult to predict. Uncertainty is ubiquitous, and resolving it is a primary human motivation (Kagan, 1972). Uncertainty about potential future threats can be debilitating because not having adequate information about a potentially negative future outcome can impair the ability to anticipate, prepare for, and regulate responses (Grupe & Nitschke, 2013). Exaggerated attempts to resolve uncertainty are foundational to worry, and represent a central component of many anxiety disorders (Barlow, 2002). Psychologists (Baumeister, 1985; van den Bos, 2010) and existential philosophers (Camus, 1942; Heidegger, 1927; Sartre, 1937) have described the experience of confronting uncertainty as disorienting and unpleasant (Heidegger, 1927; Kierkegaard, 1983; Sartre, 1939). However, the existentialists note an important upside to this confrontation: in the very act of acknowledging the hard fact of uncertainty people make progress toward living an honest, authentic, and meaningful life. For example, Sartre (1939) found that in the process of coming to terms with uncertainty, he realized the basic opportunity for human freedom, creativity, and meaning. As summarized by Grene (1984), a central point of existentialism is that human integrity grows from acknowledging the difficult truths of the world, including uncertainty, and being honest about them.

This orientation of honesty toward the facts of experience characterizes mindfulness, which is commonly described as an open and receptive awareness to whatever is occurring in the present moment (Brown, Ryan, & Creswell, 2007). The Satipaṭṭhāna Sutta -- a primary discourse on mindfulness that has been a cornerstone of Buddhist contemplative practice for its 2500 year history -- suggests mindfulness is particularly beneficial when applied to precisely
those states considered dreadful by the existentialists, including uncertainty. One reason for this is that mindfulness is theorized to promote a more equanimous, receptive awareness toward difficult experiences, such that a person is better able to see them clearly, “unadulterated by habitual reactions and projections” (Anālayo, 2003, p. 60). The present study will empirically examine whether trait mindfulness promotes adaptive responses to aversive events under conditions of uncertainty as measured by self-reported and cortical measures of appraisal and anticipation.

Past research has linked dispositional mindfulness with adaptive responses to a variety of emotional threats (for a review, see Goodman, Quaglia & Brown, in press). Uncertainty represents a robust threat to a considerable number of people, and evidence from several studies indicates that uncertainty can negatively influence processes involved during both emotional appraisal and anticipation. Appraisal responses include amplified perceptions of unpleasantness (Grupe & Nitschke, 2010; Sarinopoulos, Dixon, Short, Davidson, & Nitschke, 2006; Sanfey, 2009) and states of negative affect (Hirsch & Inzlicht, 2008; Nader & Balleine, 2007). This heightening of unpleasantness by uncertainty is theorized to result, at least in part, from changes during the anticipation of uncertain future outcomes, and specifically the tendency to expect that uncertainty will lead to aversive outcomes. This tendency to associate uncertainty with aversiveness is a phenomenon known as covariation bias (Tomarken, Mineka and Cook, 1989), and it plays a central role in the amplification of unpleasant emotional responses to uncertainty (Grupe & Nitschke, 2013).

The present research will first attempt to replicate effects from a past study (Grupe & Nitschke, 2011) that examined the influence of uncertainty on emotional anticipation and appraisal processes. This study provided evidence that uncertainty amplifies self-reported
unpleasant perceptions and negative affect. In addition to these self-report measures, past research has provided peripheral nervous system (Grupe & Nitschke, 2011) and neuroimaging (Sarinopoulos et al., 2010) evidence that uncertainty amplifies unpleasant emotional appraisal processes. The present study attempts to extend this incipient body of evidence using cortical measures known as event-related potential (ERPs): patterns of electrical activity measured at the surface of the scalp that are time locked to the presentation of a stimulus. Of interest to the present research is a widely-studied ERP component known as the Late Positive Potential (LPP), which is sensitive to differences in the valence and arousal inducing properties of an emotional stimulus (Carretie et al., 2001; 2004; Cuthbert et al., 2000; Schupp et al., 2003), as well as top-down modulation of emotional stimulus appraisal and meaning (Hajcak et al., 2010; Hajcak & Nieuwenhuis, 2006; Olofsson et al., 2008).

Another goal of the present study is to examine differences in anticipatory processing of emotional stimuli under conditions of uncertainty. Past research using the experimental paradigm used in the present study found that participants demonstrated inflated expectations and post-experiment estimates that uncertainty leads to aversive outcomes (Grupe & Nitschke, 2011). Additional research indicates that uncertainty modifies activity in neural regions during the anticipation of emotional stimuli (for a review, see Grupe & Nitschke, 2013). The present study will extend this existing body of evidence by examining self-reported expectations during states of uncertainty, as well as a cortical measure of emotional anticipation known as the Stimulus Preceding Negativity (SPN). The SPN is an event-related potential measure that is thought to reflect the anticipation and the intensity of motivational engagement toward a forthcoming emotional stimulus (Moser et al., 2009; Poli, Sarlo, Bortoletto, Buodo, & Palomba, 2007; Takeuchi, Mochizuki, Masaki, Takasawa, and Yamazaki, 2005). Similar to the LPP, the
SPN is sensitive to the valence and arousal inducing properties of a stimulus (Howard, Longmore, & Mason, 1992; Poli et al., 2007), and the top-down modulation of stimulus meaning (Moser et al., 2009; Thiruchselvam et al., 2011).

Finally, the present study will explore dispositional mindfulness – the frequency with which people enter into states of open and receptive awareness to the present – as a psychological quality that modulates self-reported and cortical measures of emotional stimulus appraisal and anticipation under conditions of uncertainty. I expect that when participants are exposed to aversive stimuli under conditions of uncertainty, mindfulness will promote less unpleasant emotional appraisals of the stimuli, as indicated by lower self-reported unpleasant affect and picture ratings, and attenuated LPP responses to aversive emotional stimuli. I also expect mindfulness will modulate processes involved during the anticipation of emotional stimuli. Mindfulness is expected to promote lower levels of covariation bias, and I will explore the relation between mindfulness and the SPN during emotional stimulus anticipation under conditions of uncertainty.

In sum, the present study has been designed to replicate and extend past research linking uncertainty to changes in stimulus appraisal and anticipation. I will also explore the important role that mindfulness may play in ameliorating the influence of uncertainty on measures of emotional stimulus appraisal and anticipation. In the sections that follow I will describe several distinct types of uncertainty discussed in the scholarly literature, and will specifically target informational uncertainty – a state in which information about the probability of a future outcome is restricted or absent – as the focus of the present study. Then I will describe extant literature on the influence of uncertainty on stimulus appraisal processes, and how mindfulness might promote more adaptive appraisals of uncertainty-related stimuli. Next, I will discuss the
literature on the effect of uncertainty during anticipation. People are intrinsically motivated to resolve informational uncertainty (Kagan, 1972), and I will describe covariation assessment as a way people accomplish this. Then I will discuss evidence that prior expectations can distort covariation assessments and bias predictions about uncertain future outcomes. When people develop the tendency to expect uncertainty will lead to aversive outcomes the experience of informational uncertainty can become highly aversive, and I will describe research that implicates covariation bias in the development of maladaptive cognitive and emotional responses to uncertainty. After discussing the nature of uncertainty and anticipatory processes, I will outline my rationale for exploring the influence of mindfulness on anticipatory processing under conditions of uncertainty.

Uncertainty

Several types of uncertainty have been described in the literatures of psychology, economics, philosophy, and neuroscience and it is important to distinguish between them because they have unique influences on human experience (van den Bos & Lind, 2009). For example, the philosophical concept of vagueness claims the very existence of everyday objects is uncertain (Unger, 1980). This vagueness suggests that what we perceive as everyday objects (i.e., a desk) are fundamentally uncertain, insofar as their constituent elements/parts (i.e. drawers, legs, etc.) and the boundaries they share with other objects (i.e., a bolts, nails) are imprecise and uncertain (Unger, 1980; Horgan, 1995). Another type of uncertainty known as personal uncertainty is similar to the construct of cognitive dissonance (Festinger & Carlsmith, 1957) and focuses on the uncomfortable feelings that arise when one is aware that something personal about the self is inconsistent or vague (Baumeister,1985; Van den Bos, 2010). Put simply, personal uncertainty is the uncomfortable affective experience that results from being uncertain
about the self or where one stands on important issues about the self (Van den Bos, 2010). The Uncertainty Management Model (Van den Bos, 2010), a theoretical framework used to predict the effects of personal uncertainty, suggests that people are motivated to resolve the discomfort of personal uncertainty through worldview defense (van den Bos, Poortvliet, Maas, Midedema, & Vandenham, 2005; van den Bos, van Ameijde, & van Gorp, 2006), religious zealotry, and compensatory conviction (Festinger, Riecken, & Schachter, 1956; McGregor, Haji, Nash, & Teper, 2008; McGregor & Marigold, 2003; McGregor, Zanna, Holmes, & Spencer, 2001).

Several other programs of research have examined individual differences in the way people relate to uncertainty about the self. According to Uncertainty Orientation Theory (Sorrentino and Roney, 1999) some individuals are positively oriented toward approaching and resolving uncertainty (uncertainty orientation), while others ignore and avoid it in favor of familiarity (certainty orientation). Uncertainty Identity Theory (UIT; Hogg, 2007) is another psychological theory that regards the drive to resolve uncertainty as a motivating force. An extension of Social Identity Theory (Tajfel & Turner, 1986/2004), UIT explores uncertainty as a fundamental human motivation that causes people to identify with groups as a way to defend the self from feelings of personal uncertainty. People who have high self-uncertainty are, for example, more likely to identify with extremist groups that have clearly defined boundaries and stable ideologies (Hogg, 2007).

While there are numerous psychological theories about uncertainty, the most basic and widely studied form has its roots in the scholarly work of economics, and is known as informational (or Knightian) uncertainty. Research on informational uncertainty explores how people respond to situations where there is limited information about the probability of occurrence for a future outcome. The primary distinction between informational and personal
uncertainty (and its close relatives) involves the restricted focus of personal uncertainty to negative affective states that result from uncertainty about the self. Informational uncertainty, on the other hand, is a not restricted to the affective consequences stemming from uncertainty about self. It is broader construct that involves cognitive and affective responses to situations in which the information needed to predict future outcomes is limited or completely unknown.

Informational uncertainty has been widely studied in the context of decision making and economics, and can be further split into two different types: risk and ambiguity (Knight, 1921). The primary distinction between risk and ambiguity involves whether the probability of a future outcome occurring is known or unknown. Under conditions of risk (also known as unambiguous probability; Ellsberg, 1961), the probability of an outcome occurring is known (Hsu, Bhatt, Adolphs, Tranel & Camerer, 2005; Levy, Snell, Nelson, Rustichini, & Glimcher, 2009). For example, the option to select any spade from a deck of playing cards is less risky than the option to select any queen precisely because the relative probability of each outcome is known. In contrast, ambiguity involves a complete lack of information about the probability of a particular outcome occurring (Camerer & Weber, 1992; Fox & Tversky, 1995; Knight, 1921). For example, if a person was asked to predict what kind of picture would be displayed without having any foreknowledge about them.

**Informational Uncertainty and Emotional Appraisal.**

Uncertainty increases the physiological arousal and intensity of emotional experience, and this is sometimes perceived positively (Critchley, Mathias, & Dolan, 2001; Sorrentino, Ye, & Szeto, 2009; Whalen, 2007). For example, pleasant experiences are prolonged when they are followed by uncertain events, and people seem to intuitively leverage this as a way to increase excitement for pleasant experiences. We wrap gifts, throw surprise parties, and seek dangerous
thrills like skydiving (Bar-Anan, Wilson, & Gilbert, 2009; Wilson, Centernar, Kermer & Gilbert, 2005) in part because our excitement is amplified when what is to come is hidden and unknown. The experience of uncertainty has been shown to instigate introspection and contemplation (Sorrentino, Bobocel, Gitta, Olson, & Hewitt, 1988), and uncertainty about important future outcomes, such as performance on a test or at a sporting event, can evoke “facilitative anxiety” that leads people to prepare and perform on important tasks more effectively (Alpert and Haber, 1960).

While there are positive aspects to uncertainty, sometimes it can have deleterious consequences for mental health. Uncertainty about important, potentially aversive future outcomes can impair performance and curtail the ability to plan for the future (Grupe & Nitschke, 2013). When paired with a potentially aversive outcome, uncertainty is almost universally experienced as aversive (Grupe & Nitschke, 2011; Hirsch & Inzlicht, 2008; van den Bos, Poortvliet, Maas, Miedema, & Vandenham, 2005), and exposure to uncontrollable or unpredictable events has been linked to the manifestation of depression (Msetfi, Murphy, Simpson, & Kornbrot, 2005). For example, people who are exposed to unpredictable patterns of shocks (vs. predictable patterns of shocks) show heightened baseline levels of anxiety (i.e., contextual fear) to the experimental context (Davis, 1998), and these differences in heightened baseline anxiety distinguish between clinically anxious and non-anxious people (Grillon, Morgan, Davis, & Southwick, 1998; Pole, Neylan, Best, Orr, & Marmar, 2003).

**Informational uncertainty and negative affect.** The distinction between ambiguity and risk has important consequences for decision making, and for the experience of felt uncertainty (Kahneman, Slovic, & Tversky, 1982). Risk has been shown to instigate aversive responses across several species, including chimpanzees, birds, fish, and bumblebees (Caraco, 1981;
Kacelnik & Bateson, 1996; Gilby and Wrangham, 2007). While risk varies in terms of its tolerability, ambiguity is almost universally experienced as aversive among human and non-human animals. When given the option between making a decision that involves risk or ambiguity, people avoid ambiguity, even in situations where it has a considerably higher payoff than risk, a phenomenon known as ambiguity avoidance (Curley, Yates, & Abrams, 1986; Ellsberg, 1961; Camerer & Weber, 1992).

Ambiguity is avoided even when the situation is clearly innocuous. For example, both rats and humans prefer to receive a sequence of shocks that are predictable over an equivalent sequence that is unpredictable (Abbot, 1985; Abbot and Badia, 1979; Badia and Culbertson, 1972; Miller, Marlin, & Berk, 1977; Mineka and Kihlstrom, 1978). While predictable and unpredictable shocks elicit a clear fear response, only unpredictable shocks evoke states of contextual fear, a sustained state of fear in the experimental context (Davis, 1998). Additionally, the unpredictability of a stimulus only evokes such negative reactions when paired with an aversive stimulus, and not with a neutral stimulus (Grillon, Baas, Lissek, Smith, & Milstein, 2004). The unpredictability of a forthcoming aversive stimulus has been shown to amplify levels of fear and aversion not only to the unpredictable stimulus, but to the situations in which uncertainty is experienced (Davis, 1998).

**Informational uncertainty and stimulus perception.** While evidence suggests uncertainty can amplify unpleasant affect, it can also amplify perceptions of a stimulus as unpleasant (Grupe & Nitschke, 2011). When people do not have adequate knowledge about the future, the ability to anticipate threats and how to best regulate responses to them is impaired (Nitschke & Grupe, 2013). This impaired state can produce considerable anxiety because is suggests that one’s current mental representation of the situation/environment is not complete, or
is incorrect (Hirsch & Inzlicht, 2008; Peterson, 1999). One way people attempt to update their mental representations and resolve uncertainty is through a process known as covariation assessment. However, people are notoriously poor at covariation assessment, and exaggerated attempts to resolve uncertainty can lead to biased expectations that serve not only to amplify negative affect in uncertain contexts, but to actually distort basic perceptual processes (Sarinopoulos, Dixon, Short, Davidson, & Nitschke, 2006; Kirk, Skov, Hulme, Christense, & Zeke, 2009; Sanfey, 2009).

**Specific aim 1.** Several studies have demonstrated that unpredictable threats are more anxiety provoking and elicit greater physiological responses than the same threats when they are predictable (Bar-Anan, Wilson, & Gilbert, 2009; Dickerson & Kemeny, 2004; Grupe & Nitschke, 2011; Hirsch & Inzlicht, 2008; Kimmel, 1967; Nader & Belleine, 2007; Sarinopoulos et al., 2010). Moreover, when people associate uncertainty with aversive outcomes, these biased expectations can influence how unpleasant stimuli are actually perceived (Grupe & Nitschke, 2011; Sarinopoulos, Dixon, Short, Davidson, & Nitschke, 2006). The first aim of the present research was to replicate these findings by providing evidence of greater self-reported unpleasant affect and unpleasant stimulus ratings when participants were uncertain about the nature of a forthcoming emotional stimulus, compared to when they were certain (see Figure 1, Specific Aim 1). The paradigm administered in the present study exposed participants to a cueing stimulus that provided information about the nature of the forthcoming emotional picture as either certain (aversive or neutral) or uncertain. On half of the experimental trials, participants were asked to rate the valence of their affective state after being exposed to the emotional stimulus, and on the other half of trials, participants were asked to rate their perception of the valence of the image stimulus itself. After checking to determine participants understood the
Figure 1. Trial Events during the trial sequence of the cued image task and their relation to specific aims.
nature of the stimulus cues, I tested whether aversive and neutral images preceded by uncertainty cues elicited more self-reported negative appraisals (higher unpleasant affect and stimulus ratings) compared to aversive and neutral images preceded by certainty cues? Consistent with past research using this paradigm (Grupe & Nitschke, 2011), this aim was to replicate evidence that participants self-report affect and perceptions of the pictures as more unpleasant when experienced under uncertainty.

**Neural Correlates of Emotional Appraisal during Informational Uncertainty.** Considerable research has linked the amygdalae to learning and fear expression (LeDoux, 1996), and many studies suggest amygdalae activity is increased during the appraisal of uncertainty (Davis and Whalen, 2001; Phelps and LeDoux, 2005; Rosen and Donley, 2006; Rosen and Schulkin, 1998; Whalen, 1998). Informational uncertainty increases states of fear and anxiety and increases amygdalae activity in human (Bornhovd et al., 2002) and nonhuman primates (Belova, Patton, Morrison, & Salzman, 2007). For example, activity in the amygdalae increases in the mere presence of unpredictability in both mice and humans. In an otherwise innocuous context an unpredictable pattern of sound pulses was found to increase activity in the amygdalae and instigate avoidance-related behaviors in mice (Herry et al., 2007). Additionally, these authors found that these identical sound patterns were shown to increase amygdalae activation and heighten attention bias to emotional faces in humans, an indicator of anxious arousal. Another study found that the magnitude of associated uncertainty with aversion predicted increased activity in the amygdalae during the anticipation of uncertain outcomes (Sarinopoulos et al., 2010). Under more complex conditions, such as during gambling tasks where the probability of a particular outcome is variable, amygdalae activity is also increased by the degree of uncertainty (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005; Levy, Snell, Nelson, Rustichini, & Glimcher,
While findings linking uncertainty with amygdalar activation are compelling, it should be highlighted that heightened activity in the amygdalae does not directly translate to increases in negative emotions. While sometimes amygdalar activity indicates overt experiences of fear and anxiety, the consequences of amygdalar activation on cognitive and affective experience are largely controlled by regions of the prefrontal cortex (Whalen, 2007).

A recent meta-analysis of neuroimaging studies found that decisions made under conditions of risk and ambiguity had similar activation profiles involving sub-regions of the ACC and orbitofrontal cortices (OFC; Krain, Wilson, Arbuckle, Castellanos, & Milham, 2006). The ACC is a limbic structure involved in error detection, reinforcement learning (Holroyd & Coles, 2002; Luu, Tucker, Derryberry, Reed, & Poulsen, 2003), and the capacity to regulate cognitive and emotion responses (Bush, Luu, & Posner, 2000). Increased ACC activity is directly associated with higher levels of physiological arousal when emotional stimuli are presented under conditions of informational uncertainty (Grupe & Nitschke, 2013; Sarinopoulos et al., 2010). Moreover, when participants make decisions that could lead to a reward, the level of risk involved is directly related to activity in the anterior cingulate and orbitofrontal cortices during the period after a participant’s behavioral response and before feedback about the outcome (Critchley, Mathias, & Dolan, 2001; Harris, Sheth, & Cohen, 2008). Importantly, activity in the ACC and orbitofrontal cortex increases linearly as the risk becomes ambiguous (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005). In summary, considerable evidence suggests that well-defined neural responses involved in stimulus appraisal are altered following manipulations of informational uncertainty.

**Cortical evidence.** While a variety of neuroimaging studies have provided experimental evidence that informational uncertainty elicits patterns of brain activity related to heightened
states of physiological arousal following exposure to unpleasant stimuli (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005; Levy, Snell, Nelson, Rustichini, & Glimcher, 2010; Sarinopoulos et al., 2010), brain-based evidence from studies capturing event-related potentials (ERPs) have shown analogous effects (Hirsh & Inzlicht, 2008; Tritt, Peterson, and Inzlicht, under review). Of primary interest to the present study is a component known as the Late Positive Potential (LPP), an ERP measured at the surface of the scalp that is time locked to the presentation of emotional stimuli.

**The Late Positive Potential.** The LPP is a positive-going slow wave that is maximal over the centro-parietal midline in the 400 – 2000 ms latency range (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). LPPs are present in some studies for the entire duration that emotional stimuli are presented (e.g., up to 6 seconds; Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006), and can even extend after stimulus offset (Hajcak & Olvet, 2008). LPP amplitudes are theorized to reflect sustained attentional allocation and attentional narrowing induced by stimuli that carry motivational relevance (Ferrari, Bradley, Codispoti and Lang, 2011; Gable and Harmon-Jones, 2013; Hajcak and Olvet, 2008; Lang, Bradley, & Cuthbert, 1997; Schupp et al., 2000; Weinberg and Hajcak, 2011). The LPP is also sensitive to manipulations of stimulus meaning and top-down regulation of emotional appraisal processes (Blechert, Sheppes, Di Tella, Williams, & Gross, 2012; Hajcak & Nieuwenhuis, 2006), and there is evidence to suggest that the early time window of the LPP may more closely related to the motivational relevance of a stimulus, while later time windows reflect perceptions and evaluations of stimulus meaning (Schupp, Flaisch, Stockburger, & Jundhofer, 2006).

Decades of experimental studies have elucidated factors that influence the LPP. For example, the LPP is influenced by the context in which an emotional stimulus is presented.
(Cacioppo et al., 1993). When negative stimuli are embedded within a larger sequence of positive stimuli, LPP amplitudes are increased. This finding suggests that LPP amplitudes are amplified by evaluative inconsistency (Cacioppo et al., 1993). The LPP is particularly sensitive to manipulations of attention. For example, distraction manipulations that divert participants’ attention away from the arousing properties of a stimulus attenuate LPP amplitudes, as does the presentation of emotional stimuli in unattended locations of the visual field. LPP amplitudes are also influenced by meaning evaluation, such that LPP amplitudes are blunted when participants receive descriptions of emotional picture stimuli that frame them in a more positive way (Foti & Hajcak, 2008). This reduction of LPP amplitude is even sustained when participants are re-exposed to the stimulus 30 minutes later (MacNamara, Oschner, & Hajcak, 2011), which suggests that LPP amplitudes may be particularly sensitive to changes in stimulus appraisal.

Moser et al. (2009) demonstrated the sensitivity of the LPP to a top-down appraisal manipulation by providing participants with instructions to use specific emotion regulation strategies to modify their emotional experiences during anticipation of emotional pictures. Three conditions were deployed in the study. On some trials participants were cued to view the pictures “as if from a detached, third person perspective” (reappraisal), while on other trials they were cued to “imagine [they] were personally partaking in the pictured events” (self-focused), or to simply view the pictures and respond naturally. Results indicated that instructions to decrease emotional responses by reappraising the picture content were associated with attenuated LPP amplitudes (Moser et al., 2009). In a similar study, Thiruchselvam et al. (2011) examined the modulation of the LPP following cues to engage in top-down emotion regulation strategies. In this study participants received a cue to either (1) simply attend to the picture as normal (view and watch), (2) to distract themselves by “generating thought unrelated to the image presented on
the screen” (distraction), or (3) to “adopt the perspective of a detached observer” (reappraisal). Results indicated that instructions to distract or reappraise negative emotional stimuli were associated with an attenuated LPP compared to normal viewing. However, these authors extended the previous findings of Moser et al (2009) by examining when these effect occurring during the time-course of the LPP. The process model of emotion regulation suggests that attention-centric emotion regulation strategies have earlier influences than top-down reappraisal strategies (Gross, 1998). Consistent with this theory, when participants were instructed to distract themselves from the emotional content, the LPP was modulated at an early time (as early as 300 ms), whereas instructions to reappraise modulated the LPP much later after stimulus exposure (1500 ms).

Simultaneous recording of EEG and fMRI has implicated a network of brain regions that differentially generate and modulate the LPP based on stimulus valence, including the visual cortices, temporal cortices, amygdalae, orbitofrontal cortex, insula, and posterior cingulate cortex (Liu, Huang, McGinnis-Dewees, Keil, & Ding, 2012). LPP amplitude is modulated by beta-adrenergic receptor activity in the amygdalae, which exerts downstream effects in visual cortical areas (de Rover et al., 2012). Other studies have suggested the LPP arises due to a global inhibition of activity in the visual cortex that has been linked to an extended processing duration for an emotional stimulus (Brown, van Steenbergen, Band, de Rover, & Nieuwenhuis, 2012). This is convergent with findings that increases in LPP amplitude are associated with slower reaction times during cognitive tasks and interference with attention-related ERPs on the subsequent trials (Weinberg and Hajcak, 2011).

Substantial research has indicated that LPP amplitudes are modulated by motivationally salient emotional stimuli compared to neutral stimuli (Ferrari, Bradley, Codispoti and Lang,
2011; Gable and Harmon-Jones, 2013; Hajcak, Weinberg, MacNamara, & Foti, 2012; Keil et al., 2001; Olofsson, Nordin, Sequeira, & Polich, 2008). LPP amplitudes are highest for affective stimuli that are directly related to biological imperatives, particularly threat and reproduction (Weinberg and Hajcak, 2010). Several studies have indicated that LPP amplitudes are reduced by top-down control over attention and emotional responses, such as when participants are instructed to deliberately focus their attention to non-arousing features of a stimulus (Hajcak et al., 2001), or to engage in cognitive reappraisal or distraction in reference to emotionally charged images (Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011) or facial expressions (Blechert, Sheppes, Di Tella, Williams, & Gross, 2012; Hajcak and Nieuwenhuis, 2006; MacNamara, Ochsner, & Hajcak, 2011). The LPP is also sensitive to cultural differences in emotional suppression (Murata, Moser, & Kitayama, 2012). Additional evidence suggests the modulating influence of stimulus valence on the LPP reflects rapid processing driven specifically by a current focal stimulus, and are not influenced by the valence of stimuli presented on preceding trials (Schupp, Schmälzle, Flaisch, Weike, & Hamm, 2013).

Of central importance to the present study, LPP amplitudes are increased when people confront a variety of distinct threats, including uncertainty, which further supports the LPP as a robust measure of stimulus appraisal. For example, LPP amplitudes are increased when spider-phobic individuals are presented with spider-related stimuli (Schienle, Schäfer, and Nauman, 2008). The experience of acute stress has been found to bias stimulus processing toward unpleasant cues, as measured by heightened LPP amplitude (Weymar, Schwabe Löw, & Hamm, 2012). LPP amplitudes are also amplified when participants engage in proximal defenses against existential threats, such as death (Klackl, Jonas, & Kronbichler, 2013). Most importantly, when participants’ are exposed to stimuli that increase uncertainty (e.g., ambiguous facial expressions),
LPP amplitude is increased compared to unambiguous positive and negative emotional stimuli (Tritt, Peterson, and Inzlicht, under review).

**Specific aim 2.** An incipient body of neuroimaging and ERP evidence indicates that uncertainty modulates neurological activity associated with the appraisal of aversive stimuli presented under conditions of uncertainty (Davis and Whalen, 2001; Phelps and LeDoux, 2005; Rosen and Donley, 2006; Rosen and Schulkin, 1998; Sarinopoulos et al., 2010; Whalen, 1998), including a post-stimulus marker of emotional appraisal known as the LPP (Tritt, Peterson, and Inzlicht, under review). The second specific aim of the present study is to determine whether emotional appraisal as indexed by the LPP is largest for aversive stimuli presented following uncertainty about the nature of an emotional image stimulus, compared to when participants know that an upcoming emotional image stimulus will be aversive (see Figure 1, Specific Aim 2). After conducting a region of interest analysis to determine that the LPP is modulated by affective picture content at electrode locations consistent with past research, I will examine whether uncertainty about a forthcoming stimulus increases LPP amplitude following exposure to aversive and neutral image stimuli.

**Mindfulness and Emotional Appraisal**

Ancient Buddhist and contemporary Western descriptions of mindfulness highlight heightened attention and awareness of the present as a primary defining feature (Brown & Ryan, 2003; Bodhi, 2011). As a mode of attention deployment, mindfulness involves establishing open and receptive attention to internal and external experiences as they occur in the present moment (Anālayo, 2003; 2013; Bishop, 2002; Bodhi, 2011; Brown & Ryan, 2003; Dreyfus, 2011; Dunne, 2011; Kabat-Zinn, 1994). Said differently, mindfulness involves maintaining an “equanimous receptivity” to whatever occurs in present moment experience (Anālayo, 2003; 2014; Bodhi,
2011). Rather than preferencing or evaluating certain experiences, mindfulness involves simply remaining aware of what occurs (Teasdale, 1999), including unpleasant experiences. This is not to say that thoughts, appraisals, and judgments do not arise during states of mindfulness, or that pleasant and unpleasant experiences are avoided (or approached). A characteristic that exemplifies the receptive nature of mindfulness involves allowing the stream of emotions, thoughts, and appraisals – whatever arises in awareness -- to take their course through awareness. This capacity to grant all experiences equal time on the stage of awareness promotes a more balanced, empirical perspective toward the data of immediate experience (Brown, Ryan, & Creswell, 2007), such that the full-range of experiences is allowed, including those experiences we are motivated to avoid, such as uncertainty. This mindful orientation enables one to watch the unfolding of subjective states from the perspective of an observer, rather than getting carried away by the flow of thoughts and ongoing commentary about experience (Brown and Ryan, 2003; Kabat-Zinn, 1990).

Clinical perspectives on mindfulness propose that this heightened receptivity promotes psychological and behavioral flexibility such that clients are better able to stay with and witness aversive experiences, rather than avoid them, and thereby promotes more autonomous, skillful responses (Follette et al., 2006; Greeson et al., 2009). Mindfulness has been incorporated into several evidence-based therapies to enhance the effective treatment of psychopathology due to these adaptive regulatory benefits (Didonna, 2009), including Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1990), Dialectical Behavior Therapy (DBT; Linehan, 1993), Acceptance and Commitment Therapy (ACT; Hayes, 2005) and Mindfulness-Based Cognitive Therapy (MBCT; Segal et al., 2002). A number of meta-analytic reviews support the efficacy of mindfulness-based therapies for the treatment of several psychological disorders, including those
that covary with maladaptive responses to uncertainty, such as generalized anxiety disorder and depression (Bohlmeijer, Prenger, Taal, & Cuijpers, 2010; Hofmann, Sawyer, Witt & Oh, 2010; Piet & Hougaard, 2011; Vollestad, Nielsen, & Nielsen, 2012).

Mindfulness is theorized to promote greater receptivity to affective states, and as a consequence, heightened sensitivity to interoceptive cues that indicate the need to regulate emotions (Teper, Segal, & Inzlicht, 2013). The burgeoning scientific literature on mindfulness is beginning to provide behavioral evidence for these emotion regulatory outcomes. For example, mindfulness training has been shown to improve the self-regulation of attention (Goldin et al., 2009; Jha et al., 2007) and to promote a greater willingness to stay with and experience aversive emotional stimuli (Arch & Craske, 2006). Dispositional mindfulness has been associated with adaptive responses to a variety of aversive emotional states, including social evaluative threat (Brown, Ryan, Creswell, & Niemiec, 2008; Brown, Weinstein, & Creswell, 2012), aversive socioemotional stimuli (Brown et al, 2013; Way et al., 2010; Taren, Creswell, and Gianaros, 2013), and mortality salience (Kashdan, Afram, Brown, Birnbeck, & Drvoshanov, 2011; Niemiec et al., 2010).

I theorize that mindfulness might also play a role in promoting adaptive emotional responses following uncertainty. Anxious responses to uncertainty are perpetuated when people repetitively engage in future-oriented thinking about potentially negative uncertain outcomes (Grupe & Nitschke, 2013), and such exaggerated attempts to resolve uncertainty are antithetical to mindfulness. Mindfulness is inherently present-oriented state during which affect is experienced in an open and receptive way, including negative affect (Arch & Craske, 2006). Dispositional mindfulness has been associated with lower levels of rumination, and lower levels of self-reported negative affect (Brown & Ryan, 2003). Rather than attempting to change or
resolve uncertainty, a mindful approach involves confronting uncertainty receptively and observing the thoughts, feelings, and emotions that follow. By dampening the tendency to manipulate and resolve uncertainty, mindfulness may promote more comfort with uncertainty and ameliorate the tendency for uncertainty to increase negative appraisals, indexed here by negative affect and picture ratings, following an uncertainty cue and subsequent exposure to aversive stimuli.

**Specific aim 3.** The third specific aim of the present study is to determine whether trait mindfulness will predict less unpleasant affect and stimulus ratings following the display of uncertain stimulus cues (see Figure 1, Specific Aim 3). To address this aim I will test whether trait mindfulness lessens unpleasant affect after uncertain stimulus cues and aversive images. I will also test whether trait mindfulness will predict less negative image ratings after uncertain stimulus cues and aversive images. Additionally, to test the specificity of these questions concerning mindfulness, I will also examine whether traits that contrast with mindfulness, such as uncertainty distress and anxiety-related traits, will predict higher unpleasant affect and more negative image ratings following uncertainty stimulus cues and aversive images.

**Mindfulness and neural measures of emotional appraisal.** Evidence drawn from neuroimaging and ERP-related studies are consistent with behavioral studies by suggesting that mindfulness promotes adaptive responses to negative affective states. Dispositional mindfulness as measured by the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) has been associated with heightened activity in the prefrontal cortex and the down-regulation of amygdalae activity during states of rest (Way, Creswell, Eisenberger, & Lieberman, 2010), and following emotional threats (Creswell, Way, Eisenberger, & Lieberman, 2007; Frewen et al., 2010; Modinos, Ormel, & Aleman, 2010), and has recently been associated with smaller right
amygdala volume (Taren et al., 2013). Other studies have linked MAAS-measured dispositional mindfulness (Way et al., 2010) as well as mindfulness training (Hölzel et al., 2008) with neural activation in the orbitofrontal cortex, a brain region implicated in the processing of uncertainty (Hsu et al., 2005; Krain et al., 2006), emotional appraisal (Oschner & Gross, 2005; Davidson, 2000), and the top-down regulation of amygdalae activity (Quirk and Beer, 2006). Dispositional mindfulness has also been associated with cortical indicators that are thought to be generated in the ACC and are responsive to stimulus uncertainty, such as the Error-Related Negativity (Teper and Inzlicht, 2013) and Feedback Related Negativity (Teper and Inzlicht, in press).

**Mindfulness and the Late Positive Potential.** Mindfulness is theorized to reduce the influence of appetitive and defensive impulses on perceptions and thought (Davis and Thompson, in press; Anālayo, in press), and emerging studies on mindfulness and the LPP provide empirical support this perspective. Recent ERP evidence indicated that two measures of dispositional mindfulness – the MAAS and the FFMQ act with awareness subscale – predicted attenuated LPP responses elicited by highly arousing pleasant (e.g., erotica) and unpleasant (e.g., mutilations) motivationally salient emotional images (Brown, Goodman, & Inzlicht, 2013). Another study conducted by Sobolewski, Holt, Kublik, and Wrobel (2011) reported similar findings when comparing experienced meditators with meditation naïve participants. That is, mindfulness practitioners showed reduced LPP deflections to unpleasant emotional stimuli compared to non-meditating controls.

These dampening effects of mindfulness on LPP responses to aversive emotional stimuli can be observed as early as 400ms after stimulus contact, and this is particularly interesting in light of previous work on emotion regulation and the LPP. As mentioned earlier (in the previous section on the LPP), studies have found that manipulations of attention (e.g., distraction) and
stimulus appraisal (e.g., taking a third person perspective) dampen LPP amplitudes to emotional picture content (Moser et al., 2009; Thiruchselvam et al., 2011). When participants are instructed to distract themselves from the emotional content, the LPP is modulated at an early time (as early as 300 ms), whereas instructions to engage in top-down reappraisal of the emotional content modulated the LPP much later after stimulus exposure (1500 ms). This is consistent with the process model of emotion regulation (Gross, 1998), which suggests that attention-related emotion regulation strategies have earlier influences than more effortful top-down reappraisal strategies. That mindfulness has been shown to attenuate the LPP responses at such an early stage in the time-course of emotional processing suggests that this dampening effect is more likely the result of an attention-deployment strategy, rather than a more effortful, top-down emotion regulation strategy, and is consistent with the theoretical framework that the adaptive emotional responses to aversive stimuli result from a distinct way of deploying attention.

**Specific aim 4.** This sensitivity of the LPP to uncertainty, emotional appraisal, and dispositional mindfulness suggests it is a viable window into the differences in emotional appraisal under conditions of uncertainty, as well as the moderation of this uncertainty amplification effect by dispositional mindfulness. The fourth specific aim of the present study is to determine whether dispositional mindfulness is associated with attenuated LPP responses to aversive emotional stimuli under conditions of uncertainty (relative to certainty) during an early time window of the LPP (see Figure 1, Specific Aim 4). To address this question I will test whether mindfulness is associated with lower deflections of the LPP following aversive images preceded by uncertainty relative to certainty cues across three time windows. Additionally, to test the specificity of these questions concerning mindfulness, I will also examine whether traits
that contrast with mindfulness, such as uncertainty distress and anxiety-related traits, will predict higher LPP deflections elicited by aversive image uncertainty, relative to certainty stimulus cues.

**Informational Uncertainty and Emotional Anticipation.**

In the previous sections, evidence was reviewed that suggests that uncertainty can increase unpleasant affect and negative stimulus perceptions during the appraisal of aversive emotional stimuli (Grupe & Nitschke, 2010; Sarinopoulos, Dixon, Short, Davidson, & Nitschke, 2006). This heightening of unpleasantness by uncertainty is theorized to result, at least in part, from changes during the anticipation of uncertain future outcomes, and specifically the tendency to expect that uncertainty will lead to aversiveness (Grupe & Nitschke, 2013), a phenomenon known as covariation bias (Tomarken, Mineka and Cook, 1989). In addition to replicating and extending past research on emotional appraisal following uncertainty, the present study will explore differences during anticipatory processing of emotional stimuli under conditions of uncertainty.

Prior research using an identical experimental paradigm has provided evidence that suggests participants commonly demonstrate expectations for uncertainty to lead to aversive outcomes (Grupe & Nitschke, 2011). Additional research indicates that uncertainty modifies activity in neural regions during the anticipation of emotional stimuli (for a review, see Grupe & Nitschke, 2013). The present study will replicate and extend this existing body of evidence by examining self-reported expectations during states of uncertainty, as well as a cortical measure of emotional anticipation known as the Stimulus Preceding Negativity (SPN). The SPN is an ERP measure thought to reflect the anticipation and the intensity of motivational engagement toward a forthcoming emotional stimulus (Moser et al., 2009; Poli, Sarlo, Bortoletto, Buodo, & Palomba, 2007; Takeuchi, Mochizuki, Masaki, Takasawa, and Yamazaki, 2005). Similar to the LPP, the
SPN is sensitive to the valence and arousal inducing properties of a stimulus (Howard, Longmore, & Mason, 1992; Poli et al., 2007), and the top-down modulation of stimulus meaning, or appraisal (Moser et al., 2009; Thiruchselvam et al., 2011).

Finally, the present study will explore dispositional mindfulness as a psychological quality that moderates self-reported and cortical measures of emotional stimulus anticipation under conditions of uncertainty. Mindfulness is expected to promote lower levels of covariation bias, and I will explore the relations between mindfulness and the SPN during emotional stimulus anticipation under conditions of uncertainty. In the following section, I will discuss relevant scholarly literature on the relationship between uncertainty and worry, and will outline how prior expectations for uncertainty to lead to aversive outcomes can lead to maladaptive perceptual and affective responses to uncertainty. After discussing the nature of uncertainty and anticipatory processes, I will outline my rationale for exploring the influence of mindfulness on anticipatory processing under conditions of uncertainty.

Uncertainty and Worry. The amplification of fear and aversion when faced with uncertainty can be debilitating, and can lead some people to worry excessively. Uncertainty is considered a primary feature of worry, which is defined as a state of anxious concern focused on how uncertain future events will occur (Buhr and Dugas, 2002; MacLeod, Williams, & Bekerian, 1991). Worry about uncertainty future outcomes can become crippling when people have exaggerated expectations that uncertainty will lead to aversive outcomes, a phenomenon known as covariation bias (Grupe & Nitschke, 2010). This heightened tendency to associate uncertainty with aversiveness commonly leads to maladaptive results in several life domains, such as health and finances (Camerer and Weber, 1992). It is not surprising that uncertainty about potentially negative future outcomes can drive people to worry excessively. Uncertainty signals that our
cognitive representations of the world are incomplete or inaccurate, and this can impair abilities to plan for and regulate responses to potentially negative future outcomes (Hirsh & Inzlicht, 2008). One way people detect and attempt to resolve uncertainty is through a process known as covariation assessment, and it is through this process that prior expectations and beliefs can begin to distort cognitive and affective responses to uncertainty in maladaptive ways.

**Covariation assessment.** People naturally develop elaborate cognitive representations to make sense of the world (Piaget, 1954), and these representations enable people to make the world seem coherent and meaningful (Heine, Proulx, & Vohs, 2006). Our mental representations are particularly useful during anticipation, and allow for predictions and planning for potential future adversity when faced with uncertainty (Grupe & Nitschke, 2013). When mental representations are recognized as lacking or inconsistent, people experience uncertainty and engage in various cognitive strategies to resolve it (Heine et al., 2006). This exploration represents a major brick in the foundations of social psychology research conducted in the 1950’s-1970’s. For example, when people face uncertainty about their standing in relation to others, they become motivated to engage in social comparison to resolve their uncertainty (Festinger, 1958). Similarly, when people are uncertain about the causes of others’ behavior they make causal attributions to understand the causes of their behavior (Heider, 1958; Kelley, 1973). When people simultaneously hold two conflicting ideas, they experience dissonance and become motivated to resolve the inconsistency (Festinger, 1957). In each of these instances the source of uncertainty involves detecting and recognizing that our mental representations are lacking or inaccurate.

Covariation assessment is a process used for detecting the relations between stimuli, behaviors, and outcomes (for reviews see Alloy & Tabachnik, 1984; Crocker, 1981). This
capacity to anticipate the future clearly serves an adaptive function as a way to make sense of past events, control the present, prepare for the future, obtain goals, and avoid negative outcomes. However, when people hold inaccurate beliefs or expectations about a situation, or how the future will unfold, this information can bias the outcome of covariation assessment processes and lead to predictions that are not in line with objective situational information.

**Biased expectations.** There is a substantial body of evidence that suggests people are notoriously poor at predicting future outcomes (Cordray & Shaw, 1978; Kahneman & Tversky, 1973; Nisbett & Ross, 1980). One common reason for such prediction errors is that the expectations people hold about a situation are heavily weighted and can distort perceptions of the situation. When our expectations are in line with objective situational information our predictions about future outcomes are typically more accurate than when our expectations are divergent from objective situational information. One reason for this is that our expectations can distort our covariation estimates, and any predictions we make based on those estimates will overwhelmingly reflect our preconceived notions and expectations, rather than the objective situation (Alloy & Tabachnik, 1984; Hastorf & Cantril, 1954; Nisbett & Ross, 1980). For example, when participants are asked to estimate the covariation between two dichotomous variables, their covariation estimates indicate utilization of only the information that they personally deem important, even when information that would disconfirm the covariation is manipulated to be more salient (Arkes & Harkness, 1983). This distorting influence of prior expectations becomes even more prominent under conditions of ambiguity. When people are placed in ambiguous situations and have no objective information on which to base covariation judgments, predictions depend primarily on prior expectations. That is, pre-existing beliefs and
expectations profoundly influence our predictions about future outcomes when faced with uncertainty and distort perceptions and affective states.

The expectations we bring to bear on our experiences have important implications for perceptual, affective, and cognitive processes. For example, in a study by Nitschke et al. (2006), participants who were led to think a substance would taste better than they expected reported lower aversion than participants who received accurate information. Expectations for more pleasant taste increased the activation of taste-related brain regions, and these changes in brain activation were corroborated with subjective reports of increased pleasantness. This evidence suggests that very basic perceptual processes can be influenced by expectations (Nitschke et al., 2006). Other similar studies have found that manipulating participants’ expectancies can bias olfactory and gustatory stimuli (de Araujo, Rolls, Velazco, Margot, & Cayeux, 2005) and aesthetic judgments of art and wine (Kirk, Skov, Hulme, Christensen, & Zeke, 2009). The most robust evidence comes from the widely known placebo effect found in drug studies and the treatment of pain, in which participants’ expectations have been shown to influence perceptions of treatment outcome. What is key about the findings from these studies is that expectations can exert a powerful influence on and distort perceptual processes.

**Covariation biases.** When uncertainty elicits expectations for unpleasantness, the anticipation and attempts to resolve uncertainty can become exaggerated, and become a potent source of anxiety (Grupe, Oathes, & Nitschke, 2011; Kagan, 1972). Anxious responses under conditions of uncertainty can lead to heightened expectations for aversion and distort the process of covariation assessment. The tendency to associate uncertainty with aversive outcomes is a type of covariation bias (Tomarken, Mineka and Cook, 1989), and research has implicated
covariation bias as a strong factor that contributes to the development of clinical anxiety disorders (Barlow, 2000; Borkovec, 2002).

Human and non-human primates are biologically predisposed to selectively associate particular stimuli and situations with aversiveness (e.g., blood and injury; Cook and Mineka, 1990; Pury and Mineka, 1997). While most people selectively associate threatening stimuli with aversive outcomes (Cook and Mineka, 1990), these effects are exaggerated among people with heightened anxiety and fear (Davey and Dixon, 1995). When selective associations become exaggerated, such as when uncertainty evokes heightened levels of fear and anxiety, they can play a central role in the etiology and maintenance of anxiety. Covariation bias is central to this process (Davey, 1992; 1995). A growing body of research has demonstrated that the presence of covariation bias can amplify the experience of fear (De Jong, Van den Hout, & Mercklebach, 1995). Exaggerated covariation assessments are thought to develop from experiencing a negative event that evokes anxiety, and the degree of anxiety elicited determines how strong the covariation bias will become (Pauli, Wiedemann, Dengler, & Kühlkamp, 2001).

Three distinct types of covariation bias are commonly studied in literature on anxiety (and will be measured in the proposed research): a priori covariation bias, online covariation bias, and a posteriori (or post-experiment) covariation bias.

*A priori covariation bias.* A priori covariation bias reflects a general baseline tendency to associate a stimulus with aversiveness prior at the outset of an experiment, when participants have no foreknowledge about the actual probability of co-occurrence between uncertainty and aversive outcomes. Studies examining a priori covariation bias have found that people with social phobia have a heightened a priori covariation bias to associate angry facial expressions with aversive experience, compared to non-phobics (Garner, Mogg, & Bradley, 2006; Hermann,
Ofer & Flor, 2004). Additional research suggests a priori covariation biases may be the outcome of prior states of anxiety in the context of uncertainty (Wiedemann, Pauli, & Dengler, 2001).

**Online covariation bias.** A second type of distorted covariation assessment is known as online covariation bias or expectancy bias, which refers to heightened expectations that one will receive a threatened aversive stimulus (UCS; such as an electrical shock or startle probe), more frequently following the presentation of a threatening stimulus (CS) compared to an innocuous stimulus (Davey, 1992; 1995). Exposure to fear-relevant stimuli has been found to increase online expectancy ratings and skin conductance responses, and a posteriori (post-experiment) estimates of covariation bias (Amin & Lovibond, 1997). Across numerous studies, expectancy bias has been associated with trait anxiety (Chan and Lovilond, 1996). It has been suggested that online expectancy bias is related to deficits in threat appraisal and may contribute to the non-specific fear that is characteristic of anxiety disorders (Boddez et al., 2011). Online expectancy bias has been associated with the persistence of PTSD symptoms among soldiers returning from Iraq (Engelhard, de Jong, van den Hout, & Overveld, 2009), and online expectancy ratings are resistant to extinction in phobics (de Jong and Merckelbach, 1993).

**A posteriori covariation bias.** The third type of covariation bias involves the tendency to hold inflated retrospective (post-experiment) estimates of the co-occurrence between two stimuli, usually a negative stimulus and an aversive outcome (Chapman and Chapman, 1969; Tomarken, Mineka, & Cook, 1989). However, the valence dimension of emotional stimuli may not be the primary stimulus dimension that drives the development of a posteriori covariation biases. Using a fear potentiated startle paradigm, Witvliet and Vrana, (2000) found that the arousal inducing properties of a stimulus may be more important to the development of biased post-experiment estimates than the valence of the stimulus.
Pathological anxiety and phobias are strongly linked with biased post-experiment covariation estimates. Contamination phobic individuals associate the co-occurrence of contamination stimuli with aversive outcomes more than non-phobic individuals (Connolly, Lohr, Olatunji, Hahn, & Williams, 2009), and people with social phobia exhibit higher a posteriori covariation bias between social cues and negative outcomes (Herman, Ofer & Flor, 2004). Additionally, changes in the degree of covariation bias are an important indicator for psychological treatment. For example, a posteriori covariation biases are reduced among phobics who undergo behavioral treatment (de Jong and Merkelbach, 1993), and people with higher levels of a posteriori covariation bias toward spiders immediately following treatment are more likely to relapse after treatment and continue experiencing exaggerated fear of spiders (de Jong, van den Hout, & Merckelbach, 1995).

**Specific aim 5.** A recent study by Grupe and Nitschke (2011) demonstrated a priori and online covariation biases in response to stimulus uncertainty using the same paradigm as in the present study. Using a nearly identical paradigm, Sarinopoulos et. al (2010) found that uncertainty-related a posteriori covariation bias was associated with neural regions involved in the regulation of aversive experience. More specifically, they discovered that unpleasant stimuli preceded by uncertainty cues induced greater amygdalae activation than unpleasant images preceded by certainty cues. In line with other research described above, these studies suggest that covariation biases may predict the degree to which uncertainty amplifies unpleasant affect and unpleasant stimulus perceptions following aversive stimuli.

The fifth aim of the present research was to replicate past research that demonstrates that a priori and online covariation bias amplify unpleasant affect and stimulus ratings following the display of unpleasant stimuli under conditions of uncertainty. After checking whether
participants demonstrated significant a priori and online covariation biases, I examined the following two questions associated with specific aim 5 (see Figure 1, specific aim 5). Do expectations to associate uncertain cues with an unpleasant outcome (a priori and online covariation bias) predict more unpleasant affect after image exposure? Do expectations to associate uncertain cues with unpleasant outcomes (a priori and online covariation bias) predict more unpleasant image ratings after image exposure? I also examined whether a posteriori expectations to associate uncertain cues with aversive outcomes would be related to more unpleasant affect and image ratings after image exposure. In line with past research (Grupe & Nitschke, 2011), I did not expect that these a posteriori expectations would be associated with affect and image ratings.

**Informational Uncertainty and Neural Correlates of Anticipation.** A variety of neuroimaging studies provide experimental evidence that informational uncertainty elicits patterns of brain activity during anticipation that relates to downstream increases in physiological arousal during the anticipation of a reward/loss (Critchley, Mathias, & Dolan, 2001). In this study, Critchley et al. (2001) participants were presented with a playing card and asked to guess whether the next card would be higher or lower (S1) before receiving performance feedback indicating a monetary reward or loss (S2). Neural activity in the ACC and orbitofrontal cortex was modulated by the degree of outcome uncertainty, and increases in ACC activity were directly related to higher autonomic arousal as measured by galvanic skin response. These results are consistent with a recent meta-analysis that has associated the anticipation of performance feedback following decisions made under conditions of risk and ambiguity with the modulation of activity in the anterior cingulate and orbitofrontal cortices (Krain et al., 2006). Cortical measures of stimulus anticipation have also been identified that are sensitive to
manipulations of uncertainty (Brown, Seymour, Boyl, El-Deredy, & Jones, 2007) and emotional arousal (Moser et al., 2009; Poli, Sarlo, Bortoletto, Buodo, & Palomba, 2007; Takeuchi, Mochizuki, Masaki, Takasawa, and Yamazaki, 2005).

**The Stimulus Preceding Negativity.** The stimulus preceding negativity (SPN; also known as the non-motor contingent negative variation; Brunia & Damen, 1988) is a negative deflection of the stimulus-locked ERP that occurs during periods of emotional anticipation for a forthcoming stimulus (van Boxtel & Böcker, 2004). It is typically elicited using an S1-S2 paradigm, where S1 is a neutral cue that signals the display S2, which is commonly an emotional stimulus (Hajcak, Weinberg, MacNamara, & Foti, 2012). When the duration between S1 and S2 is sufficiently long (> 2s), the SPN can be divided into distinct subcomponents. An early SPN that occurs within the first 1000 ms is commonly called the orienting wave, and is thought to reflect the processing of S1 (Connor and Lang, 1969). There is a later component that reaches its negative maximum just before the display of S2, called the anticipatory wave (Weerts and Lang, 1973), and this component is thought to reflect heightened preparatory processing or attentional orienting toward an upcoming stimulus.

In paradigms where S2 would require some sort of motor response from the participant, the SPN reflects preparation for a motor response. But when no motor response is required, the component is thought to reflect the anticipation and the intensity of motivational engagement toward a forthcoming emotional stimulus (Moser et al., 2009; Poli, Sarlo, Bortoletto, Buodo, & Palomba, 2007; Takeuchi, Mochizuki, Masaki, Takasawa, and Yamazaki, 2005). Early studies of the SPN found significantly greater deflections during the anticipation of impending shock (Irwin et al., 1966; Rockstroh, Elbert, Sanavan, Lutzenberger, & Birbaumer, 1989), aversive noise (Regan & Howard, 1995) and unpleasant emotional pictures (Klorman & Ryan, 1980).
Furthermore, SPN amplitude has been correlated with other autonomic measures, such as heart rate and fear-potentiated startle (Baas et al., 2002).

Similar to the LPP, the SPN has been consistently found to be larger during anticipation of emotionally evocative stimuli (Simons et al., 1979), with larger negative deflections of the wave preceding unpleasant, but not pleasant pictures. Additional evidence has indicated the SPN is highly sensitive to the arousal inducing properties of the stimulus. For instance, Poli et al. (2007) manipulated both stimulus valence and arousal dimensions, and found the SPN deflections were larger (more negative) for images with higher normative arousal ratings. Also similar to the LPP, emerging evidence supports the theory that SPN deflections may reflect the motivational relevance of the picture content represented at S2, rather than the valence of an upcoming stimulus. Evidence for this assertion comes from studies where the SPN is larger for positive emotional stimuli that are highly arousing and motivationally salient, such as erotica (Howard, Longmore, & Mason, 1992).

One study of the SPN that is directly relevant to the present research was conducted to examine the influence of uncertainty and expectations on SPN amplitudes during the anticipation of pain induced by a heat stimulus (Brown, Seymour, Boyl, El-Deredy, & Jones, 2007). Expectancy ratings were found to influence SPN-measured anticipation, such that higher expectations of pain were associated with larger deflections of the SPN. In addition, participants’ ratings of the pain were directly associated with their prior expectations.

More recent studies of the SPN during anticipation of emotional stimuli are beginning to emerge that examine how top-down influences on emotion modulate the component. As already discussed, Moser et al. (2009) provided participants with instructions to use specific emotion regulation strategies to modify their emotional experiences during the anticipation of emotional
pictures. Three conditions were deployed in the study. On some trials participants were cued to view the pictures “as if from a detached, third person perspective” (reappraisal), while on other trials they were cued to “imagine [they] were personally partaking in the pictured events” (self-focused), or to simply view the pictures and respond naturally. Results indicated that instructions to decrease emotional responses by reappraising the picture content were associated with significantly larger (more negative) deflections of the SPN to unpleasant emotional stimuli, compared to viewing these unpleasant stimuli in a self-focused way. The authors suggested that this finding reflects that attempts to down-regulate emotion through reappraisal was associated with enhanced orienting and less negative anticipation of the upcoming picture.

In a related study, and as also discussed previously, Thiruchselvam et al. (2011) examined the modulation of SPN following cues to engage in top-down emotion regulation strategies. In this study participants received a cue to either (1) simply attend to the picture as normal (view and watch), (2) to distract themselves by “generating thought unrelated to the image presented on the screen” (distraction), or (3) to “adopt the perspective of a detached observer” (reappraisal). To determine whether participants were following the distraction instructions appropriately and not turning away from the emotional stimuli before it was presented, they examined the SPN, and found that cues to engage in distraction from the stimulus were associated with larger SPN amplitudes compared to the no-regulation instruction conditions. That participants had a higher SPN indicates that they were anticipating and orienting their attention towards the impending unpleasant stimulus before it was displayed (Thiruchselvam et al., 2011), and subsequently distracting themselves.

**Specific aim 6.** Research on the SPN suggests that the component reflects processes involved in the anticipation of motivationally relevant emotional stimuli, including the orienting
of attention toward the forthcoming stimulus. Similar to the LPP, the SPN is reliability elicited in response to highly arousing unpleasant stimuli, and has been shown to be sensitive to manipulations of expectation under conditions of stimulus uncertainty. Taken together, this evidence suggests that the SPN may be a valuable cortical marker to assess the influence of uncertainty on emotional stimulus anticipation. The sixth specific aim of the present study was to explore whether a cortical marker of pre-stimulus emotional anticipation known as the SPN increased following uncertain relative to certain-aversive and neutral stimulus cues (see Figure 1, specific aim 6). To replicate past research that has found the SPN sensitive to cueing information about the nature of an upcoming emotional stimulus, I will examine whether neutral, aversive, and uncertain stimulus cues indicating a subsequent stimuli is aversive will increase deflections of the SPN compared to cues indicating the stimulus will be neutral. I expect aversive and uncertainty cues to elicit higher SPN amplitudes than neutral cues, which would reflect heightened anticipation for the forthcoming emotional stimulus.

**Mindfulness and Anticipation.**

While I am aware of no existing evidence indicating that mindfulness would reduce covariation bias, the suggestion that mindfulness would attenuate covariation bias is consistent with current theoretical perspectives of the construct. One reason mindfulness may reduce covariation bias is due to its empirical orientation toward the facts of present-moment experience. Rather than engaging in thought about experiences, a mindful mode of processing is “similar to that of the objective scientist seeking accurate knowledge of some phenomenon” (Brown, Ryan, & Creswell, 2007, pp. 214). From this perspective, mindfulness should promote a greater willingness to stay with experiences that people are frequently motivated to avoid, such as uncertainty. In this way, mindfulness may function as a type of exposure (Arch & Craske,
When people avoid uncertainty they are less likely to learn that uncertainty is not always associated with aversive outcomes. By exposing oneself to the full experience of uncertainty, a person is more likely to learn that uncertainty does not always lead to unpleasantness, and could slow the development of online covariation bias, as well as weaken existing ones (a priori covariation bias).

**Specific aim 7.** The seventh specific aim of the present study was to explore whether trait mindfulness will predict lower levels of a priori and online covariation bias. To address this aim I ask the following research questions. First, is trait mindfulness related to lower a priori expectations for uncertainty cues to be followed by aversive images (less a priori covariation bias)? Second, is trait mindfulness associated with lower online expectations for uncertainty cues to be followed by aversive pictures (less online covariation bias)? To increase confidence in any mindfulness-related findings, analogous tests will be conducted to explore whether traits that contrast with mindfulness – such as measures of uncertainty distress, including intolerance for uncertainty and emotional responses to uncertainty, and anxiety-related traits, including neuroticism, worry, and depression – will predict opposite associations with a priori and online covariation biases.

**Mindfulness and the neural correlates of anticipation.** The majority of research on mindfulness and anticipatory processing to date comes from studies that have explored the influence of mindfulness on the perception of pain (Gard et al., 2012; Kingston et al., 2007; Grant and Rainville, 2009; Perlman et al., 2010; Zeidan et al., 2010; 2011). While anticipation of pain and emotion are distinct, they both induce anticipatory arousal and modulate brain activity in similar regions, and it has been suggested that anticipation of pain and emotion have similar mechanisms of action (Wiech et al., 2008). Gard et al. (2012) found that mindfulness
practitioners were able to reduce anxious arousal during anticipation of unpleasant electrical shock by 29% during a mindful state, and this reduction was associated with increased rostral anterior cingulate cortex activity. A second study found that experienced meditators self-report the same pain intensity as controls, but less unpleasantness, and enhanced habituation in the amygdalae and the anterior mid-cingulate during the anticipation of pain (Lutz, McFarlin, Perlman, Salomans, & Davidson, 2012). One potential mechanism for this pain reduction involves differences in anticipatory processing. Mindfulness is theorized to reduce the influence of expectations on pain due to decreased cognitive elaboration on sensory feedback (Zeidan et al., 2011).

Specific aim 8. While no research exists (to my knowledge) linking trait mindfulness with the modulation of SPN amplitude, past research has shown the SPN is sensitive to cue valence (Poli et al., 2007; Howard, Longmore, & Mason, 1992), attention deployment, and instructions to engage in top-down emotion regulation strategies (Moser et al., 2009; Thiruchselvam, 2011), as well as uncertainty (Brown, Seymour et al., 2007; Tritt, Peterson, & Inzlicht, under review). Trait mindfulness has been shown to decrease attention-related ERPs that are sensitive to emotional stimuli (Quaglia, Goodman, & Brown, under review). Thus, the eighth and final aim of the present study was to explore the relation of trait mindfulness to emotional stimulus anticipation by examining SPN amplitudes elicited by each type of stimulus cue (see Figure 1, Specific Aim 8). This investigation will be guided by two questions. First, is trait mindfulness associated with attenuated SPN amplitudes following uncertain, aversive relative to neutral stimulus cues? Second, to test the specificity of these questions concerning mindfulness, I will also examine whether traits that contrast with mindfulness (uncertainty
distress and anxiety-related traits) will predict larger SPN amplitudes elicited by uncertain and aversive cues, relative to neutral cues.

**The Present Research**

Uncertainty has been shown to amplify unpleasant experiences, and considerable evidence suggests anxiety is increased when emotional stimuli are preceded by uncertainty cues (Sarinopolous et al., 2010; Grupe et al., 2011). Research conducted using an identical paradigm as in the present study has provided evidence for this uncertainty amplification using self-reported expectations, stimulus ratings, peripheral nervous system (Grupe et al., 2011) and neuroimaging measures (Sarinopoulos et al., 2010). The present research will attempt to replicate effects from Grupe & Nitschke (2011) by demonstrating the influence of uncertainty-cues on self-reported emotional anticipation and appraisal. Second, the present study will attempt to extend this past research by capturing cortical measures of stimulus appraisal (the LPP) and anticipation (the SPN) that past research has indicated are sensitive to motivational relevance of a stimulus (Carretie et al., 2001; 2004; Cuthbert et al., 2000; Moser et al., 2009; Poli, Sarlo, Bortoletto, Buodo, & Palomba, 2007; Schupp et al., 2003; Takeuchi, Mochizuki, Masaki, Takasawa, and Yamazaki, 2005) and manipulations of uncertainty (Tritt, Peterson, & Inzlicht, under review; Brown, Seymour et al., 2007). Third, the present study will explore dispositional mindfulness as a psychological quality that dampens self-reported and cortical measures of negative emotional stimulus appraisal and anticipation under conditions of uncertainty.

The specific aims of the present study and their associated events in the trial structure of the cued image task are depicted in Figure 1. Participants observed one of three types of anticipatory cues [neutral (O), aversive (X), or uncertain (?)] before the presentation of an
aversive or neutral image. In between the cue and the image stimulus, participants were asked to rate how much they expected the subsequent stimulus will be pleasant vs. unpleasant, and after the image was displayed they were asked to rate either the valence of the picture, or their emotional state on Likert scales. The experimental paradigm collected all three measures of covariation bias described above, namely a priori, online, and a posteriori covariation biases.

**Specific aim 1.** Several studies have demonstrated that unpredictable threats are more anxiety provoking and elicit greater physiological responses than the same threats when they are predictable (Bar-Anan, Wilson, & Gilbert, 2009; Dickerson & Kemeny, 2004; Grupe & Nitschke, 2011; Hirsch & Inzlicht, 2008; Kimmel, 1967; Nader & Belleine, 2007; Sarinopoulos et al., 2010). Moreover, when people associate uncertainty with aversive outcomes, these biased expectations can influence how unpleasant stimuli are appraised (Grupe & Nitschke, 2011; Sarinopoulos, Dixon, Short, Davidson, & Nitschke, 2006). The first specific aim of the present study was to replicate the findings that stimuli presented under conditions of uncertainty elicit greater self-reported unpleasant affect and unpleasant stimulus ratings compared when the nature of the emotional stimulus is known. After checking to determine participants understood the nature of the stimulus cues, I examined the following questions:

- **Question 1.1.** When aversive and neutral images are preceded by uncertainty cues do they elicit more negative appraisals (higher unpleasant affect) after exposure to the image than neutral and aversive images preceded by certainty cues?

- **Question 1.2.** When aversive and neutral images are preceded by uncertainty cues do they elicit more negative appraisals (higher unpleasant stimulus ratings) after exposure to the image than neutral and aversive images preceded by certainty cues?
Specific aim 2. An emerging body of neuroscientific evidence indicates that uncertainty also modulates neurological activity involved during the appraisal of aversive stimuli presented under conditions of uncertainty (Davis and Whalen, 2001; Phelps and LeDoux, 2005; Rosen and Donley, 2006; Rosen and Schulkin, 1998; Sarinopoulos et al., 2010; Whalen, 1998), including a post-stimulus marker of attention and emotional appraisal known as the LPP (Tritt, Peterson, and Inzlicht, under review). The second specific aim of the present study was to determine whether emotional appraisal as indexed by the LPP is largest for aversive and neutral stimuli presented following uncertainty cues, relative to certainty cues. After conducting a region of interest analysis to determine that the LPP is modulated by affective picture content at electrode locations consistent with past research, I examined the following questions:

- **Question 2.1.** Do certain and uncertain aversive images elicit larger LPP amplitudes than certain and uncertain neutral images?
- **Question 2.2.** Do uncertainty-cued aversive and neutral images elicit larger LPP amplitudes than certainty-cued aversive and neutral stimuli?

Specific aim 3. The third specific aim of the present study was to determine whether trait mindfulness would predict more benign appraisals - less unpleasant affect and less unpleasant stimulus ratings - following the display of uncertain stimulus cues. To address this aim I examined the following questions:

- **Question 3.1.** Does trait mindfulness predict lower unpleasant affect following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images?
• **Question 3.2.** Does trait mindfulness predict lower unpleasant stimulus ratings following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images?

• **Question 3.3.** Do traits that contrast with mindfulness (measures of uncertainty distress and anxiety-related traits) predict higher unpleasant affect following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images?

• **Question 3.4.** Do traits that contrast with mindfulness predict higher unpleasant stimulus ratings following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images?

**Specific aim 4.** The fourth specific aim of the present study was to determine whether dispositional mindfulness would predict attenuated LPP responses to aversive relative to neutral emotional stimuli under conditions of uncertainty and certainty, during an early time period (500-1000ms) of the LPP. To address this aim I examined the following questions:

• **Question 4.1.** Is trait mindfulness associated with lower deflections of the LPP following aversive images relative to neutral images when preceded by uncertainty and certainty cues?

• **Question 4.2.** Do traits that contrast with mindfulness predict higher LPP deflections elicited by aversive images relative to neutral images when preceded by uncertainty and certainty cues?

**Specific aim 5.** Empirical evidence suggests that anticipatory, covariation biases may predict the degree to which uncertainty amplifies of unpleasant affect and unpleasant stimulus perceptions following aversive stimuli (Grupe & Nitschke, 2011; Sarinopoulos et al., 2010). The
fifth aim of the present research was to replicate this past research by demonstrating a priori and online covariation biases amplify unpleasant affect and stimulus ratings following the display of unpleasant stimuli under conditions of uncertainty. After checking whether participants demonstrated significant a priori and online covariation biases, I examined the following two questions:

- **Question 5.1.** Do anticipations or expectations to associate uncertain cues with unpleasant outcomes (a priori and online covariation bias) predict more unpleasant affect after neutral and aversive image exposure under conditions of uncertainty relative to certainty?

- **Question 5.2.** Do expectations to associate uncertain cues with unpleasant outcomes (a priori and online covariation bias) predict more unpleasant image ratings after neutral and aversive image exposure under conditions of uncertainty relative to certainty?

**Specific aim 6.** The sixth specific aim of the present study was to explore whether a cortical marker of pre-stimulus emotional anticipation known as the SPN was larger (less positive) following uncertain and certain-aversive stimulus cues compared to neutral stimulus cues. After conducting a region of interest analysis to determine that the SPN was modulated by affective picture cues at electrode locations consistent with past research, I examined the following questions:

- **Question 6.1.** Do uncertain and certain-aversive stimulus cues elicit larger (less positive) deflections of the SPN compared to certain-neutral stimulus cues?
Specific aim 7. The seventh specific aim of the present study was to explore whether trait mindfulness would predict lower levels of a priori and online covariation bias. To address this aim I examined the following research questions.

- **Question 7.1.** Does trait mindfulness predict lower expectancies for the first uncertainty cue to be followed by an aversive image (less a priori covariation bias)?
- **Question 7.2.** Does trait mindfulness predict lower online expectations for aversive pictures to follow from uncertain and certain-aversive cues relative to neutral cues (less online covariation bias)?
- **Question 7.3.** Do traits that contrast with mindfulness predict higher expectancies for the first uncertainty cue to be followed by an aversive image (higher a priori covariation bias)?
- **Question 7.4.** Do traits that contrast with mindfulness predict higher online expectations for aversive pictures to follow from uncertain and certain-aversive cues relative to neutral cues (less online covariation bias)?

Specific Aim 8. The eighth aim of the present study was to explore whether trait mindfulness was associated with differences in the SPN amplitudes elicited by each type of stimulus cue. This investigation was guided by two questions:

- **Question 8.1.** Is trait mindfulness related to attenuated SPN amplitudes elicited by uncertain and aversive cues, compared to neutral cues?
- **Question 8.2.** Do traits that contrast with mindfulness predict higher SPN amplitudes following uncertain and aversive cues, relative to neutral cues?
Method

Power Analysis

A previous study assessing mindfulness as a moderator of LPP amplitude (Brown, Goodman, & Inzlicht, 2013), yielded a medium ($d = .63$ to $.70$) effect size. A repeated measures MLM-based power analysis was conducted using Optimal Design Software (Raudenbush et al., 2011). Assuming medium effect size, a sample of $N = 60$ participants was considered sufficient to achieve a power of .80 when is set at .05.

Participants

Participants consisted of 64 undergraduate students at a mid-Atlantic university who were right-handed and volunteered to partially fulfill a course requirement for their Introductory Psychology course. Participants with a history of neurological or psychiatric illness were excluded from the study ($n=2$). Data from six participants were discarded due to excessive paroxysmal artifact in the EEG signal ($n = 6$) or poor electrode impedances ($n = 2$), and three participants were excluded for procedural non-compliance during the EEG recording for the Cued Image Task [sleeping ($n = 1$), eating ($n = 1$), rushing ($n = 1$)]. The remaining 52 participants [(29 (58%) female; 2 undeclared] gave informed consent prior to participation in accordance with the Institutional Review Board.

Psychometric Measures

**Trait Mindfulness.** Two widely used measures were administered to capture individual differences in trait mindfulness. Central to most definitions of mindfulness in the western scholarly literature is the increased quality of present-focused attention and awareness. However, many other distinct facets (e.g. nonjudgment, the ability to describe experiences) have been incorporated in several existing measures of mindfulness, largely stemming from the wide
utilization of mindfulness as tool in psychotherapeutic contexts (Goodman, Quaglia, & Brown, 2013). The Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) and the Act with Awareness Subscale of the Five Factor Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietmeyer, & Toney, 2006) are robust measures of dispositional mindfulness that directly capture conceptualization of the mindfulness construct in a way that is consistent with our theoretical approach. For this reason, I decided to measure mindfulness using these measures, rather than many of the other psychometric instruments that take distinct approaches to the construct.

The Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003; sample α = .85) captures individual differences in the tendency to be attentive to and aware of the present moment using 15 items. Responses are indicated on a 6-point Likert-type scale (almost always to almost never) to items such as "I find it difficult to stay focused on what’s happening in the present" and "I snack without being aware that I’m eating." Higher scores on the MAAS indicate higher mindfulness. Several independent analyses attest to the validity and unidimensional factor structure of the MAAS (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006; Brown & Ryan, 2003; Carlson & Brown, 2005; Cordon & Finney, 2008; MacKillop & Anderson, 2007). A second mindfulness measure -- The Five-Factor Mindfulness Questionnaire (FFMQ; Baer et al., 2006; sample α = .94) -- captures 5 distinct skills used during mindfulness practice in 39-items, and uses a 1 (never or very rarely true) to 5 (very true or always true) Likert type scale. Of interest to the present study is the Acting with Awareness subscale (sample α = .89), as it most closely reflects our conceptualization of mindfulness as open and receptive awareness. Higher scores on the FFMQ indicate higher levels of mindfulness.
Uncertainty Distress. Two scales were administered to capture individual differences in distress evoked from states of uncertainty. The Intolerance of Uncertainty Scale (IUS; Buhr & Dugas, 2002; sample $\alpha = .93$) was administered to measure individual differences in affective responses to situations with uncertain outcomes. The 27-item IUS assesses the degree to which people endorse notions that uncertainty is stressful and upsetting, uncertainty leads to the inability to act, uncertain events are negative and should be avoided, and uncertainty is unfair, all using a 5-point Likert scale ranging from 1 (not at all characteristic of me) to 5 (entirely characteristic of me). The 48-item Uncertainty Response Scale (URS; Greco & Roger, 2001; sample $\alpha = .81$) was administered to capture individual differences in the way people cope with uncertainty across three domains (emotional responses to uncertainty, cognitive responses to uncertainty, and the desire to change uncertainty). The scale has high internal consistency and test-retest reliability and has been validated using psychological and physiological measures sensitive to uncertainty threat. The present study will focus on the emotional responses to uncertainty subscale.

Anxiety. Three measures were administered to assess maladaptive personality traits related to anxious responses to uncertainty. Participants completed the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990; sample $\alpha = .94$) to assess clinically significant aspects of worry, such as the generality of worry across time and situations, and the inability to control the worrying process. Responses to each of the 16-item PSWQ items are indicated on a 1 (not typical of me at all) to 5 (very typical of me) Likert-type scale. The neuroticism subscale of the NEO-FFI (Costa and McCrae, 1992; sample $\alpha = .78$) was administered to assess dispositional anxiety, hostility, depression, impulsiveness and vulnerability using a 5-point scale (strongly disagree to strongly agree). Higher scores on this
scale indicate higher neuroticism. Depressive symptomology was measured using the 20-item Beck Depression Inventory (Beckham & Leber, 1985; sample $\alpha = .88$).

**Stimulus Materials**

Images used in the present study were selected from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2008) and were identical to those used by Grupe & Nitschke (2011). The most aversive images specific to each gender were selected separately on the basis of having the most unpleasant valence ($M = 2.31$) and highest arousal ($M = 6.09$) ratings based on publish norms (Lang et al., 2008). These pictures generally included pictures of mutilated bodies or violent attack scenes. Neutral images were selected on the basis of having neutral valence and arousal ratings and consisted primarily of photographs of everyday household objects. Participants were randomized to receive one of three pseudorandom presentation orders to control for order effects. Each stimulus set contained 4 blocks of 27 images from their gender-respective stimulus pool. Each stimulus block was matched to contain similar valence and arousal ratings for aversive and neutral images (see Table 1). Although the same picture sets were used for each gender, the stimulus orders varied which IAPS slides followed certain vs. uncertain cues. To ensure each of the stimulus orders were statistically equivalent, a $6$ (Stimulus Orders) $\times$ $4$ (Stimulus Type: certain aversive, certain neutral, uncertain

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1 The IAPS Slides administered for each gender and stimulus category were:

- **Male Aversive:** 1300, 1930, 2053, 2120, 2141, 2205, 2730, 2800, 2900, 3000, 3015, 3030, 3051, 3053, 3060, 3063, 3071, 3100, 3101, 3102, 3110, 3120, 3130, 3140, 3150, 3160, 3170, 3220, 3230, 3261, 3266, 3301, 3400, 3500, 3530, 3550, 6010, 6020, 6022, 6190, 6244, 6250, 6313, 6350, 6370, 6560, 6570, 6830, 8230, 9040, 9140, 9220, 9594, 9921.
- **Female Aversive:** 1300, 1930, 2053, 2120, 2141, 2205, 2730, 2900, 3000, 3015, 3030, 3060, 3071, 3100, 3102, 3110, 3120, 3130, 3140, 3150, 3170, 3180, 3220, 3230, 3261, 3301, 3400, 3500, 6010, 6020, 6022, 6190, 6213, 6244, 6250, 6313, 6350, 6370, 6550, 6560, 6834, 9040, 9050, 9140, 9220, 9250, 9252, 9253, 9300, 9410, 9433, 9490, 9561, 9571, 9594, 9910, 9921.

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Table 1. *Mean normative valence and arousal ratings for each pseudo-random stimulus order*

<table>
<thead>
<tr>
<th></th>
<th>Neutral</th>
<th>Uncertain-Neutral</th>
<th>Aversive</th>
<th>Uncertain-Aversive</th>
</tr>
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<td>Arousal</td>
<td>Valence</td>
<td>Arousal</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order 1</td>
<td>5.45 (.82)</td>
<td>3.41 (.82)</td>
<td>5.47 (.82)</td>
<td>3.43 (.79)</td>
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<tr>
<td>Order 2</td>
<td>5.47 (.92)</td>
<td>3.43 (.85)</td>
<td>5.41 (.54)</td>
<td>3.38 (.71)</td>
</tr>
<tr>
<td>Order 3</td>
<td>5.47 (.85)</td>
<td>3.40 (.81)</td>
<td>5.43 (.75)</td>
<td>3.44 (.79)</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order 1</td>
<td>5.46 (.78)</td>
<td>3.15 (.71)</td>
<td>5.59 (1.06)</td>
<td>3.17 (.74)</td>
</tr>
<tr>
<td>Order 2</td>
<td>5.54 (.89)</td>
<td>3.18 (.71)</td>
<td>5.45 (.86)</td>
<td>3.10 (.73)</td>
</tr>
<tr>
<td>Order 3</td>
<td>5.46 (.78)</td>
<td>3.14 (.69)</td>
<td>5.53 (.98)</td>
<td>3.19 (.77)</td>
</tr>
</tbody>
</table>

*Note.* Each pseudo-random trial order contained 32 neutral slides and 32 aversive slides preceded by respective certainty cues. Sixteen aversive slides and 16 neutral slides were preceded by uncertainty cues. Each rating is indicated on a 0 to 9 scale.
aversive, uncertain neutral) Between Subjects Factorial ANOVA was conducted on the normative valence and arousal ratings to verify that each of the stimulus sets were statistically equivalent. As expected, there were no main effect for stimulus order \( [F(5, 575) = .39, p = .86, \eta^2 = .004] \) and no significant order \( \times \) stimulus type interaction \( [F(15, 575) = .08, p = .99, \eta^2 = .002] \) on valence. The model testing arousal also indicated no significant main effect for stimulus order \( [F(5, 575) = 1.10, p = .36, \eta^2 = .01] \), nor an order \( \times \) stimulus type interaction, \( F(15, 575) = .27, p = .99, \eta^2 = .01 \). This suggests statistical equivalence between the stimulus categories across normative valence and arousal ratings that accompany the IAPS stimulus set (Lang et al., 2008).

**Procedure**

Each participant was randomized to receive one of three gender-specific pseudorandom trial orders while they completed the battery of individual difference measures. Following the administration of self-report measures, each participant was fitted to a Stretch-Lyrca EEG cap (Neuroscan Quikcap®) and received verbal instructions about how to complete a Cued Image Task on the computer. The task was administered using similar parameters as prior studies (Grupe & Nitschke, 2011; Sarinopoulos et al., 2010), in which participants observe one of three types of anticipatory cues (neutral, aversive, or uncertain) before the presentation of an aversive or neutral image. In between the cue and the image stimulus, participants are asked to rate how much they expected the subsequent stimulus to be pleasant vs. unpleasant, and after the image is displayed they were asked to rate the valence of the picture, or of their mood state.

Trials began with the visual presentation of a 2 second cue image in the center of the computer monitor that indicated to participants the valence (aversive or neutral) of an upcoming picture. Three different types of anticipatory cues were displayed: an “X” cue, which always
indicated the upcoming picture would be unpleasant (e.g. a mutilated body), an “O” cue, which always indicated an upcoming picture would be neutral (e.g., a spoon), and a “?” cue, which indicated uncertainty about the type of picture that would be displayed. Exactly 50% of the images following uncertainty cues were neutral, and 50% were aversive. Participants received on-screen instructions explaining the relations between cues and pictures, but were not informed that the “?” cues preceded the exact same number of unpleasant and neutral images. An illustration of each of the four types of trial sequences is depicted in Figure 2.

Immediately following the presentation of a cue, participants were presented with an expectancy rating scale. The prompt “Expect Aversive Picture?” appeared above a visual Likert-type scale with values ranging from 1 (expect neutral) to 9 (expect aversive), and the mid-point value of 5 labeled as ‘uncertain.’ Participants used left and right arrow buttons on an external button box to navigate an indicator arrow to their chosen expectancy rating value, and then pressed an enter button to confirm their expectancy rating. The scale remained on the screen until participants indicated a response.

The expectancy rating scale was be followed by a random interstimulus interval between 4 to 10 seconds and then a neutral or unpleasant image appeared centrally on the screen for a duration of 1 second. Each picture was between 5 to 7 seconds, after which a mood or picture valence rating scale (only one rating per trial) appeared. Both scales were be labeled as follows: -4 = “unpleasant/negative,” 0 = “neutral,” +4 = “pleasant/happy.” 50% of the time participants were asked to rate their mood, and 50% of the time they were asked to rate the previous image. Participants indicated their rating using the identical procedure used for the expectancy rating. A 1 to 5 second intertrial interval will followed the rating scales. Each interstimulus and intertrial
Figure 2. Trial structure for each type of trial in the Cued Image Task.

Note. Each row represents a different type of trial. The pictures presented are exemplars of those that appeared during the task, but do not belong to the IAPS picture set. Cue types: ‘X’ = Aversive; ‘O’ = Neutral; ‘?’ = Uncertain.
interval consisted of a black background with a centrally presented yellow crosshair, on which the participants were instructed to fixate.

Participants completed a total of four blocks, each block contained 8 neutral images and 8 aversive images preceded by certainty cues (‘O’ and ‘X’, respectively). An additional 4 aversive and 4 neutral images were preceded by uncertainty cues (‘?’). Over the entire course of the study, participants viewed 32 aversive and 32 neutral images following certainty cues, and 32 images following uncertainty cues (16 aversive and 16 neutral images). Randomized within each block were 4-5 trials that presented cues which were not followed by an image. At the conclusion of each block 3-4 images appeared without being preceded by an anticipatory cue. Each participant took approximately 12 minutes per block, and had the opportunity for a short break in-between blocks. Following the Cued Image Task, each participant completed a post-experiment questionnaire that contained a short measure of covariation bias. Participants were asked: “What percentage of the question mark cues were followed by aversive events?” Upon completion of these measures, the experimenter removed the EEG sensor cap, and then debriefed and dismissed the participant.

**EEG recording and signal processing**

EEG was recorded using 36 sintered Ag/AgCl electrodes mounted in a Quik Cap (Neuroscan; El Paso, TX). Electrode positions were based on the 10-20 international system with a forehead ground and two monopolar references placed on the left and right mastoids. Continuous EEG was digitized at a sampling rate of 1000 Hz using a NuAmps Express digital amplifier (Neuroscan; El Paso, TX). Frequencies above 30Hz were removed using an online low-pass filter. The electro-oculogram (EOG) was recorded with monopolar
electrodes located below and on the outer canthus of each eye. Offline, the monopolar EOG channels were combined into bipolar channels.

EEGLAB 12.0 (Delorme & Makeig, 2004) and Matlab (Mathworks, www.mathworks.com) were used for offline EEG data processing. Bad channels were detected and removed with the automatic detection algorithms provided by EEGLAB. Continuous back-to-back epochs (1s) were generated from the continuous EEG signal. Epochs containing nonstereotypical artifacts were detected and rejected using native EEGLAB artifact detection algorithms sensitive to abnormal values, distributions, spectra, and linear trends. After rejecting epochs contaminated with paroxysmal artifacts, independent components analysis (ICA) using the infomax algorithm was used to correct remaining artifacts in the continuous EEG signal. High-pass filtering above .1 Hz has been shown to reduce ERP amplitudes (Luck, 2005), but ICA decomposition works most effectively on data that has been filtered over .5 Hz. To overcome this problem I followed the method outlined by Debener, Thorne, Schneider, and Viola (2010). Data containing stereotypical artifacts (e.g. blinks, eye movements, EKG) were high-pass filtered at 1hz offline to improve ICA decomposition, and then native EEGlab algorithms for epoch rejection (joint probability and kurtosis) were used to remove additional offending artifacts from the derived continuous ICA component activity. ICA was then conducted a second time on the remaining clean back-to-back epochs to improve the quality of the ICA decomposition and derive more ICA components that account for neural sources. The ICA weights from this second pass were then re-referenced to a common average reference and imported back into the original unfiltered continuous EEG data. Data epochs of interest were then extracted from the continuous EEG signal to capture the SPN (0 – 4000ms expectancy response) and LPP (-1000 to 1500ms picture stimulus) components. Epochs of interest were
baseline corrected and ICA components representing artifact were detected and pruned from the continuous EEG signal using MARA, an algorithm designed to detect and subtract artifactual ICA components from the underlying raw EEG signal (Winkler, Haufe, & Tangermann, 2011). Finally, epochs with signal that exceeded +/- 75 µV were removed. Grand average, artifact-free raw data epochs were then exported for analysis using SAS.

**Statistical Analysis**

Multiple steps were taken to ensure data met normality assumptions during the data analysis process. To check for violations of normality, skewness and kurtosis statistics were examined for all self-report, task-based, and ERP measures. Variables with skewness and kurtosis values that exceeded +/- 1.00 were considered to be in violation of the normality assumption, and frequency tables were then examined to identify offending values. Extreme observations were winsorized (Dixon & Tukey, 1968), meaning that outliers (i.e. higher than the 97th percentile and below the 3rd percentile) were replaced by a value nearer to the next highest value.

To account for the nested structure of the data, multilevel linear models with restricted maximum likelihood estimation (REML; Bryk & Raudenbush, 1992) were conducted using SAS PROC MIXED (Singer, 1998). Compound symmetry (TYPE=CS) was verified as the covariance structure with the lowest (best) goodness-of-fit indices (-2LL, AIC, BIC) across models with distinct outcome measures, as compared to Unstructured, Diagonal, Variance Components, and Autoregressive covariance structures. Independent mixed models were tested to explore any main and interactive effects between cue type and/or stimulus type, and psychological traits (dispositional mindfulness, uncertainty distress, and anxiety-related traits) on the primary dependent measures of interest (expectancy, picture, and mood ratings; SPN and
LPP amplitude). Independent variables representing cue type (0 = neutral; 1 = aversive; and 2 = uncertain) and stimulus type (0 = certain neutral; 1 = certain aversive; 2 = uncertain neutral; 3 = uncertain aversive) were identified as categorical variables using the CLASS statement (Singer, 1998). SAS treats variables included in the CLASS statement as categorical predictors and creates internal dummy variables to represent the levels of the variable.

**Results**

**Preliminary Analyses**

*Did participants understand the nature of the stimulus cues?* To examine whether participants understood the nature of the stimulus cues, a one-way repeated measures ANOVA was conducted to compare participants online expectancy ratings following neutral (“O”), aversive (“X”), and uncertainty (“?”) cues. It was expected that participants would self-report higher expectations for aversive images (higher expectancy ratings) following aversive stimulus cues than neutral for uncertain and neutral cues. Additionally, expectancy ratings for uncertain cues were expected to be higher than neutral cues. The model was significant, \( F(2, 102) = 361.09, p < .0001, \eta_p^2 = .88 \). Participants expected aversive images to follow from “X” cues (\( M = 7.66, \) s.d. = .90) more than “O” cues (\( M = 2.19, \) s.d. = 1.01) and “?” cues (\( M = 5.70, \) s.d. = .854); uncertain cues elicited higher expectancy ratings than neutral cues (both \( ps < .0001 \)). This pattern of participant expectancy ratings suggests that participants understood the nature of the cues.

**Specific aim 1: Uncertainty and self-reported appraisal.**

Grupe & Nitschke (2011) found that self-reported mood and picture ratings for aversive images were higher when preceded by uncertainty compared to certainty cues. To gain a more complete perspective on the nature of uncertainty and stimulus valence on self-reported appraisal, analyses were conducted to compare the main and interactive effects of stimulus cue
and stimulus valence on self-reported mood and picture ratings. Both mood and picture ratings were made on a -4 (“unpleasant/negative”) to +4 (“pleasant/happy”) scale with the midpoint (0) marked as “neutral”. The means and standard deviations for affect and stimulus ratings across cue type and stimulus type are depicted in Table 2.

Table 2. *Means and standard deviations for affect and stimulus ratings by cue type and stimulus type.*

<table>
<thead>
<tr>
<th>Measure</th>
<th>Certain Neutral</th>
<th>Uncertain Neutral</th>
<th>Certain Aversive</th>
<th>Uncertain Aversive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affect Ratings</td>
<td>.61 (.61)</td>
<td>.60 (.69)</td>
<td>-2.29 (.97)</td>
<td>-2.11 (1.06)</td>
</tr>
<tr>
<td>Picture Ratings</td>
<td>.72 (.60)</td>
<td>.52 (.56)</td>
<td>-2.40 (.74)</td>
<td>-2.64 (.79)</td>
</tr>
</tbody>
</table>

*Notes.* Ratings were made on a scale from -4 (unpleasant/negative) to +4 (pleasant/happy) with a midpoint of 0 labeled “neutral.”

**Question 1.1:** When aversive and neutral images are preceded by uncertainty cues do they elicit more negative appraisals (higher unpleasant affect) after exposure to the image than neutral and aversive images preceded by certainty cues? To test whether aversive and neutral images preceded by uncertainty cues elicited more negative appraisals (unpleasant affect) after image exposure than when aversive and neutral images were preceded by certainty cues, a 2 (stimulus valence: neutral, aversive) × 2 (cue type: certain, uncertain) repeated measures ANOVA was conducted on self-reported affect ratings. As expected, the model indicated a highly significant main effect for image valence [$F(1, 51) = 236.80, p < .0001, \eta^2_p=.82$], such that participants reported more unpleasant affect following aversive images ($M =$ -
2.196, s.d. = .14) compared to neutral images (M = .61, s.d. = .09). This result suggests that the stimuli influenced self-reported state affect in a way consistent with the valence of the emotional picture content. There was a not a significant main effect for cue \([F(1, 51) = 4.00, p = .051, \eta^2_p = .07]\), nor a significant cue \(\times\) stimulus valence interaction \([F(1, 51) = 2.79, p = .10, \eta^2_p = .05]\), which indicates that uncertainty did not amplify unpleasant affect following the display of the emotional stimuli.

Question 1.2: When aversive and neutral images are preceded by uncertainty cues do they elicit more negative appraisals (higher unpleasant stimulus ratings) after exposure to the image than neutral and aversive images preceded by certainty cues? To examine whether aversive and neutral images preceded by uncertainty cues elicited more negative perceptual appraisals (unpleasant image ratings) following image exposure than aversive and neutral images preceded by certainty cues, an analogous 2 (stimulus valence: neutral, aversive) \(\times\) 2 (cue type: certain, uncertain) repeated measures ANOVA was conducted on self-reported image ratings.

As with the prior analysis on mood ratings, there was a main effect for stimulus valence, \(F(1, 51) = 470.162, p < .0001, \eta^2_p = .90\). Participants self-reported perception of aversive images (M = -.2.52, s. d. = .10) were more unpleasant than neutral images (M = .62, s.d. = .07). This suggests participants’ perceptions of the images were consistent with the valence of the emotional images. There was also highly significant main effect of cue type \([F(1, 51) = 16.54, p = .0002, \eta^2_p = .25]\). Images were rated as more unpleasant when they were preceded by uncertain (M = -1.06, s.d. = .06) compared to certain cues (M = -.842, s.d. = .06). This indicates that uncertainty can alter the appraisal of emotional stimuli by increasing perceptions of unpleasantness. There was not a significant stimulus valence \(\times\) cue type interaction \([F(1, 51) = .19, p = .66, \eta^2_p = .004]\), which suggests the amplification of unpleasantness by uncertainty did not depend on whether the
stimulus was neutral or aversive. **Specific Aim 2: Uncertainty and cortical measures of stimulus appraisal.**

The second specific aim of the present study was to determine whether emotional appraisal as indexed by the LPP is largest for aversive and neutral stimuli presented following uncertainty about the nature of an emotional image stimulus, compared to when participants know an upcoming emotional image stimulus will be aversive or neutral. Before conducting this test it was necessary to conduct a region of interest analysis to determine whether the LPP component is present and sensitive to the emotional valence at electrode locations and time periods consistent with past research. Following the region of interest analysis, mixed models will be tested to formally evaluate the questions from specific aim 2.

**Preliminary Region of Interest Analysis on the Late Positive Potential.** Visual inspection of the ERP waveforms across electrode sites and stimulus conditions revealed that the LPP began, on average, ~500ms after stimulus onset and continued, on average, until ~2500ms after onset. This signal window is generally consistent with past studies using emotional visual stimuli (e.g., Cuthbert et al., 2000; Hajcak MacNamara, Foti, & Keil, 2011; Weinberg and Hajcak, 2011, Foti et al., 2010; Schupp et al., 2000). Figure 3 displays the scalp distribution of grand average LPP waveforms for each stimulus condition across a -100 ms (pre-stimulus) to 2500 ms (post-stimulus) recording period. Fifteen electrode sites of interest were divided into two independent spatial factors (anteriority and laterality) and one factor representing the early, middle, and late time windows of the LPP (signal window). Following the recommendations of Luck (2005), the cue and valence measures were collapsed into one variable (stimulus condition) to ease interpretation and minimize experimentwise error rate by reducing the number of
Figure 3. Scalp distribution of grand average LPP waveforms depicting each stimulus condition across a -100 ms (pre-stimulus) to 2500 ms (post-stimulus) recording period.
individual p-value computations (and potentially spurious 4 and 5-way interactions). Once a region of interest is statistically isolated, subsequent models will be conducted with stimulus condition variable separated into the cue and valence factors.

To examine the effects of electrode location, signal window, and stimulus condition on LPP amplitude a 5 [anteriority: frontal (F3, Fz, F4), fronto-cranial (FC3, FCz, FC4), central (C3, Cz, C4), centro-parietal (CP3, CPz, CP4), parietal (P3, Pz, P4)] × 3 [laterality: left (F3, FC3, C3, CP3, P3), midline (Fz, FCz, Cz, CPz, Pz), right (F4, FC4, C4, CP4, P4)] × 3 (signal window: 500-1000 ms, 1500-2000 ms, 2001-2500 ms) × 4 (stimulus condition: certain-neutral, certain-aversive, uncertain-neutral, uncertain-aversive) repeated measures mixed model using restricted maximum likelihood estimation (REML) (e.g., Bryk and Raudenbush, 1992) was tested. Means and standard deviations for average LPP amplitudes during each time window for left-hemisphere, midline, and right-hemisphere electrode sites are depicted in Tables 3-5, respectively. Parameter estimates for the full model are depicted in Table 6. Figure 4 depicts the ERP waveforms associated with neutral and aversive images preceded by certain and uncertain cues at the site CPz in the early, middle, and late signal windows. Figure 5 displays the scalp topographies at 100ms intervals depicting the time course of the differences in LPP amplitude between aversive and neutral stimuli. Figure 6 depicts the same information, but for the difference between aversive stimuli preceded by uncertain cues and aversive stimuli preceded by certain cues.

**Main effects.** There were significant main effects for anteriority [$F(4, 204) = 297.84, p < .0001$], laterality [$F(2, 102) = 14.40, p < .0001$], signal window [$F(2, 102) = 79.48, p < .0001$], and stimulus condition [$F(3, 153) = 112.14, p < .0001$]. The main effect of anteriority indicated, as expected, that LPP amplitude significantly increased at each level of anteriority as electrode
Table 3. Means and standard deviations for LPP amplitudes (µv) for each stimulus condition across early, middle, and late signal windows at left-hemisphere electrode positions

<table>
<thead>
<tr>
<th></th>
<th>Certain Neutral (0)</th>
<th>Certain Aversive</th>
<th>Uncertain Neutral</th>
<th>Uncertain Aversive</th>
<th>Grand Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td><strong>Frontal</strong></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Window</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000 ms</td>
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<td>-0.48 (4.73)</td>
<td>0.64 (4.95)</td>
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<tr>
<td>1500-2000 ms</td>
<td>-2.20 (3.57)</td>
<td>-1.67 (4.24)</td>
<td>-2.11 (3.90)</td>
<td>-2.06 (4.45)</td>
<td>-2.01 (4.03)</td>
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<td>2001-2500 ms</td>
<td>1.57 (3.74)</td>
<td>1.88 (4.29)</td>
<td>0.79 (4.95)</td>
<td>2.11 (5.04)</td>
<td>1.58 (4.53)</td>
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<tr>
<td><strong>Fronto-central</strong></td>
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<td></td>
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<td></td>
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<tr>
<td>Window</td>
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<tr>
<td>500-1000 ms</td>
<td>0.87 (3.40)</td>
<td>1.77 (4.02)</td>
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<td>1500-2000 ms</td>
<td>-1.14 (2.66)</td>
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<td>-0.39 (3.94)</td>
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<td>2001-2500 ms</td>
<td>2.03 (3.27)</td>
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<td>1.44 (3.93)</td>
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<td><strong>Central</strong></td>
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<tr>
<td>500-1000 ms</td>
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<td>1500-2000 ms</td>
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<td>0.79 (3.66)</td>
<td>1.78 (3.73)</td>
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<td>2001-2500 ms</td>
<td>1.86 (2.99)</td>
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<td>3.44 (4.33)</td>
<td>2.52 (4.01)</td>
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<td>Window</td>
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<tr>
<td>500-1000 ms</td>
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<td>1500-2000 ms</td>
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<td>3.20 (2.82)</td>
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<td>4.17 (3.38)</td>
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<td>2001-2500 ms</td>
<td>2.63 (3.28)</td>
<td>3.74 (3.82)</td>
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<td>500-1000 ms</td>
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<tr>
<td>1500-2000 ms</td>
<td>4.70 (3.45)</td>
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<td>4.97 (3.62)</td>
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<td>5.57 (4.06)</td>
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<tr>
<td>2001-2500 ms</td>
<td>1.99 (2.54)</td>
<td>2.89 (3.73)</td>
<td>2.73 (3.29)</td>
<td>2.61 (4.17)</td>
<td>2.56 (3.48)</td>
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<tr>
<td></td>
<td>1.35 (2.80)</td>
<td>2.30 (3.56)</td>
<td>2.08 (3.43)</td>
<td>1.90 (4.67)</td>
<td>1.91 (3.67)</td>
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Table 4. Means and standard deviations for LPP amplitudes (µv) for each stimulus condition across early, middle, and late signal windows at midline electrode positions.

<table>
<thead>
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<th>Certain Neutral (0)</th>
<th>Certain Aversive</th>
<th>Uncertain Neutral</th>
<th>Uncertain Aversive</th>
<th>Grand Mean</th>
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</thead>
<tbody>
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<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
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<td>Frontal</td>
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<tr>
<td>Window</td>
<td>Fz</td>
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<tr>
<td>500-1000 ms</td>
<td>-0.20 (3.69)</td>
<td>0.90 (4.22)</td>
<td>0.50 (4.05)</td>
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<td>1500-2000 ms</td>
<td>-2.26 (3.30)</td>
<td>-0.91 (4.20)</td>
<td>-1.20 (3.88)</td>
<td>-1.27 (4.91)</td>
<td>-1.14 (4.75)</td>
</tr>
<tr>
<td>2001-2500 ms</td>
<td>1.20 (3.50)</td>
<td>2.27 (4.12)</td>
<td>1.42 (3.75)</td>
<td>2.21 (4.66)</td>
<td>1.77 (4.03)</td>
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<tr>
<td>Fronto-central</td>
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<td>Window</td>
<td>FCz</td>
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<tr>
<td>500-1000 ms</td>
<td>0.24 (4.07)</td>
<td>1.55 (4.58)</td>
<td>0.33 (4.26)</td>
<td>1.61 (5.57)</td>
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<td>1500-2000 ms</td>
<td>-2.06 (3.57)</td>
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<td>-1.70 (4.34)</td>
<td>-0.97 (5.84)</td>
<td>2.63 (4.27)</td>
</tr>
<tr>
<td>2001-2500 ms</td>
<td>1.78 (3.77)</td>
<td>3.24 (4.21)</td>
<td>1.74 (3.79)</td>
<td>3.76 (4.95)</td>
<td>1.52 (4.12)</td>
</tr>
<tr>
<td>Central</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window</td>
<td>Cz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000 ms</td>
<td>1.64 (3.31)</td>
<td>3.53 (4.13)</td>
<td>1.37 (3.79)</td>
<td>4.05 (5.07)</td>
<td>1.32 (4.18)</td>
</tr>
<tr>
<td>1500-2000 ms</td>
<td>0.48 (3.02)</td>
<td>2.13 (4.39)</td>
<td>0.30 (3.71)</td>
<td>2.37 (5.01)</td>
<td>3.80 (4.26)</td>
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<tr>
<td>2001-2500 ms</td>
<td>2.58 (3.25)</td>
<td>4.86 (4.15)</td>
<td>2.19 (3.65)</td>
<td>5.56 (4.92)</td>
<td>1.52 (4.12)</td>
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<tr>
<td>Centro-Parietal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Window</td>
<td>CPz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000 ms</td>
<td>2.95 (3.51)</td>
<td>4.62 (4.10)</td>
<td>2.88 (3.82)</td>
<td>5.93 (4.85)</td>
<td>3.97 (4.20)</td>
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<tr>
<td>1500-2000 ms</td>
<td>3.10 (2.92)</td>
<td>4.62 (4.39)</td>
<td>2.84 (3.88)</td>
<td>5.30 (4.94)</td>
<td>4.67 (4.31)</td>
</tr>
<tr>
<td>2001-2500 ms</td>
<td>3.41 (3.78)</td>
<td>5.26 (4.22)</td>
<td>3.37 (3.93)</td>
<td>6.66 (4.50)</td>
<td>3.65 (4.29)</td>
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<tr>
<td>Window</td>
<td>Pz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000 ms</td>
<td>2.96 (4.01)</td>
<td>5.19 (4.23)</td>
<td>2.78 (4.38)</td>
<td>5.84 (5.55)</td>
<td>6.07 (4.29)</td>
</tr>
<tr>
<td>1500-2000 ms</td>
<td>4.96 (3.36)</td>
<td>6.99 (4.26)</td>
<td>4.68 (3.47)</td>
<td>7.63 (5.17)</td>
<td>3.68 (4.80)</td>
</tr>
<tr>
<td>2001-2500 ms</td>
<td>2.35 (3.88)</td>
<td>4.79 (4.22)</td>
<td>2.21 (4.39)</td>
<td>5.35 (5.77)</td>
<td>2.83 (4.61)</td>
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Table 5. Means and standard deviations for LPP amplitudes (µv) for each stimulus condition across early, middle, and late signal windows at right-hemisphere electrode positions.

<table>
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<tr>
<th></th>
<th>Certain Neutral (0)</th>
<th>Certain Aversive</th>
<th>Uncertain Neutral</th>
<th>Uncertain Aversive</th>
<th>Grand Mean</th>
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<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td><strong>Frontal</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000 ms</td>
<td>-0.02 (4.15)</td>
<td>-2.67 (3.41)</td>
<td>1.45 (3.70)</td>
<td>1.15 (4.02)</td>
<td>-2.22 (3.98)</td>
</tr>
<tr>
<td>1500-2000 ms</td>
<td>0.73 (4.74)</td>
<td>1.86 (4.20)</td>
<td>2.28 (4.39)</td>
<td>1.76 (4.57)</td>
<td>1.95 (4.11)</td>
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<tr>
<td>2001-2500 ms</td>
<td>0.33 (4.41)</td>
<td>-2.23 (3.61)</td>
<td>1.78 (3.96)</td>
<td>1.44 (4.51)</td>
<td>1.54 (4.51)</td>
</tr>
<tr>
<td><strong>Fronto-central</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Window</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>500-1000 ms</td>
<td>0.43 (3.74)</td>
<td>-1.30 (3.55)</td>
<td>3.10 (4.13)</td>
<td>1.25 (3.68)</td>
<td>-0.68 (3.91)</td>
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<tr>
<td>1500-2000 ms</td>
<td>1.84 (4.36)</td>
<td>0.00 (4.49)</td>
<td>1.62 (4.39)</td>
<td>2.43 (3.89)</td>
<td>2.39 (4.18)</td>
</tr>
<tr>
<td>2001-2500 ms</td>
<td>0.62 (4.20)</td>
<td>-1.27 (2.92)</td>
<td>3.51 (4.38)</td>
<td>1.50 (4.51)</td>
<td>2.09 (4.37)</td>
</tr>
<tr>
<td><strong>Central</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000 ms</td>
<td>1.98 (2.92)</td>
<td>0.84 (2.22)</td>
<td>2.68 (2.81)</td>
<td>2.43 (3.32)</td>
<td>1.34 (3.32)</td>
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<td>1500-2000 ms</td>
<td>2.78 (3.19)</td>
<td>1.51 (3.61)</td>
<td>3.90 (2.91)</td>
<td>2.99 (2.52)</td>
<td>3.31 (3.43)</td>
</tr>
<tr>
<td>2001-2500 ms</td>
<td>1.24 (3.62)</td>
<td>0.44 (3.10)</td>
<td>2.05 (3.58)</td>
<td>1.28 (4.00)</td>
<td>2.74 (3.69)</td>
</tr>
<tr>
<td><strong>Centro-Parietal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000 ms</td>
<td>2.61 (3.28)</td>
<td>3.19 (3.48)</td>
<td>2.46 (3.21)</td>
<td>2.18 (3.11)</td>
<td>4.19 (4.03)</td>
</tr>
<tr>
<td>1500-2000 ms</td>
<td>3.89 (4.09)</td>
<td>4.71 (4.16)</td>
<td>4.05 (4.18)</td>
<td>2.91 (3.78)</td>
<td>3.58 (4.05)</td>
</tr>
<tr>
<td>2001-2500 ms</td>
<td>2.82 (3.91)</td>
<td>3.38 (3.79)</td>
<td>2.75 (3.66)</td>
<td>2.33 (4.25)</td>
<td>2.97 (4.15)</td>
</tr>
<tr>
<td><strong>Parietal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000 ms</td>
<td>2.58 (3.26)</td>
<td>4.24 (3.20)</td>
<td>1.85 (2.72)</td>
<td>1.63 (3.24)</td>
<td>5.19 (4.13)</td>
</tr>
<tr>
<td>1500-2000 ms</td>
<td>3.73 (4.02)</td>
<td>5.72 (4.32)</td>
<td>2.94 (3.59)</td>
<td>2.55 (3.39)</td>
<td>2.64 (3.85)</td>
</tr>
<tr>
<td>2001-2500 ms</td>
<td>2.91 (4.18)</td>
<td>4.52 (3.70)</td>
<td>2.24 (4.01)</td>
<td>1.97 (4.42)</td>
<td>2.36 (4.16)</td>
</tr>
</tbody>
</table>
Table 6. *Parameter estimates modeling the scalp distribution of LPP amplitudes (µv) across signal window and stimulus condition.*

<table>
<thead>
<tr>
<th>Effect</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteriority</td>
<td>(4, 204)</td>
<td>297.84</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Laterality</td>
<td>(2, 102)</td>
<td>14.40</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Signal window</td>
<td>(2, 102)</td>
<td>79.48</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Stimulus condition</td>
<td>(3, 153)</td>
<td>112.14</td>
<td>.0001</td>
</tr>
<tr>
<td>Anteriority × Laterality</td>
<td>(8, 408)</td>
<td>3.26</td>
<td>.0013</td>
</tr>
<tr>
<td>Anteriority × Signal window</td>
<td>(8, 408)</td>
<td>103.86</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Laterality × Signal window</td>
<td>(4, 204)</td>
<td>4.88</td>
<td>.0009</td>
</tr>
<tr>
<td>Anteriority × Stimulus condition</td>
<td>(12, 612)</td>
<td>4.60</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Laterality × Stimulus condition</td>
<td>(6, 306)</td>
<td>4.24</td>
<td>.0004</td>
</tr>
<tr>
<td>Signal window × Stimulus condition</td>
<td>(6, 306)</td>
<td>0.82</td>
<td>.5553</td>
</tr>
<tr>
<td>Anteriority × Laterality × Signal window</td>
<td>(16, 814)</td>
<td>1.22</td>
<td>.2458</td>
</tr>
<tr>
<td>Anteriority × Laterality × Stimulus condition</td>
<td>(24, 1222)</td>
<td>1.61</td>
<td>.1815</td>
</tr>
<tr>
<td>Anteriority × Signal window × Stimulus condition</td>
<td>(24, 1224)</td>
<td>0.28</td>
<td>.9998</td>
</tr>
<tr>
<td>Laterality × Signal window × Stimulus condition</td>
<td>(12, 612)</td>
<td>0.35</td>
<td>.9797</td>
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<tr>
<td>Anteriority × Laterality × Signal window × Stimulus condition</td>
<td>(48, 2436)</td>
<td>0.19</td>
<td>1.000</td>
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</tbody>
</table>

*Note.* Levels of anteriority were frontal, fronto-central, central, centro-parietal, and parietal. Levels of laterality were left hemisphere, midline, and right hemisphere. Levels of signal window were early (500ms – 1000ms), middle (1500ms – 2000ms), and late (2001-2500ms). Levels of stimulus condition were certain-neutral, certain-aversive, uncertain-neutral, and uncertain-aversive. Tukey-Kramer adjusted p-values are presented.

sites became more posterior (all ps < .0001). The main effect of laterality indicated that electrodes on the left-side of the midlines had significantly lower LPP amplitudes than midline and right-lateralized electrode sites (ps < .0006). Midline and electrodes to the right of the midline were not significantly different from each other (p = .87). The main effect of signal window revealed significant differences across all three windows. The middle signal window (1500-1000 ms) had significantly more positive LPP amplitudes than the early (500-1000 ms)
and late signal windows (2001-2500 ms); the late signal window had significantly more positive LPP amplitudes than the early signal window (both ps < .0001). The main effect of stimulus condition replicated past research indicating LPP amplitude is sensitive to unpleasant, arousing emotional images (Cuthbert et al., 2000; Hajcak MacNamara, Foti, & Keil, 2011; Weinberg and Hajcak, 2011, Foti et al., 2010; Schupp et al., 2000). Irrespective of cue type, aversive images (certain: $M = 2.74$, s.d. = 4.39; and uncertain: $M = 3.09$, s.d. = 5.15) elicited significantly higher LPP amplitudes compared to neutral images (certain: $M = 1.52$, s.d. = 3.70; and uncertain images: $M = 1.52$, s.d. = 4.22, all ps < .0001). Importantly, aversive images preceded by uncertainty cues evoked significantly more positive deflections of LPP amplitude than aversive
Figure 5. Scalp topographies depicting differences in late positive potential amplitudes between aversive and neutral images at every 100 ms interval within the early, middle and late signal windows.

Note. Blue = negative amplitude; Red = positive amplitude.
Figure 6. Scalp topographies depicting differences in late positive potential amplitudes between aversive images elicited by uncertainty and certainty cues at every 100 ms during the early, middle and late signal windows.

Note. Blue = negative amplitude; Red = positive amplitude.
images preceded by certainty cues \( (p = .01) \). This suggests that stimulus uncertainty amplified the LPP amplitudes elicited by motivationally relevant aversive stimuli. No differences were observed between neutral stimuli when preceded by uncertainty and certainty cues \( (p = .77) \).

**Two-way interactions.** There was a significant anteriority \( \times \) stimulus window interaction, \( F(8, 408) = 103.86, p < .0001 \). LPP amplitudes during the early signal window (500-1000 ms) were significantly less positive than the middle (1500-2000 ms) and late (2001-2500 ms) signal windows across frontal, frontocentral, and central regions \( (all \ p_s < .0001) \). At central and centro-parietal the regions, the early and middle signal windows had higher amplitudes than the late window \( (all \ p_s > .04) \), and the early window. There was no difference in LPP amplitude during the early and middle signal windows. At parietal sites, LPP amplitudes were larger during the early window, compared to the middle and late windows \( (all \ p_s < .0001) \).

A significant laterality \( \times \) stimulus window interaction \( [F(4, 204) = 4.88, p = .0009] \) indicated that during the early signal window LPP amplitudes were largest at mid-line electrodes compared to left and right lateralized electrodes \( (all \ p_s > .001) \). The left and right hemispheres did not differ in LPP amplitude during the early window. During the middle window, midline electrode sites had significantly higher LPP amplitudes than left and right lateralize sites \( (both \ p_s < .0001) \), and there was a significant hemispheric difference indicating larger LPP amplitudes at right lateralized electrodes \( (p = .005) \). During the late window, this right sided preponderance was sustained: LPP amplitudes were larger at midline and right-side electrodes compared to left-sided electrodes \( (both \ p_s < .0001) \), but there was not a significant difference between midline and right-sided electrodes, \( p = .17 \).

A significant anteriority \( \times \) stimulus condition interaction indicated the effect of stimulus condition on LPP amplitude was different across levels of anteriority, \( F(12, 612) = 5.28, p < \)
At frontal sites, there were no significant differences in LPP amplitude due to stimulus condition (all $p$s > .58). However, LPPs elicited by certain and uncertain aversive images had higher LPP amplitudes than certain and uncertain neutral images at each level of anteriority from fronto-central to parietal scalp regions (all $p$s < .0001). At the centro-parietal midline there was evidence to suggest LPPs in response to aversive stimuli are amplified by uncertainty (see Figure 4). Across the centro-parietal leads, LPP amplitude elicited by aversive images were significantly larger when preceded by uncertainty cues ($M = 5.10$; s.d. = 4.50) compared to when they were preceded by certainty cues ($M = 4.11$, s.d. = 4.00, $p = .01$). This effect did not emerge at other scalp regions. Certainty and uncertainty cues did not influence LPP responses to neutral images at any region.

A significant laterality × stimulus condition interaction [$F(6, 306) = 4.24, p = .0004$] revealed that aversive images preceded by certain and uncertain cues were larger than neutral images across all electrode locations (all $p$s < .0003). Neutral images were not different across cue type. At right-lateralized scalp regions, aversive images preceded by uncertainty cues were significantly larger than those preceded by certainty cues, $p = .05$. Three-way and four-way interactions were not significant (all $p$s > .18).

In summary, these results are consistent with previous research that has indicated the greatest magnitude LPPs in response to emotional stimuli occur at centro-parietal and parietal regions during the processing of affective pictures (e.g., Cuthbert et al., 2000; Ferrari, Bradley & Lang, 2011; Hajcak, MacNamara, Foti & Keil, 2011; Schupp et al., 2000). The results suggest that during the early stimulus window, LPP amplitude was maximal and most sensitive to stimulus condition at the centro-parietal midline (CPz). During the middle window, the LPP began to take on a right-hemisphere preponderance at CP4, but was statistically equivalent with
CPz in amplitude and sensitivity to stimulus condition. These results are consistent with the scalp distribution depicted in the Figure 3, and time course of the LPP as depicted in Figures 5 and 6. In what follows, models of the LPP will be tested at electrode sites CPz and CP4.

**Questions 2.1 and 2.2: Do certain and uncertain aversive images elicit larger LPP amplitudes than certain and uncertain neutral images? Do uncertainty-cued aversive and neutral images elicit larger LPP amplitudes than certainty-cued aversive and neutral stimuli?** To formally address the questions from specific aim 2, whether aversive images elicited larger LPP amplitudes than neutral images (Question 2.1), and whether stimulus uncertainty elicited larger LPP amplitudes than stimulus certainty (Question 2.2), I conducted a 2 (electrode site: CPz, CP4) × 3 (signal window: early, middle, late) × 2 (stimulus valence: neutral, aversive) × 2 (cue type: certain, uncertain) repeated measures mixed model using restricted maximum likelihood estimation, with all independent variables entered as repeated measures. Table 7 displays the parameter estimates for the full mixed model. Means and standard deviations are available in Tables 4-6.

**Main effects.** There was a significant main effect for electrode site \(F(1, 51) = 8.27, p = .006\], and Tukey-Kramer adjusted post-hoc comparisons indicated LPP amplitudes were higher at electrode site CPz than CP4, \(t(51) = 2.88, p = .006\]. There were also significant main effects for Stimulus cue \(F(1, 51) = 12.64, p = .0008\] and Stimulus valence, \(F(1, 51) = 130.07, p < .0001\]. As expected, stimuli preceded by uncertainty cues elicited significantly larger LPP amplitudes than when stimuli were preceded by certainty cues, \(t(51) = -3.56, p = .0008\]. Aversive stimuli elicited significantly larger LPP amplitudes than neutral stimuli \(t(51) = -11.41, p < .0001\], which was also expected. There was not a main effect of signal window, \(F(2, 102) = 1.62, p = .20\].
Table 7. Parameter estimates modeling the effects of signal window, stimulus cue, and stimulus valence on LPP amplitudes (µv) at electrode sites CPz and CP4.

<table>
<thead>
<tr>
<th>Effect</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode</td>
<td>(1, 51)</td>
<td>8.27</td>
<td>.0059</td>
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<tr>
<td>Signal window</td>
<td>(2, 102)</td>
<td>1.62</td>
<td>.2034</td>
</tr>
<tr>
<td>Stimulus cue</td>
<td>(1, 51)</td>
<td>12.64</td>
<td>.0008</td>
</tr>
<tr>
<td>Stimulus valence</td>
<td>(1, 51)</td>
<td>130.07</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Electrode × Signal window</td>
<td>(2, 102)</td>
<td>5.43</td>
<td>.0057</td>
</tr>
<tr>
<td>Electrode × Stimulus cue</td>
<td>(1, 51)</td>
<td>0.01</td>
<td>.9059</td>
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<tr>
<td>Electrode × Stimulus valence</td>
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<td>3.08</td>
<td>.0854</td>
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<tr>
<td>Signal window × Stimulus cue</td>
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<tr>
<td>Signal window × Stimulus valence</td>
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<tr>
<td>Stimulus cue × Stimulus valence</td>
<td>(1, 51)</td>
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<td>.0024</td>
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<td>Electrode × Signal window × Stimulus cue</td>
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<td>.8803</td>
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<td>Electrode × Signal window × Stimulus valence</td>
<td>(2, 102)</td>
<td>0.62</td>
<td>.5418</td>
</tr>
<tr>
<td>Electrode × Stimulus cue × Stimulus valence</td>
<td>(1, 51)</td>
<td>0.46</td>
<td>.5011</td>
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<tr>
<td>Signal window × Stimulus cue × Stimulus valence</td>
<td>(2, 102)</td>
<td>0.45</td>
<td>.6404</td>
</tr>
<tr>
<td>Electrode × Signal window × Stimulus cue × Stimulus valence</td>
<td>(2, 102)</td>
<td>0.03</td>
<td>.9715</td>
</tr>
</tbody>
</table>

Notes. Levels of electrode were CPz and CP4. Levels of signal window were early (500ms – 1000ms), middle (1500ms – 2000ms), and late (2001-2500ms). Levels of stimulus cue were certain and uncertain. Levels of stimulus valence were aversive and neutral. Tukey-Kramer adjusted p-values are presented.

Two-way interactions. There was a significant Electrode × Signal window interaction, F(2, 102) = 5.43, p = .006. Tukey-Kramer post-hoc tests indicated no differences in LPP amplitude between electrode sites CPz and CP4 during the early signal window [t(102) = -0.87, p = .95], but during the middle [t(102) = 3.33, p = .001] and late signal windows [t(102) = 2.03, p = .045], LPP amplitudes were larger at CPz compared to CP4.
The significant main effects for stimulus cue and stimulus valence were qualified by a significant stimulus cue × stimulus valence interaction on LPP amplitude, \( F(1, 51) = 10.16, p = .002 \). An examination of the simple effects of this interaction indicated that when stimuli were of neutral valence, there were no differences in LPP amplitude due to stimulus cue, \( t(51) = -.26, p = .99 \). However, when stimulus valence was aversive, uncertainty cues elicited significantly larger LPP amplitudes than certainty cues, \( t(51) = -4.77, p < .0001 \).

In sum, results these results provide robust support for specific aim 2. Aversive stimuli elicited larger LPP amplitudes than neutral stimuli, and uncertainty cues elicited larger LPP amplitudes than certainty cues (i.e. main effects). Consistent with past research, uncertainty cues were found to increase negative appraisals of unpleasant stimuli. There were no other significant 2-way, 3-way, or 4-way interaction terms (see Table 7).

**Specific aim 3. Mindfulness and self-reported stimulus appraisal.**

The third specific aim of the present study was to determine whether trait mindfulness would predict more benign appraisals - less unpleasant affect and less unpleasant stimulus ratings - following the display of uncertain stimulus cues. To provide additional support, traits that contrast with mindfulness, including uncertainty-distress and anxiety-related traits, were tested and expected to increase unpleasant affect and stimulus ratings following uncertainty-cued aversive and neutral images, compared to certainty-cued aversive and neutral images.

**Preliminary assessment of psychological trait relations.** Prior to conducting these tests, I examined the correlations between each of the individual difference measures to ensure all traits were related in the expected directions. The MAAS and FFMQ were highly correlated \( (r_{51} = .79, p < .0001) \), as were measures of uncertainty distress (the IUS and URS; \( r_{51} = .84, p < .0001 \)). Anxiety-related traits were also intercorrelated as expected. Neuroticism scores were
highly correlated with the BDI and the PSWQ ($r_{51} = .61$ and $r_{51} = .62$, respectively; $ps < .0001$), and the PSWQ was related to the BDI, $r_{51} = .32$, $p = .02$. Correlations between measures of mindfulness with uncertainty-distress and anxiety-related traits are depicted in Table 8. As expected, the correlations between the MAAS, FFMQ$_{AW}$, and ACS attentional control were inversely related with measures of uncertainty distress (IUS and URS measures) and all three anxiety-related traits (NEO neuroticism, PSWQ, BDI depression).

Table 8. Correlations between measures of mindfulness, uncertainty distress, and anxiety related traits.

<table>
<thead>
<tr>
<th>Trait variables</th>
<th>Uncertainty distress</th>
<th>Anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IUS uncertainty</td>
<td>URS emotion</td>
</tr>
<tr>
<td>MAAS mindfulness</td>
<td>-.61***</td>
<td>-.63***</td>
</tr>
<tr>
<td>FFMQ awareness</td>
<td>-.40*</td>
<td>-.50**</td>
</tr>
</tbody>
</table>

Notes. $N = 52$ ($n = 50$ for IUS and URS). MAAS = Mindful Attention Awareness Scale; FFMQ = Five-Factor Mindfulness Questionnaire; ACS = Attention Control Scale; IUS = Intolerance of Uncertainty Scale; URS = Uncertainty Response Scale; NEO-FFI = Neuroticism Extroversion Openness-Five Factor Inventory; PSWQ = Penn State Worry Questionnaire; BDI = Beck Depression Inventory. 

* $P < 0.01$, ** $P < 0.001$, *** $P < 0.0001$

**Question 3.1:** Does trait mindfulness predict lower unpleasant affect following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images? To directly test whether trait mindfulness predicted lower unpleasant affect following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images?
neutral images, I conducted a 2 separate 2 (cue type: 0 = certain, 1 = uncertain) × 2 (stimulus valence: 0 = neutral, 1 = aversive) repeated measures mixed models with restricted maximum likelihood estimation, with each model covarying one measure of mindfulness.

In both models testing whether MAAS and FFMQ_AW mindfulness would reduce unpleasant affect following emotional stimulus exposure, there were no significant effects besides the main effect for stimulus valence described earlier when testing specific aim 1 (all ps > .39). That is, aversive images elicited higher self-reported unpleasant affect compared to neutral images, and uncertainty cues elicited more unpleasant affect than certainty cues, but there were no significant main or interaction effects for MAAS or FFMQ_AW mindfulness. This suggests that there is not sufficient evidence to conclude that mindfulness ameliorates negative affect following stimulus exposure.

**Question 3.2. Does trait mindfulness predict lower unpleasant stimulus ratings following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images?** Analogous mixed models to those tested in Question 3.1 were conducted to determine whether mindfulness may reduce unpleasant perceptions of the images, as indicated in post-stimulus picture ratings. That is, 2 separate 2 (cue type: 0 = certain, 1 = uncertain) × 2 (stimulus valence: 0 = neutral, 1 = aversive) repeated measures mixed models with restricted maximum likelihood estimation were conducted, with each model covarying one measure of mindfulness. There were significant main effects for cue type [F(1, 49) = 5.09, p = .03] and stimulus valence [F(1, 49) = 1116.94, p < .0001], but there were no significant main effects for the MAAS or FFMQ_AW (ps > .12), nor any significant interaction effects (all ps > .26). In sum, there was no evidence to suggest that dispositional mindfulness ameliorated the influence of stimulus valence and cue-type on post-stimulus picture ratings.
Question 3.3. Do traits that contrast with mindfulness (measures of uncertainty distress and anxiety-related traits) predict higher unpleasant affect following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images?

To assess whether traits that contrast with mindfulness would predict higher unpleasant affect following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images, repeated measures mixed models with restricted maximum likelihood estimation were conducted similar to those above. Five independent 2 (cue type: certainty, uncertainty) × 2 (stimulus valence: neutral, aversive) mixed models, were conducted with one trait entered as a covariate in each model. The first two models covaried measures of uncertainty distress (the IUS and URS, respectively), and the latter three models covaried anxiety related traits (NEO neuroticism, PSWQ worry, and BDI depression, respectively).

The first two mixed models covarying measures of uncertainty distress (IUS intolerance of uncertainty and URS emotional responses to uncertainty) yielded no significant main effects or interactions on post-stimulus affect ratings (all $p$s > .27). Likewise, there were no significant main or interaction effects for NEO-FFI neuroticism on post-stimulus affect ratings ($p$s > .10). The latter two models testing PSWQ worry and BDI depression on affect ratings yielded no significant main effects ($p$s > .25), but there was a significant PSWQ worry × stimulus valence interaction [$F(1, 138) = 9.98, p = .002$] and a significant BDI depression × stimulus valence interaction with post-stimulus affect ratings, $F(1, 144) = 3.75, p = .05$.

Figure 7 depicts the interaction between stimulus valence and PSWQ worry on post-stimulus affect ratings, and Figure 8 depicts the interaction between stimulus valence and BDI depression and on post-stimulus affect ratings. The slopes of the regression lines predicting post-stimulus mood ratings with PSWQ worry were significantly different for neutral and
Figure 7. Interaction between stimulus valence and PSWQ worry on post-stimulus affect ratings.

Note. PSWQ Worry scores were group-mean centered. Mood Rating (-4 = unpleasant/negative; 0 = neutral; 4 = pleasant/happy).

aversive images. As is evident in Figure 7, post-stimulus affect ratings following aversive pictures became more unpleasant as PSWQ worry scores increased. However, post-stimulus mood ratings following neutral images became more positive as PSWQ worry scores increased. This similar pattern was found for BDI depression. This evidence suggests that heightened
Figure 8. Interaction between stimulus valence and BDI depression on post-stimulus affect ratings.

Note. BDI depression scores were group-mean centered. Mood Rating (-4 = unpleasant/negative; 0 = neutral; 4 = pleasant/happy).

predispositions of worry and depression are related to greater unpleasant affect following the display of aversive stimuli, compared to neutral stimuli.

**Question 3.4.** Do traits that contrast with mindfulness predict higher unpleasant stimulus ratings following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images? To examine whether traits that contrast with mindfulness would predict higher unpleasant stimulus ratings following uncertainty-cued aversive and neutral images compared to certainty-cued aversive and neutral images, an
analogous sequence of 5 repeated measure mixed models was conducted on post-stimulus picture ratings. Each of the five 2 (cue type: certainty, uncertainty) × 2 (stimulus valence: neutral, aversive) repeated measures mixed models, were conducted with one trait entered as a covariate in each model. The first two models covaried measures of uncertainty distress (the IUS and URS, respectively), and the latter three models covaried anxiety related traits (NEO neuroticism, PSWQ worry, and BDI depression, respectively).

There were no significant main or interaction effects with IUS intolerance of uncertainty or URS emotional responses to uncertainty on picture ratings (all $p$s > .14). There were also no main or interaction effects for BDI depression or NEO-FFI neuroticism (all $p$s > .11). The model testing PSWQ worry indicated no significant main effect for worry, but there was a significant PSWQ worry × stimulus valence interaction on post-stimulus picture ratings, $F(1, 138) = 9.49, p = .003$.

Figure 9 depicts the interaction between stimulus valence × PSWQ Worry on post-stimulus picture ratings. Consistent with the model tested on affect ratings in Question 3.3, the slopes of the regression lines predicting post-stimulus picture ratings were significantly different for neutral and aversive valence categories. Post-stimulus picture ratings for aversive stimuli were more unpleasant as PSWQ increased, but post-stimulus picture ratings for neutral stimuli became more positive as PSWQ increased.

In summary, the results of tests related to specific aim 3 indicated that there was no evidence to suggest that dispositional mindfulness blunted self-reported negative appraisals in response to the emotional images, with no significant effects of dispositional mindfulness on
Figure 9. Interaction between stimulus valence and PSWQ worry on post-stimulus picture ratings.

Note. PSWQ Worry scores were group-mean centered. Mood Rating (-4 = unpleasant/negative; 0 = neutral; 4 = pleasant/happy).

post-stimulus self-reported affect or post-stimulus self-reported image ratings. However, two anxiety-related traits – PSWQ worry and BDI depression – did account for significant variability in emotional appraisal processes. A heightened predisposition to worry, as captured by the PSWQ worry scale, was predictive of significantly higher self-reported post-stimulus unpleasant affect and image ratings, and higher levels of BDI depression was associated with greater self-reported post-stimulus unpleasant affect following aversive images.

Specific aim 4. Mindfulness and a cortical measure of stimulus appraisal.
The fourth specific aim of the present study was to determine whether dispositional mindfulness was predictive of attenuated LPP responses to aversive emotional stimuli relative to neutral stimuli under conditions of uncertainty and certainty, during an early time period (500-1000ms) of the LPP. To address questions 4.1 and 4.2, I conducted a sequence of 2 (electrode site: CPz, CP4) × 3 (signal window: early, middle, late) × 2 (stimulus valence: neutral, aversive) × 2 (cue type: certain, uncertain) repeated measures mixed model using restricted maximum likelihood estimation, with each of the individual difference variables sensitive to mindfulness (Question 4.1) and traits that contrast with mindfulness (Question 4.2) entered as a covariate in separate models. Means and standard deviations are available in Tables 3-7.

**Question 4.1. Is trait mindfulness associated with lower deflections of the LPP following aversive images relative to neutral images when preceded by uncertainty and certainty cues?** To address whether trait mindfulness was associated with lower deflections of the LPP following aversive images relative to neutral images when preceded by uncertainty and certainty cues, two mixed models were conducted (factors specified above) with each model covarying MAAS and FFMQAW measures, respectively. Figure 10 depicts the average LPP waveforms evoked by each stimulus condition across all three stimulus windows for participants higher and lower in MAAS mindfulness (as derived by a median split) at electrode sites CPz and CP4.

**MAAS mindfulness on LPP amplitude.** Significant parameter estimates for the model testing the effect of MAAS dispositional mindfulness on signal window, stimulus cue and
Figure 10. Grand average LPP waveforms at electrode locations CPz and CP4 elicited by certain and uncertain aversive and neutral visual stimuli, shown separately for high and low MAAS mindfulness groups created by a median split.
Table 9. Significant parameter estimates modeling the effects of MAAS mindfulness, signal window, stimulus cue, and stimulus valence on LPP amplitudes (µv) at electrodes CPz and CP4.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode</td>
<td>(1, 51)</td>
<td>8.32</td>
<td>.0057</td>
</tr>
<tr>
<td>Electrode × Signal window</td>
<td>(2, 102)</td>
<td>5.49</td>
<td>.0054</td>
</tr>
<tr>
<td>Stimulus cue</td>
<td>(1, 51)</td>
<td>12.72</td>
<td>.0008</td>
</tr>
<tr>
<td>Stimulus valence</td>
<td>(1, 51)</td>
<td>130.91</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Stimulus cue × Stimulus valence</td>
<td>(1, 51)</td>
<td>10.23</td>
<td>.0024</td>
</tr>
<tr>
<td>MAAS</td>
<td>(1, 50)</td>
<td>5.22</td>
<td>.0266</td>
</tr>
<tr>
<td>MAAS × Stimulus valence</td>
<td>(1, 1150)</td>
<td>18.78</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

Notes. Levels of electrode were CPz and CP4. Levels of signal window were early (500ms – 1000ms), middle (1500ms – 2000ms), and late (2001-2500ms). Levels of stimulus cue were certain and uncertain. Levels of stimulus valence were aversive and neutral. Tukey-Kramer adjusted p-values are presented.

stimulus valence at electrodes CPz and CP4 are depicted in Table 9. Model parameters not involving mindfulness were consistent with those previously reported in Question 2.1, so the present results will focus on mindfulness-related effects of interest. There was a significant main effect of MAAS dispositional mindfulness, $F(1, 50) = 5.22, p = .02$. In contrast to my expectations and past research on mindfulness and the LPP (Brown et al., 2013), higher levels of dispositional mindfulness were associated with larger deflections of the LPP. There was also a significant MAAS × stimulus valence interaction, $F(1, 1150) = 18.78, p < .0001$. Figure 11 displays the interaction between MAAS dispositional mindfulness and stimulus valence on LPP amplitude. The slopes of the regression lines predicting LPP amplitude by MAAS were significantly different due to the valence of the stimulus. For aversive stimuli, higher levels of MAAS dispositional mindfulness predicted more positive deflections of the LPP. For neutral
interaction between stimulus valence and MAAS mindfulness on LPP amplitude (µv) at electrode sites CPz and CP4 across all three signal windows.

Figure 11. Interaction between stimulus valence and MAAS mindfulness on LPP amplitude (µv) at electrode sites CPz and CP4 across all three signal windows.

stimuli, slope of the line predicting LPP amplitude by mindfulness was significantly less positive. There were no other significant interaction effects involving the MAAS.

*FFMQ aw mindfulness on LPP amplitude.* A second analogous model was conducted to examine the effect of FFMQ aw mindfulness on LPP amplitude, and the findings were consistent with the model testing the MAAS. Significant parameter estimates for the model testing the effect of FFMQ aw dispositional mindfulness on signal window, stimulus cue and stimulus valence at electrodes CPz and CP4 are depicted in Table 10. There was a significant main effect
of FFMQ<sub>AW</sub> mindfulness, \( F(1, 50) = 13.00, p = .0007 \). As with the MAAS, higher levels of FFMQ<sub>AW</sub> mindfulness were associated with larger deflections of the LPP. There was also a significant FFMQ<sub>AW</sub> × stimulus valence interaction, \( F(1, 1127) = 10.93, p = .001 \). Figure 12 displays the interaction between FFMQ<sub>AW</sub> dispositional mindfulness and stimulus valence. The slopes of the regression lines predicting LPP amplitude by FFMQ<sub>AW</sub> were significantly different due to the valence of the stimulus. For aversive stimuli, higher levels of FFMQ<sub>AW</sub> dispositional mindfulness predicted more positive deflections of the LPP. For neutral stimuli, the slope of the line predicting LPP amplitude by FFMQ<sub>AW</sub> mindfulness was significantly less positive. There were no other significant interaction effects involving the FFMQ<sub>AW</sub>.

Table 10. *Significant parameter estimates modeling the effects of FFMQ<sub>AW</sub> mindfulness, signal window, stimulus cue, and stimulus valence on LPP amplitudes (µv) at electrodes CPz and CP4.*

<table>
<thead>
<tr>
<th>Effect</th>
<th>( Df )</th>
<th>( F )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode</td>
<td>(1, 50)</td>
<td>7.38</td>
<td>.0009</td>
</tr>
<tr>
<td>Electrode × Signal window</td>
<td>(2, 100)</td>
<td>1.68</td>
<td>.1923</td>
</tr>
<tr>
<td>Stimulus cue</td>
<td>(1, 50)</td>
<td>12.28</td>
<td>.0010</td>
</tr>
<tr>
<td>Stimulus valence</td>
<td>(1, 50)</td>
<td>127.80</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Stimulus cue × Stimulus valence</td>
<td>(1, 50)</td>
<td>9.64</td>
<td>.0031</td>
</tr>
<tr>
<td>FFMQ&lt;sub&gt;AW&lt;/sub&gt;</td>
<td>(1, 50)</td>
<td>13.00</td>
<td>.0007</td>
</tr>
<tr>
<td>FFMQ&lt;sub&gt;AW&lt;/sub&gt; × Stimulus valence</td>
<td>(1, 1127)</td>
<td>10.93</td>
<td>&lt;.0010</td>
</tr>
</tbody>
</table>

*Notes.* Levels of electrode were CPz and CP4. Levels of signal window were early (500ms – 1000ms), middle (1500ms – 2000ms), and late (2001-2500ms). Levels of stimulus cue were certain and uncertain. Levels of stimulus valence were aversive and neutral. Tukey-Kramer adjusted \( p \)-values are presented.
Figure 12. Interaction between stimulus valence and FFMQ$_{AW}$ mindfulness on LPP amplitude ($\mu$V) at electrode sites CPz and CP4 across all three signal windows.

**Correlations between mindfulness and LPP amplitude.** Table 11 shows the pattern of correlations for MAAS and FFMQ$_{AW}$ mindfulness at electrode site CPz. The effects for stimulus condition were consistent with earlier models: uncertain and certain-cued aversive stimuli elicited significantly larger deflections of the LPP compared to neutral images ($p$ < .0001). LPP amplitudes were also significantly greater when aversive images were preceded by uncertainty compared to certainty cues ($p$ < .0001). Both the MAAS and FFMQ$_{AW}$ were predictors of
Table 11. Correlations between LPP amplitude (µv) and mindfulness at electrode site CPz.

<table>
<thead>
<tr>
<th></th>
<th>Certain Neutral</th>
<th>Uncertain Neutral</th>
<th>Certain Aversive</th>
<th>Uncertain Aversive</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MAAS mindfulness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early (500-1000 ms)</td>
<td>.24</td>
<td>.25</td>
<td>.30*</td>
<td>.30*</td>
</tr>
<tr>
<td>Middle (1500-2000 ms)</td>
<td>-.06</td>
<td>.08</td>
<td>.08</td>
<td>.14</td>
</tr>
<tr>
<td>Late (2001-2500 ms)</td>
<td>.03</td>
<td>.06</td>
<td>.13</td>
<td>.20</td>
</tr>
<tr>
<td>Full window</td>
<td>.05</td>
<td>.12</td>
<td>.17</td>
<td>.21</td>
</tr>
<tr>
<td><strong>FFMQ awareness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>.17</td>
<td>.14</td>
<td>.18</td>
<td>.18</td>
</tr>
<tr>
<td>Middle</td>
<td>.03</td>
<td>.11</td>
<td>.14</td>
<td>.18</td>
</tr>
<tr>
<td>Late</td>
<td>.14</td>
<td>.21</td>
<td>.22</td>
<td>.29*</td>
</tr>
<tr>
<td>Full window</td>
<td>.15</td>
<td>.15</td>
<td>.11</td>
<td>.22</td>
</tr>
</tbody>
</table>

Notes. N = 52. MAAS = Mindful Attention Awareness Scale; FFMQ = Five-Factor Mindfulness Questionnaire Act with Awareness. *P < 0.05

positive LPP amplitude during the early window, indicating that higher mindfulness was associated with larger deflections of the LPP, and for the MAAS this positive relation was particularly strong for certain and uncertain aversive stimuli compared to neutral stimuli.

**Question 4.2. Do traits that contrast with mindfulness predict higher LPP deflections elicited by aversive images relative to neutral images when preceded by uncertainty and certainty cues?** To determine whether traits that contrast with mindfulness predict higher LPP deflections elicited by aversive images relative to neutral images when preceded by uncertainty and certainty cues, 5 models were conducted similar to the two above that tested mindfulness, with each model covarying one psychological trait. A sequence of 2 (electrode site: CPz, CP4) × 3 (signal window: early, middle, late) × 2 (stimulus valence: neutral, aversive) × 2 (cue type: certain, uncertain) repeated measures mixed models using restricted
maximum likelihood estimation were tested, with each of the 5 individual difference variables sensitive to uncertainty distress and anxiety-related traits entered into separate models as covariates.

**IUS intolerance of uncertainty on LPP amplitude.** The model testing IUS intolerance of uncertainty indicated no main effect for the IUS, $F(1, 48) = 0.94, p = .34$. However, there was a significant IUS $\times$ stimulus valence interaction, $F(1, 1104) = 9.40, p = .0022$. Table 12 depicts all the significant parameter estimates for the model and Figure 13 displays the interaction between IUS intolerance of uncertainty and stimulus valence. The slopes of the regression lines predicting LPP amplitude by IUS intolerance of uncertainty were significantly different due to

Table 12. *Significant parameter estimates modeling the effects of IUS intolerance of uncertainty, signal window, stimulus cue, and stimulus valence on LPP amplitudes (µV) at electrodes CPz and CP4.*

<table>
<thead>
<tr>
<th>Effect</th>
<th>df</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode</td>
<td>(1, 49)</td>
<td>10.20</td>
<td>.0025</td>
</tr>
<tr>
<td>Electrode $\times$ Signal window</td>
<td>(2, 98)</td>
<td>4.64</td>
<td>.0118</td>
</tr>
<tr>
<td>Stimulus cue</td>
<td>(1, 49)</td>
<td>12.89</td>
<td>.0008</td>
</tr>
<tr>
<td>Stimulus valence</td>
<td>(1, 49)</td>
<td>126.21</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Stimulus cue $\times$ Stimulus valence</td>
<td>(1, 49)</td>
<td>10.49</td>
<td>.0022</td>
</tr>
<tr>
<td>IUS $\times$ Stimulus valence</td>
<td>(1, 1104)</td>
<td>9.40</td>
<td>.0022</td>
</tr>
</tbody>
</table>

*Notes.* Levels of electrode were CPz and CP4. Levels of signal window were early (500ms – 1000ms), middle (1500ms – 2000ms), and late (2001-2500ms). Levels of stimulus cue were certain and uncertain. Levels of stimulus valence were aversive and neutral. Tukey-Kramer adjusted $p$-values are presented.
the valence of the stimulus. For aversive stimuli, higher levels of IUS intolerance of uncertainty were associated with smaller deflections of the LPP. For neutral stimuli, slope of the line predicting LPP amplitude was significantly more positive, with higher IUS intolerance of uncertainty scores predicting larger deflections of the LPP. Thus, IUS intolerance for uncertainty was predictive of LPP amplitude in the direction opposite of both measures of mindfulness.

Figure 13. Interaction between stimulus valence and IUS intolerance of uncertainty on LPP amplitude (µv) at electrode sites CPz and CP4 across all three signal windows.
**URS emotional responses to uncertainty on LPP amplitude.** The model testing URS emotional responses to uncertainty indicated no significant main effect for the URS \( F(1, 48) = 1.74, p = .19 \), but there were significant URS × Electrode \( F(1, 1104) = 7.69, p = .006 \) and URS × stimulus valence interactions, \( F(1, 1104) = 5.68, p = .02 \). No other interaction effects with the URS were significant. Table 13 depicts all the significant parameter estimates for the model.

Table 13. Significant parameter estimates modeling the effects of URS emotional responses to uncertainty, signal window, stimulus cue, and stimulus valence on LPP amplitudes (µv) at electrodes CPz and CP4.

<table>
<thead>
<tr>
<th>Effect</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode</td>
<td>(1, 49)</td>
<td>10.18</td>
<td>.0025</td>
</tr>
<tr>
<td>Electrode × Signal window</td>
<td>(2, 98)</td>
<td>4.65</td>
<td>.0118</td>
</tr>
<tr>
<td>Stimulus cue</td>
<td>(1, 49)</td>
<td>12.86</td>
<td>.0008</td>
</tr>
<tr>
<td>Stimulus valence</td>
<td>(1, 49)</td>
<td>126.00</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Stimulus cue × Stimulus valence</td>
<td>(1, 49)</td>
<td>10.47</td>
<td>.0022</td>
</tr>
<tr>
<td>URS × Electrode</td>
<td>(1, 1104)</td>
<td>7.69</td>
<td>.0057</td>
</tr>
<tr>
<td>URS × Stimulus valence</td>
<td>(1, 1104)</td>
<td>5.68</td>
<td>.0173</td>
</tr>
</tbody>
</table>

Notes. Levels of electrode were CPz and CP4. Levels of signal window were early (500ms – 1000ms), middle (1500ms – 2000ms), and late (2001-2500ms). Levels of stimulus cue were certain and uncertain. Levels of stimulus valence were aversive and neutral. Tukey-Kramer adjusted p-values are presented.

Decomposing the URS × Electrode interaction indicated that the URS was more strongly related to LPP amplitudes at CPz, compared to CP4. The URS × stimulus valence interaction indicated similar effects to those of IUS intolerance of uncertainty. Figure 14 displays the interaction between URS emotional responses to uncertainty and stimulus valence. The slopes of
Figure 14. Interaction between stimulus valence and URS emotional responses to uncertainty on LPP amplitude (µv) at electrode sites CPz and CP4 across all three signal windows.

The regression lines predicting LPP amplitude URS emotional responses to uncertainty were significantly different due to the valence of the stimulus. For aversive stimuli, higher levels of IUS intolerance of uncertainty were associated with smaller deflections of the LPP. For neutral stimuli, slope of the line predicting LPP amplitude was significantly more positive, with higher IUS intolerance of uncertainty scores predicting larger deflections of the LPP.

**NEO neuroticism on LPP amplitude.** The model testing NEO neuroticism indicated no significant main effect for the neuroticism \(F(1, 50) = 0.97, p = .33\), but there was a significant
neuroticism × stimulus valence interaction, $F(1, 1150) = 10.40, p = .001$. No other interaction effects with the neuroticism were significant. Significant parameter estimates are displayed in Table 14 and the interaction between NEO neuroticism and stimulus valence is depicted in Figure 15. Consistent with findings from models testing measures of uncertainty distress, the slopes of the regression lines predicting LPP amplitude from with neuroticism were significantly different. For aversive stimuli, higher levels of neuroticism predicted smaller deflections of the LPP. For neutral stimuli, slope of the line predicting LPP amplitude was significantly more positive, with higher neuroticism scores predicting larger deflections of the LPP.

Table 14. Significant parameter estimates modeling the effects of NEO neuroticism, signal window, stimulus cue, and stimulus valence on LPP amplitudes ($\mu v$) at electrodes CPz and CP4.

<table>
<thead>
<tr>
<th>Effect</th>
<th>df</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode</td>
<td>(1, 51)</td>
<td>8.24</td>
<td>.0060</td>
</tr>
<tr>
<td>Electrode × Signal window</td>
<td>(2, 102)</td>
<td>5.42</td>
<td>.0058</td>
</tr>
<tr>
<td>Stimulus cue</td>
<td>(1, 51)</td>
<td>12.60</td>
<td>.0008</td>
</tr>
<tr>
<td>Stimulus valence</td>
<td>(1, 51)</td>
<td>129.62</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Stimulus cue × Stimulus valence</td>
<td>(1, 51)</td>
<td>10.13</td>
<td>.0025</td>
</tr>
<tr>
<td>NEO neuroticism × Stimulus valence</td>
<td>(1, 1150)</td>
<td>10.40</td>
<td>.0013</td>
</tr>
</tbody>
</table>

Notes. Levels of electrode were CPz and CP4. Levels of signal window were early (500ms – 1000ms), middle (1500ms – 2000ms), and late (2001-2500ms). Levels of stimulus cue were certain and uncertain. Levels of stimulus valence were aversive and neutral. Tukey-Kramer adjusted $p$-values are presented.
Figure 15. Interaction between stimulus valence and NEO neuroticism on LPP amplitude (µv) at electrode sites CPz and CP4 across all three signal windows.

PSWQ worry on LPP amplitude. The model covarying PSWQ worry indicated no significant main or interaction effects involving worry (all ps > .16).

BDI depression on LPP amplitude. The model testing BDI depression indicated no significant main effect for depression \([F(1, 50) = 0.93, p = .34]\), but there were significant depression \(\times\) electrode \([F(1, 1150) = 8.41, p = .004]\), and depression \(\times\) electrode \(\times\) valence interactions, \(F(1, 1150) = 6.37, p = .0118\). No other interaction effects with the depression were significant. Significant parameter estimates are displayed in Table 15. The differences in slopes
between neutral and aversive stimuli by BDI depression were significantly different at electrodes CPz and CP4. Plots depicting this depression × electrode × stimulus valence interaction are depicted in Figure 16. At electrode CPz, there was not a significant depression × stimulus valence interaction, $F(1, 550) = .35, p = .56$. That is, the slopes of the regression lines predicting LPP amplitude by BDI depression were not difference across the two stimulus valences. At the right-sided electrode site CP4, however, the BDI depression × stimulus valence interaction was highly significant [$F(1, 550) = 12.62, p = .0004$], which indicates the slopes of the regression lines predicting LPP amplitude by BDI depression were significantly different for neutral compared to aversive stimuli. For aversive stimuli, higher BDI depression scores were associated with smaller deflections of the LPP. For neutral stimuli, higher BDI depression scores were associated with larger deflections of the LPP.

Table 15. *Significant parameter estimates modeling the effects of BDI depression, signal window, stimulus cue, and stimulus valence on LPP amplitudes (µv) at electrodes CPz and CP4.*

<table>
<thead>
<tr>
<th>Effect</th>
<th>$Df$</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode</td>
<td>(1, 51)</td>
<td>8.28</td>
<td>.0058</td>
</tr>
<tr>
<td>Electrode × Signal window</td>
<td>(2, 102)</td>
<td>5.44</td>
<td>.0057</td>
</tr>
<tr>
<td>Stimulus cue</td>
<td>(1, 51)</td>
<td>12.67</td>
<td>.0008</td>
</tr>
<tr>
<td>Stimulus valence</td>
<td>(1, 51)</td>
<td>130.33</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Stimulus cue × Stimulus valence</td>
<td>(1, 51)</td>
<td>10.18</td>
<td>.0024</td>
</tr>
<tr>
<td>BDI depression × Electrode</td>
<td>(1, 1150)</td>
<td>8.41</td>
<td>.0038</td>
</tr>
<tr>
<td>BDI depression × Electrode × Stimulus valence</td>
<td>(1, 1150)</td>
<td>6.37</td>
<td>.0118</td>
</tr>
</tbody>
</table>

*Notes.* Levels of electrode were CPz and CP4. Levels of signal window were early (500ms – 1000ms), middle (1500ms – 2000ms), and late (2001-2500ms). Levels of stimulus cue were certain and uncertain. Levels of stimulus valence were aversive and neutral. Tukey-Kramer adjusted $p$-values are presented.
**Figure 16.** Interaction between stimulus valence and BDI depression on LPP amplitude (µv) at electrode sites CPz and CP4 across all three signal windows.
Summary of findings addressing Specific Aim 4. In contrast to my expectations and past research (Brown et al., 2013), trait mindfulness as measured by both the MAAS and FFMQAW were directly related to LPP amplitude, such that higher levels of dispositional mindfulness were associated with larger deflections of the LPP elicited by aversive picture content. There were no significant effects due to the stimulus window, however, the correlation between the MAAS and FFMQAW measures had the most robust relations with LPP amplitude during the early stimulus window. Two measures of uncertainty distress (IUS intolerance of uncertainty and URS emotional responses to uncertainty) and two measures of anxiety-related traits (NEO neuroticism and BDI depression) predicted opposite patterns of association with mindfulness and predicted lower LPP amplitudes elicited by aversive stimuli relative to neutral stimuli. There were no significant interactive effects between psychological traits and stimulus cue on LPP amplitude, which suggests there is not sufficient evidence to conclude that these psychological traits modulate the effect of stimulus uncertainty on a neural marker of emotional stimulus appraisal.

Specific Aim 5. Uncertainty and Self-reported Stimulus Anticipation.

The fifth aim of the present research was to replicate demonstrate a priori and online covariation biases amplify unpleasant affect and stimulus ratings following the display of unpleasant stimuli under conditions of uncertainty. Before examining this question, I conducted preliminary tests to demonstrate the presence of covariation biases. Then I examined whether a priori and online covariation biases predicted higher self-reported unpleasant affect (Question 5.1) and higher self-reported unpleasant image ratings (Question 5.2) following the presentation of neutral and aversive images under conditions of uncertainty, relative to certainty. The
correlations between each measure of covariation bias and post-stimulus affect and picture ratings are depicted in Tables 16 and 17, respectively.

Table 16. *Correlations between covariation biases and post-stimulus affect ratings.*

<table>
<thead>
<tr>
<th>Covariation bias</th>
<th>CN</th>
<th>CA</th>
<th>UN</th>
<th>UA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A priori</td>
<td>-.09</td>
<td>-.23</td>
<td>-.07</td>
<td>-.25</td>
</tr>
<tr>
<td>Online</td>
<td>.17</td>
<td>.23</td>
<td>.07</td>
<td>.15</td>
</tr>
<tr>
<td>Post-experiment</td>
<td>.07</td>
<td>-.33*</td>
<td>.13</td>
<td>-.31*</td>
</tr>
</tbody>
</table>

*Notes. n = 48 for post-experiment covariation bias). CN = certain-neutral; CA = certain aversive; UA = uncertain aversive. *P < 0.05

Table 17. *Correlations between covariation biases and post-stimulus picture ratings.*

<table>
<thead>
<tr>
<th>Covariation bias</th>
<th>CN</th>
<th>CA</th>
<th>UN</th>
<th>UA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A priori</td>
<td>.10</td>
<td>-.23</td>
<td>.08</td>
<td>-.23</td>
</tr>
<tr>
<td>Online</td>
<td>-.03</td>
<td>.14</td>
<td>.06</td>
<td>.22</td>
</tr>
<tr>
<td>Post-experiment</td>
<td>.10</td>
<td>-.33*</td>
<td>.04</td>
<td>-.20</td>
</tr>
</tbody>
</table>

*Notes. N = 52 (n = 48 for post-experiment covariation bias). CN = certain-neutral; CA = certain aversive; UA = uncertain aversive. *P < 0.05

**Preliminary analysis: Did participants demonstrate a priori, online, and a posteriori covariation biases?** To demonstrate the presence of a priori and online covariation biases, two one-sample t-tests were conducted comparing expectancy ratings to the first “?” cue and online expectancy ratings (the mean expectancy rating following all but the first uncertain cue) to a value of 5, which was the mid-point on the rating scale labeled as “uncertain.” On average,
participants were more likely to expect aversive images following the first uncertain cue \([M = 5.56, \text{s.d.} = 1.70]\), \(t(51) = 2.37, p = .022, \eta_p^2 = .09\], which indicates the presence of an a priori covariation bias to associate uncertainty with aversion. Evidence for an online expectancy bias was also found. When participants were presented with uncertainty cues they expected aversive images would follow significantly more than their actual rate of 50\% \((M = 5.70, \text{s.d.} = .85)\), \(t(51) = 5.88, p < .0001, \eta_p^2 = .40\]. To test whether participants baseline a priori covariation biases were amplified as they proceeded through the experiment, a priori and online covariation biases were compared using a paired-samples t-test; the test was not significant, \(t(51) = -.553, p = .58\]. To assess post-experiment covariation bias participants were asked to estimate the percentage of “?” cues that were followed by aversive pictures after they completed the experiment. A one-sample t-test was conducted comparing these retrospective estimates to their actual rate of appearance (50\%), but there wasn’t sufficient evidence of a post-experiment covariation bias.\(^2\) Participants’ post-experiment judgments \((M = 53.83, \text{s.d.} = 15.17)\) were not different from a rate of 50\%, \(t(47) = 1.731, p = .09, \eta_p^2 = .06\]. The lack of post-experiment covariation bias is consistent with the findings of Grupe et al. (2011). However, these and other authors (Amin & Lovibond, 1998) have found significant relations between online and post-experiment estimates of covariation bias. The present study replicated this finding \((r_{48} = -.30, p = .04)\]. This relation suggests that the magnitude of online covariation bias to expect aversive images to follow uncertainty cues was associated with heightened retrospective estimates of the proportion of uncertain cues followed by aversive pictures.

**Question 5.1. Do anticipations, or expectations to associate uncertain cues with unpleasant outcomes (a priori and online covariation bias) predict more unpleasant affect**

\(^2\) Five participants did not respond to the post-experiment covariation bias item, leaving a sample of \(n=48\) for analysis.
after neutral and aversive image exposure under conditions of uncertainty relative to certainty? To test whether a priori and online covariation biases would increase unpleasant affect after exposure to aversive and neutral pictures following uncertainty, relative to certainty, two multilevel models were conducted using restricted maximum likelihood estimation in SAS PROC MIXED. In the first model, stimulus cue (certain, uncertain) and stimulus valence (neutral, aversive) were entered as repeated measures and the continuous measure of a priori covariation bias (the expectancy rating following the very first uncertainty cue) was entered into the model as a covariate. The second model was identical to the first, except online covariation bias (the average expectancy rating following all but the first uncertainty cue) was entered as a covariate. A third model was also tested to explore whether a posteriori covariation bias would be associated with self-reported affect ratings. Pearson product-moment correlations between each measure of covariation bias and post-stimulus mood ratings are depicted in Table 16.

**A priori covariation bias on self-reported affect.** The model testing a priori covariation bias on self-reported affect indicated a significant main effect of stimulus valence \( F(1, 49) = 35.72, p < .0001 \). Affect ratings were significantly more unpleasant following aversive images \( (M = -2.27, \text{s.d.} = 0.95) \) compared to neutral images \( (M = 0.60, \text{s.d.} = 0.65) \). The main effect for stimulus cue and the stimulus cue \( \times \) stimulus valence interaction terms were not significant (both \( ps > .60 \)). There was a significant main effect for a priori covariation bias \( F(1, 48) = 5.13, p = .03 \). Higher levels of a priori covariation bias were predictive of higher unpleasant affect, irrespective of cue and valence. There were no significant interactions involving a priori covariation bias (all \( ps > .16 \)). The results of the present analysis suggest that higher levels of a priori covariation bias were associated with a general tendency to self-report more unpleasant
affect, but there was not sufficient evidence to conclude that a priori covariation bias influenced affect differently due to the nature of the emotional picture content or the stimulus cue.

**Online covariation bias on self-reported affect.** The model testing online covariation bias on self-reported affect indicated, as before, a significant main effect of stimulus valence, $F(1, 49) = 6.22, p = .02$. Affect ratings were significantly more unpleasant following aversive images ($M = -2.27, \text{s.d.} = 0.95$) compared to neutral images ($M = 0.60, \text{s.d.} = 0.65$). No other main or interaction effects were significant (all $p$s > .46). These latter results suggest that online covariation bias did not account for a significant proportion of the variability in self-reported affect.

**A posteriori covariation bias on self-reported affect.** The model testing a posteriori covariation bias on self-reported affect, indicated a significant main effect of stimulus valence [$F(1, 46) = 23.27, p < .0001$]. The main effects for stimulus cue and a posteriori covariation bias, and the stimulus cue × stimulus valence interaction terms were not significant (all $p$s > .57). There was a significant a posteriori covariation bias × stimulus valence interaction, $F(1, 125) = 5.82, p = .02$. As is evident by the pattern of correlations depicted in Table 16, higher levels of a posteriori covariation bias were significantly related to higher unpleasant affect for aversive stimuli. However, a posteriori covariation bias was not a significant predictor of affect following neutral stimuli. There were no other significant interaction terms involving a priori covariation bias (all $p$s > .87). The results of the present analysis suggest that higher levels of a posteriori covariation bias were associated with heightened unpleasant affect following aversive picture content, but there was not sufficient evidence to conclude that a priori covariation bias influenced affect differently due to the nature of the stimulus cue.
Question 5.2. Do expectations to associate uncertain cues with unpleasant outcomes (a priori and online covariation bias) predict more unpleasant image ratings after neutral and aversive image exposure under conditions of uncertainty relative to certainty?

Analogous models to those conducted in Question 5.1 were tested here to address whether a priori and online covariation bias would predict more unpleasant image ratings after neutral and aversive image exposure under conditions of uncertainty relative to certainty. In the first model, stimulus cue (certain, uncertain) and stimulus valence (neutral, aversive) were entered as repeated measures and the continuous measure of a priori covariation bias was entered into the model as a covariate. The second model was identical to the first, except online covariation bias was entered as a covariate. A third model was also tested to explore whether a posteriori covariation bias would predict self-reported image ratings. Pearson product-moment correlations between each measure of covariation bias and post-stimulus picture ratings are depicted in Table 17.

A priori covariation bias on self-reported image ratings. The model testing a priori covariation bias on self-reported image ratings indicated a significant main effect for stimulus valence \(F(1, 49) = 60.46, p < .0001\), but no main effects for stimulus cue or a priori covariation bias (both \(ps > .26\)). Aversive images \((M = -2.57, \text{s.d.} = 0.75)\) were perceived as significantly more unpleasant than neutral images \((M = 0.62, \text{s.d.} = 0.59)\). There was also a significant a priori covariation bias \(\times\) stimulus valence interaction, \(F(1, 144) = 4.25, p = .04\). The slopes of the regression lines predicting picture ratings from a priori covariation bias depended on the valence of the image. Higher levels of a priori covariation bias were predictive of more unpleasant image ratings following aversive stimuli, but the slope of the relationship between a
priori covariation bias and images ratings was different for neutral images. For neutral images, higher covariation bias was associated with less unpleasant stimulus ratings.

**Online covariation bias on self-reported image ratings.** The model testing online covariation bias on self-reported perceptions of the pictures indicated a significant main effect of stimulus valence, \(F(1, 49) = 6.22, p = .02\). No other main or interaction effects were significant (all \(ps > .46\)). This latter result suggests that there is insufficient evidence to conclude that online covariation bias influences self-reported image ratings.

**A posteriori covariation bias on self-reported image ratings.** The model testing a posteriori covariation bias on self-reported image ratings indicated a significant main effect of stimulus valence \([F(1, 46) = 49.94, p < .0001]\). The main effects for stimulus cue and a posteriori covariation bias, and the stimulus cue × stimulus valence interaction terms were not significant (both \(ps > .35\)). There was a significant a posteriori covariation bias × stimulus valence interaction, \(F(1, 135) = 5.21, p = .02\]. Higher levels of a posteriori covariation bias were associated with higher unpleasant perceptions of aversive stimuli. However, a posteriori covariation bias was associated with less unpleasant perceptions of neutral stimuli. There were no other significant interaction terms involving a posteriori covariation bias (all \(ps > .46\)). The results of the present analysis suggest that higher levels of a posteriori covariation bias were associated with heightened perceptions of the pictures as unpleasant following aversive picture content, but there was not sufficient evidence to conclude that a priori covariation bias influenced affect differently due to the nature of the stimulus cue.

**Summary of findings addressing Specific Aim 5.** The results of the present analyses suggest that heightened a priori covariation bias was associated with a general tendency to self-report more unpleasant affect, and heightened perceptions of unpleasantness following the
display of aversive images. There was not sufficient evidence to conclude that online
covariation bias modulated self-reported appraisals. Higher levels of a posteriori covariation
bias were associated with heightened unpleasant affect and stimulus perceptions for aversive
stimuli. There was not sufficient evidence to conclude that a priori covariation, online, or a
posteriori covariation biases were associated with differences in self-reported appraisals due to
the nature of the stimulus cues.

Specific Aim 6: Uncertainty and a cortical measure of stimulus anticipation.

The sixth specific aim of the present study was to determine whether emotional
anticipation as indexed by the SPN is largest for certain-aversive and uncertain stimulus cues
compared to certain-neutral stimulus cues. Before conducting this test it was necessary to
conduct a region of interest analysis to determine whether the SPN component was present and
sensitive to cue type at electrode locations consistent with past research. Following the region of
interest analysis, mixed models will be tested to formally evaluate the question from Specific
Aim 6.

Preliminary Region of Interest Analysis on the SPN.

Visual inspection of the SPN waveforms averaged separately for each cue type indicated
maximal differences due to cue type across frontal and fronto-central regions of the scalp (see
Figure 17). This observed frontal scalp distribution is consistent with past studies that have
examined the modulation of SPN amplitudes during the anticipation of emotional images
(Klorman & Ryan, 1980; Moser et al., 2009; Takeuchi et al., 2005) and threat of shock (Böcker
et al., 2001). of emotional picture stimuli.

To examine the effects of electrode location, and stimulus condition on SPN amplitude, a
Figure 17. Scalp distribution of grand averaged SPN waveforms elicited by each stimulus cue across a 1000 ms (post-expectancy rating) to 4000 ms (earliest image onset) recording period.
The model indicated a significant main effect of anteriority on SPN amplitude [$F(2, 102) = 38.59, p < .0001$]. Tukey-Kramer adjusted post-hoc comparisons revealed that the SPN became significantly more negative as electrode locations progressed in posteriority from frontal ($M = 1.34, \text{ s.d. } = 3.93$) through central ($M = .43, \text{ s.d. } = 3.44$), to parietal sites ($M = -.72, \text{ s.d. } = 3.71; ps < .0006$ for all paired comparisons), a finding consistent with past research on the scalp distribution of the SPN during emotional stimulus anticipation (Brunia, van Boxtel, & Böcker, 2012). There were no main effects for laterality [$F(2, 102) = .21, p = .13$] or cue type [$F(2, 102) = .67, p = .52$], and there was not a significant anteriority × cue type interaction, $F(4, 204) = 2.06, p = .09$.

Given the apparent differences due to cue type in frontal regions depicted in Figures 17 and 18, and on the basis of past research indicating a similar scalp distribution of SPN during anticipation of emotional stimuli (Klorman and Ryan, 1980; Böcker et al., 2001; Takeuchi et al., 2005), a multilevel model was conducted in which the anteriority factor was restricted to frontal (F3, Fz, F4) and fronto-central (FC3, FCz, FC4) leads. The model indicated a significant main effect for laterality, $F(2, 102) = 4.86, p = .01$. SPN amplitudes were more negative at the midline ($M = .96, \text{ s.d. } = 3.47$) compared to the left-hemisphere ($M = 1.80, \text{ s.d. } = 4.35; p = .01$), but there were no other significant differences ($ps > .07$). There was not a significant effect of effect of anteriority on the SPN, $F(1, 51) = .02, p = .89$. Of central importance to the present study, there was a significant main effect of cue type, $F(2, 102) = 5.50, p = .005$. Uncertainty
cues (M = .79, s.d. = 3.68) elicited significantly greater (i.e., lower amplitude) SPN deflections than aversive (M = 1.55, s.d. = 3.80) and neutral cues (M = 1.61, s.d. = 4.02; ps < .02). In contrast to past research, deflections of the SPN in response to aversive and neutral cues were not different from each other, p = .97. Anteriority × cue type, laterality × cue type, and anteriority × laterality × cue type interactions were not significant, all ps > .62. Subsequent analyses testing the modulation of SPN amplitude will be conducted at anterior midline sites Fz and FCz, where cue effects on SPN amplitudes were visually and statistically maximal, a finding consistent with past studies of the SPN during emotional anticipation (Klorman and Ryan, 1980; Böcker et al., 2001; Takeuchi et al., 2005). Waveforms at these electrode sites are depicted in Figure 19.

Question 6.1. Do uncertain and certain-aversive stimulus cues elicit larger (less positive) deflections of the SPN compared to certain-neutral stimulus cues? To specifically test Question 6.1, a 3 (cue type: certain-neutral, certain-aversive, uncertain) × 2 (electrode: Fz, FCz) repeated measures mixed model was conducted on SPN amplitude. There was not a main effect for electrode site [F(1, 51) = 0.05, p = .83] nor cue type [F(2, 102) = 1.96, p = .15], nor was there an electrode × cue type interaction, F(2, 102) = 0.20, p = .82. This suggests there is not sufficient evidence to conclude that the SPN was present and modulated by cue type at the electrodes consistent with the region of interest analysis and past research on the SPN during emotional anticipation. Subsequent specific aims that test the modulation of the SPN by psychological traits (Specific Aim 8) will not be tested.

Specific aim 7: Mindfulness and self-reported stimulus anticipation.
Figure 18. Grand average SPN waveforms at electrodes Fz and FCz elicited by neutral, aversive, and uncertain stimulus cues.
The seventh specific aim of the present study was to explore whether trait mindfulness would predict lower levels of a priori covariation bias and lower online expectancies for aversive images to follow from uncertain (online covariation bias) and aversive cues, relative to neutral cues. Pearson product-moment correlations between psychological traits and a priori and online covariation biases are depicted in Table 18.

<table>
<thead>
<tr>
<th>Psychological trait</th>
<th>A priori</th>
<th>Online uncertain</th>
<th>Online aversive</th>
<th>Online neutral</th>
<th>A posteriori</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAAS mindfulness</td>
<td>-.09</td>
<td>-.10</td>
<td>-.29*</td>
<td>.14</td>
<td>.07</td>
</tr>
<tr>
<td>FFMQ awareness</td>
<td>-.12</td>
<td>.02</td>
<td>-.29*</td>
<td>.11</td>
<td>-.04</td>
</tr>
<tr>
<td>IUS uncertainty</td>
<td>-.16</td>
<td>.28*</td>
<td>.02</td>
<td>.11</td>
<td>-.07</td>
</tr>
<tr>
<td>URS emotion</td>
<td>.05</td>
<td>.28*</td>
<td>-.04</td>
<td>.04</td>
<td>-.05</td>
</tr>
<tr>
<td>NEO-FFI neuroticism</td>
<td>-.05</td>
<td>.13</td>
<td>.08</td>
<td>.08</td>
<td>-.01</td>
</tr>
<tr>
<td>BDI depression</td>
<td>.00</td>
<td>-.03</td>
<td>.10</td>
<td>-.01</td>
<td>-.01</td>
</tr>
<tr>
<td>PSWQ worry</td>
<td>.16</td>
<td>.12</td>
<td>.18</td>
<td>-.07</td>
<td>-.03</td>
</tr>
</tbody>
</table>

Notes. \( N = 52 \) (\( n = 50 \) for IUS and URS). MAAS = Mindful Attention Awareness Scale; FFMQ = Five-Factor Mindfulness Questionnaire; IUS = Intolerance of Uncertainty Scale; URS = Uncertainty Response Scale; NEO-FFI = Neuroticism Extroversion Openness-Five Factor Inventory; PSWQ = Penn State Worry Questionnaire; BDI = Beck Depression Inventory. *\( p < 0.05 \)

Question 7.1. Does trait mindfulness predict lower expectancies for the first uncertainty cue to be followed by an aversive image (less a priori covariation bias)? To address question 7.1 2 simple regression models were tested. For the first model a priori covariation bias was regressed onto MAAS mindfulness, and for the second model a priori covariation bias was regressed onto FFMQ\(_{AW}\) mindfulness. Together, the models indicated that
the MAAS \( \beta = -0.09, t(50) = -0.64, p = .52 \) and the FFMQ mindfulness measures \( \beta = -0.12, t(49) = -0.87, p = .39 \) did not account for a significant proportion of the variability in a priori covariation bias. These results suggest that trait mindfulness does not predict a smaller baseline tendency to associate uncertainty with aversive outcomes (i.e., less a priori covariation bias).

**Question 7.2. Does trait mindfulness predict lower online expectations for aversive pictures to follow from uncertain (less online covariation bias) and certain-aversive cues relative to neutral cues?** To examine the question as to whether trait mindfulness would predict lower (less unpleasant) expectancy ratings in response to uncertain and aversive cues relative to neutral cues, two repeated measures mixed models were conducted (one for each trait mindfulness measure) using restricted maximum likelihood estimation (REML) multilevel models. Cue type (neutral, aversive, uncertain) was entered as a repeated measure and MAAS and FFMQ\textsubscript{AW} measures of trait mindfulness were entered as covariates in separate models.

**MAAS.** The model testing the MAAS revealed a significant main effect for cue type \( F(2, 96) = 353.42, p < .0001 \). Uncertainty and aversive cues elicited significantly higher expectations for aversive outcomes than neutral cues, and aversive cues elicited significantly higher expectations for aversive outcomes than uncertainty cues (all \( ps < .0001 \)). The main effect of the MAAS \( F(1, 48) = 3.25, p = .08 \), and the MAAS \( \times \) cue type interaction did not reach significance, \( F(2, 96) = 2.01, p = .14 \). While the interaction term in the model was not significant, an examination of the correlations depicted in Table 18 indicate mindfulness was significantly associated with lowered expectations for aversive stimuli to follow after aversive cues \( r_{52} = -0.29, p = .04 \) but not uncertain cues \( r_{52} = -0.10, p = .50 \) or neutral cues \( r_{52} = 0.14, p = .32 \).
**FFMQ\textsubscript{AW}**. The analogous model testing the FFMQ\textsubscript{AW} indicated similar pattern of results. There a significant main effect for cue type, but there was not a significant main effect for the FFMQ\textsubscript{AW} \[ F(1, 47) = .81, p = .37 \] or a FFMQ\textsubscript{AW} \times \text{cue type} interaction, \[ F(2, 94) = 1.61, p = .20. \]

As depicted in Table 18, the FFMQ\textsubscript{AW} was consistent with the MAAS in that it was significantly associated with lower expectations of aversion following aversive cues \[ (r_{51} = -.29, p = .04) \], but not uncertain \[ (r_{51} = .02, p = .89) \] or neutral cues \[ (r_{51} = .11, p = .46) \].

**Question 7.3. Do traits that contrast with mindfulness predict higher expectancies for the first uncertainty cue to be followed by an aversive image (higher a priori covariation bias)?** To address question 7.2 five separate simple regression models were tested. The first two models regressed a priori covariation bias on IUS intolerance for uncertainty and URS emotional responses to uncertainty, respectively (measures of uncertainty distress). The latter three models regressed a priori covariation bias onto NEO neuroticism, BDI depression, and PSWQ worry, respectively (anxiety related traits). The first two models testing uncertainty distress indicated that IUS intolerance of uncertainty \[ \beta = -.16, t(48) = -1.15, p = .25 \] and URS emotional responses to uncertainty \[ \beta = .05, t(48) = 0.34, p = .73 \] were not significant predictors of a priori covariation bias. The latter three regression models testing anxiety related traits indicated that NEO neuroticism \[ \beta = -.05, t(50) = 0.37, p = .72 \], BDI depression \[ \beta = .00, t(50) = -0.01, p = .99 \], and PSWQ worry \[ \beta = .16, t(48) = 1.12, p = .27 \] were not significant predictors of a priori covariation bias. These results suggest that measures of uncertainty distress and anxiety-related traits were not associated with baseline tendencies to associate uncertainty with aversive outcomes (a priori covariation bias).

**Question 7.4. Do traits that contrast with mindfulness predict higher online expectations for aversive pictures to follow from uncertain and certain-aversive cues**
relative to neutral cues (more online covariation bias)? To examine the question as to whether traits that contrast with mindfulness predict higher (more unpleasant) expectancy ratings in response to uncertain and aversive cues relative to neutral cues, five repeated measures mixed models were conducted using restricted maximum likelihood estimation (REML). Cue type (neutral, aversive, uncertain) was entered as a repeated measure and measures of uncertainty distress (IUS intolerance of uncertainty and URS emotional responses to uncertainty) and anxiety-related traits (NEO neuroticism, BDI depression, and PSWQ worry) were entered as covariates in separate models.

**IUS intolerance of uncertainty.** The model testing IUS intolerance of uncertainty revealed a significant main effect for cue type \([F(2, 92) = 324.82, p < .0001]\), consistent with the models conducted above for mindfulness. Uncertainty and aversive cues elicited significantly higher expectations for aversive outcomes than neutral cues, and aversive cues elicited significantly higher expectations for aversive outcomes than uncertainty cues (all \(p s < .0001\)). There was also a main effect of IUS intolerance of uncertainty \([F(1, 46) = 8.14, p = .007]\), which indicated higher levels of IUS intolerance of uncertainty predicted higher expectations for aversive outcomes. The IUS intolerance of uncertainty × cue type interaction did not reach significance, \(F(2, 92) = 0.59, p = .55\).

**URS emotional responses to uncertainty.** The model testing URS emotional responses to uncertainty revealed an identical main effect for cue type \([F(2, 92) = 324.82, p < .0001]\) consistent with the analogous models reported above mindfulness. The main and interactive effects of URS emotional responses to uncertainty were not significant \([F(1, 46) = 3.18, p = .08\) and \(F(2, 92) = 0.79, p = .46\), respectively]. While the interaction term in the model was not significant, an examination of the correlations depicted in Table 18 indicates a pattern of
correlations identical to IUS intolerance of uncertainty. URS emotional responses to uncertainty was significantly associated with higher expectations for aversive stimuli to follow after uncertain cues \( r_{50} = .28, p = .04 \) but not aversive cues \( r_{50} = -.04, p = .79 \) or neutral cues \( r_{50} = .04, p = .79 \).

**NEO Neuroticism.** The model testing NEO neuroticism revealed an identical main effect for cue type \( F(2, 92) = 324.82, p < .0001 \) consistent with the analogous models reported above mindfulness. The main and interactive effects of NEO neuroticism on expectancy ratings was significant \( F(1, 48) = 4.11, p = .04 \). Higher levels of neuroticism were associated with the general tendency to expect aversive outcomes following the stimulus cues. The NEO neuroticism \( \times \) cue type interaction was not significant, \( F(2, 96) = 0.25, p = .78 \). Together, the results of the present analysis suggest that higher levels of NEO neuroticism predicted heighten overall expectations for aversive outcomes throughout the experiment.

**BDI Depression.** As in prior models, the model testing BDI depression revealed a main effect for cue type \( F(2, 96) = 345.86, p < .0001 \). The main and interactive effects of BDI depression on expectancy ratings were not significant \( F(1, 48) = 1.05, p = .31 \) and \( F(2, 96) = 0.74, p = .48 \), respectively. An examination of the correlations depicted in Table 18 indicates that BDI depression was not significantly associated with online expectancy ratings following any of the stimulus cues (all \( ps > .48 \)).

**PSWQ Worry.** The model testing PSWQ worry indicated, again, a main effect for cue type \( F(2, 92) = 328.00, p < .0001 \). The main and interactive effects of PSWQ worry were not significant \( F(1, 46) = 1.87, p = .18 \) and \( F(2, 92) = 1.30, p = .28 \), respectively. An examination of the correlations depicted in Table 18 indicates that PSWQ worry was not significantly associated with online expectancy ratings following any of the stimulus cues (all \( ps > .22 \)).
Summary of findings related to Specific Aim 7. Several tests were conducted to explore whether trait mindfulness would predict lower levels of a priori covariation bias and lower online expectancies for aversive images to follow from uncertain (online covariation bias) and aversive cues, relative to neutral cues. Measures of trait mindfulness did not predict a priori covariation bias, and neither were any of the traits that contrast with mindfulness. However, both measures of trait mindfulness were associated with lower expectations for unpleasant outcomes following aversive cues. Both measures of uncertainty distress were associated with heightened expectations for unpleasant stimuli to follow after uncertainty cues, and NEO neuroticism was associated with a general tendency to expect aversive outcomes, irrespective of the type of stimulus cue.

Specific Aim 8: Mindfulness and a cortical measure of stimulus anticipation.

The eighth aim of the present study was to explore whether trait mindfulness would be associated with lower deflections of the SPN in response to aversive and uncertain cues, relative to neutral cues. However, tests conducted during Specific Aim 6 indicated there was not sufficient evidence to suggest that stimulus cues modulated the SPN, which was a precondition to test whether mindfulness would modulate the effect of stimulus cue on SPN amplitude.

Discussion

The present study tested whether uncertainty about the nature of a forthcoming emotional stimulus would increase anticipation for unpleasant outcomes (covariation bias) and amplify post-stimulus appraisals of emotional stimuli as unpleasant, as captured by self-report and cortical measures of emotional anticipation and appraisal. The primary purpose of the study was to examine whether dispositional mindfulness, relative to traits that contrast with mindfulness, would modulate the effect of uncertainty on these markers of anticipation and appraisal.
Evidence was found that replicated and extended prior research on the effects of anticipatory uncertainty for both emotional anticipation and appraisal processes. Regarding appraisal processes, pre-stimulus cues that left participants uncertain about the nature of the forthcoming stimulus were found to increase self-reported perceptions of neutral and aversive stimuli as unpleasant (Specific Aim 1). This self-reported evidence of unpleasant appraisal following anticipatory uncertainty was corroborated by cortical evidence that indicated the combination of uncertainty and aversiveness of stimuli increased the amplitude of the LPP, an ERP marker of post-stimulus emotional appraisal (Specific Aim 2). There was not sufficient evidence to indicate that dispositional mindfulness influenced self-reported appraisal processes, but the predisposition to worry, a trait contrasting with mindfulness, was associated with heightened unpleasant appraisals, as indicated by post-stimulus self-reports of state affect and stimulus perceptions (Specific Aim 3). Individual differences in depression were also associated with heightened unpleasant affect following the display of aversive stimuli (Specific Aim 3). Dispositional mindfulness and anxiety-related traits were found to modulate the LPP in opposing directions, but the direction of this modulating influence was inconsistent with my expectations, and with past research on the influence of individual differences in LPP variability (Specific Aim 4).

Regarding stimulus anticipation, participants demonstrated biased expectations for uncertainty to be associated with aversive outcome at baseline (a prior covariation bias) and throughout the task (online covariation bias). A priori covariation bias predicted a general trend for higher unpleasant affect and greater unpleasant perceptions of the emotional stimulus content, as indicated by self-report (Specific Aim 5). A posteriori covariation bias predicted heightened unpleasant affect following the display of aversive stimuli, as well as heightened
perceptions of aversive stimuli as unpleasant (Specific Aim 5). There was not sufficient
evidence to suggest the presence of an SPN component, a cortical marker of emotional
anticipation (Specific Aims 6 and 8). However, two measures of dispositional mindfulness were
associated with reduced expectations for unpleasant outcomes following aversive cues (Specific
Aim 7). In contrast, two measures of uncertainty-distress were associated with greater
expectations for unpleasant stimuli to follow after uncertainty cues (online covariation bias), and
neuroticism was related to general expectations for emotional stimuli to be aversive (Specific
Aim 7).

**Specific Aim 1: Uncertainty and self-reported appraisal.**

Past research has demonstrated that unpredictable threats amplify unpleasantness
compared to the same threats when they are predictable (Bar-Anan, Wilson, & Gilbert, 2009;
Dickerson & Kemeny, 2004; Grupe & Nitschke, 2011; Hirsch & Inzlicht, 2008; Kimmel, 1967;
Nader & Belleine, 2007; Sarinopoulos et al., 2010), and findings from the present research were
generally consistent with this body of evidence. Past research that has used an identical cued
image task demonstrated higher levels of unpleasant affect and unpleasant stimulus perceptions
following the display of aversive images preceded by uncertainty cues relative to certainty
cues. Results from the present study did not provide evidence indicating heightened negative
affect following the display of uncertainty cues (Question 1.2), but evidence was found for a
strong general effect of uncertainty on stimulus perceptions. Participants perceived both neutral
and aversive images as being more unpleasant, that is, irrespective of the image valence, when
the stimulus was preceded by uncertainty cues compared to certainty cues. (Question 1.2).

Simply restricting information about the nature of an upcoming emotional stimulus was
enough to distort participants’ perceptions of the stimuli as more unpleasant, irrespective of their
valence. While past research has found that uncertainty amplifies unpleasant perceptions of aversive stimuli, the findings from the present study suggest a more general effect that extends to both neutral and aversive stimuli. This highlights the dramatic influence informational uncertainty can have on downstream perceptual appraisal, and suggests that uncertainty during the anticipation of potentially unpleasant future outcomes can distort the way those outcomes are perceived, even when they are innocuous.

On the other hand, there is a possible alternative interpretation for results of specific aim 1. When participants have foreknowledge about the nature of the upcoming stimulus, they are in a better position to prepare for and regulate their emotional responses (Gross, 1998; Hirsch & Inzlicht, 2008). From this perspective, it may not be that uncertainty amplifies unpleasant experiences, but that providing information that an upcoming event will be aversive allows for better preparation and regulation when faced with emotionally challenging events. In other words, it may not be that uncertainty amplifies unpleasantness, but that certainty promotes more regulated, benign appraisals (Gross, 1998). To test this possibility, future research should examine whether varying degrees of informational content about the nature of forthcoming emotional stimuli influences post-stimulus appraisal processes. As it stands, the present findings are consistent with a substantial body of evidence that indicates uncertainty can amplify the negative impact of emotional stimuli (Bar-Anan, Wilson, & Gilbert, 2009; Dickerson & Kemeny, 2004; Grupe & Nitschke, 2011; Hirsch & Inzlicht, 2008; Kimmel, 1967; Nader & Belleine, 2007; Sarinopoulos et al., 2010).

**Specific Aim 2. Uncertainty and a cortical measure of stimulus appraisal.**

The second specific aim of the present study was to determine whether emotional appraisal as indexed by the LPP is larger for aversive and neutral stimuli presented following
uncertainty about the nature of an emotional image stimulus, compared to when participants know an upcoming emotional image stimulus will be aversive or neutral. First, the present study replicated past research by providing evidence that the LPP was modulated by unpleasant, highly arousing emotional picture stimuli at electrode sites consistent with past research using emotional picture stimuli (Cuthbert et al., 2000; Hajcak MacNamara, Foti, & Keil, 2011; Weinberg and Hajcak, 2011, Foti et al., 2010; Schupp et al., 2010). Past research using galvanic skin conductance responses (Grupe & Nitschke, 2011) and neuroimaging measures (Sarinopoulos et al., 2010) have demonstrated that stimulus uncertainty can amplify physiological arousal to aversive emotional stimuli, and the present research extended this work using a cortical marker of emotional stimulus appraisal. LPP amplitudes elicited by aversive stimuli were amplified when the valence of a forthcoming stimulus was uncertain, relative to when the image valence was known in advance with certainty.

This finding that the LPP is modulated by stimulus valence and uncertainty is consistent with emerging evidence that suggests that LPP amplitudes are increased when participants are exposed to ambiguous (uncertain) compared to unambiguous emotional facial expressions (Tritt, Peterson, & Inzlicht, under review). However, there is an important difference between the manipulation of uncertainty in the present study, and in the work of Tritt, Peterson, & Inzlicht (under review). While the present study examined the influence of uncertainty during stimulus anticipation without changing the stimulus content, the study by Tritt et al. (under review) manipulated the stimulus content itself to evoke uncertainty. This difference could have distinct influences on psychological processes. The present study showed how uncertainty during anticipation of a stimulus can have downstream psychological consequences for stimulus appraisal, and thus assesses the influence of informational uncertainty on the psychological
context in which stimuli are perceived. Tritt et al.’s (under review) manipulation examined how uncertainty about the nature of an emotional stimulus itself can exert an immediate influence on appraisal processes. Despite this difference, the consistent effect of uncertainty on LPP amplitude found in both studies highlights how robust the influence of uncertainty can be on cortical markers of emotional appraisal. Together, this evidence from these two studies suggests that different types of uncertainty can bias cortical markers of appraisal in similar ways, by either influencing the psychological context in which unambiguous emotional stimuli are perceived, or by directly manipulating the ambiguity of stimulus content. Further, by directly examining the influence of an ambiguous stimulus on the LPP, participants were not given the opportunity to regulate their responses, and the findings of Tritt et al. (under review) lend support to the theory that uncertainty indeed amplifies unpleasant appraisals, rather than certainty providing an opportunity to regulate emotional responses and promote more benign appraisals.

**Specific Aim 3. Mindfulness and Self-reported Appraisal**

Considerable research has demonstrated that dispositional mindfulness is associated with more benign appraisals of aversive stimuli (Arch & Craske, 2006; Brown & Ryan, 2003; Modinos, Ormel, & Aleman, 2010). The third aim of the present study was to determine whether trait mindfulness would predict more benign appraisals of emotional stimuli when participants were uncertain about the nature of the forthcoming stimulus, relative to when they were certain. Evidence was not found to suggest that mindfulness reduced self-reported unpleasant affect (Question 3.1) or unpleasant stimulus perceptions (Question 3.2) following emotional stimulus exposure. However, evidence was found that self-reported affect and appraisals were sensitive to other individual differences. Two anxiety-related individual difference measures were related to increased unpleasant appraisals, though these traits were not related to stimulus
certainty. The predisposition to engage in ruminative, uncontrollable worry, as indexed by the PSWQ, was associated with higher levels of unpleasant affect (Question 3.3) and unpleasant perceptions of the images (Question 3.4) following stimulus exposure, but this effect did not depend on the certainty of the stimuli. Similarly, higher levels of depressive symptoms were associated with greater self-reported unpleasant affect following aversive images. These effects are consistent with past research linking greater levels of worry and depression with the experience of negative affect (Brown, Chorpita, & Barlow, 1998; Watson, Clark, & Tellegen, 1988).

**Specific Aim 4. Mindfulness and a Cortical Measure of Stimulus Appraisal.**

The fourth specific aim was to determine whether dispositional mindfulness would predict attenuated LPP responses to aversive emotional stimuli relative to neutral stimuli under conditions of uncertainty and certainty, during an early time period (500-1000ms) of the LPP. Past research has provided evidence that mindfulness attenuates LPP responses to motivationally salient pleasant and unpleasant emotional picture stimuli in a similar time period (Brown et al., 2013), while traits that contrasted with mindfulness amplified LPP responses. The present study found that dispositional mindfulness indeed modulated the LPP, and measures of uncertainty distress and anxiety-related traits modulated the LPP in an opposite direction of mindfulness, but the direction of these effects were in the opposite direction of what was expected, and were inconsistent with the findings of past research on mindfulness and the LPP (Brown et al., 2013; Sobolewski et al., 2011). Dispositional mindfulness, as measured by two psychometric instruments, was predictive of higher LPP amplitudes in response to certain and uncertain aversive emotional stimuli at centro-parietal electrodes (CPz and CP4). Dispositional
mindfulness was not associated with LPP amplitude differences due to stimulus certainty (Question 4.1).

Future research is needed to clarify why mindfulness amplified the LPP in response to aversive stimuli in the present study, but one potential reason is that the experimental paradigms used in both studies are not directly comparable, and one primary difference may have influenced the relations between mindfulness and the LPP. In the study by Brown et al. (2013), participants passively viewed images without receiving any cueing information about the nature of the upcoming image content. In the present study, participants learned about the nature of the upcoming stimuli from pre-stimulus cues. Given the high degree of sensitivity of cortical measures, this may be an important distinction that has implications for future research.

As discussed above in Specific Aims 1 and 3, it is likely the information conveyed by the stimulus cue could change the psychological context during stimulus anticipation and influence the processes involved in downstream appraisal. For example, the stimulus cues could influence how participants deployed their attention prior to and during the display of a stimulus, and this difference would likely be reflected by changes in the LPP, given the strong relation between this ERP component and attention. Past research on mindfulness and emotion regulation has suggested that mindfulness may promote a greater willingness to stay with, rather than avoid aversive emotional experiences (Arch & Craske, 2006). Indeed, this is theorized to be one of the most important benefits of mindfulness in clinical settings because mindfulness is thought to facilitate exposure and minimize avoidance of unpleasant experience (Follette et al., 2006; Greeson et al., 2009). Additionally, this heightened ability to stay with difficult experiences, such as psychological suffering, mortality, and uncertainty, is a central goal of mindfulness from the perspective of ancient wisdom traditions (Anālayo, 2003; Davis and Thompson, in press).
While entirely speculative, it is theoretically defensible that participants lower in mindfulness would be more likely to avoid and divert their attention away when information cues them that an upcoming emotional stimulus could be potentially unpleasant. On the other hand, a higher degree of mindfulness would facilitate a greater willingness to stay with a potentially unpleasant experience. If this were the case, mindfulness would be expected to promote higher LPP amplitudes in response to aversive and uncertain unpleasant stimuli, while traits that contrast with the open and receptive nature of mindfulness would promote reduced LPP amplitudes, and this is precisely what was observed in the present study. Future research should directly examine the effect of stimulus cueing information on variability in the LPP response by comparing ERP averages for trials that provide cueing information against trials that do not provide cueing information. This change would contribute to understanding the influence of cueing information on the LPP, and would elucidate how such information may modulate the subsequent processing of emotional stimuli.

Another relevant finding from the present study involves the time-course of the effect of mindfulness on LPP amplitude. While there was not a significant effect of signal window on LPP amplitude in any of the models, dispositional mindfulness had its most robust influence on the LPP during the early stimulus window (500-1000ms), as indicated by a significant correlation with LPP amplitude during only the early signal window. That mindfulness exerted the most potent influence on the LPP at an early time period is interesting in the light of prior research on the LPP and emotion regulation. The LPP is sensitive to changes in attention and to changes in stimulus meaning (see Hajcak, 2013), but consistent with the process model of emotion regulation (Gross, 1998), regulation strategies that modify attention influence the LPP much earlier than more effortful regulation strategies which involve modifying stimulus meaning.
(MacNamara, Oschner, & Hajcak; Thiruchselvam et al., 2011). More specifically, modulation of the LPP by reappraisal instructions has been consistently prominent for approximately 1000ms post stimulus presentation, while attention regulation strategies modulate the LPP as early as 300ms. Mindfulness operates at the level of attention, so as an emotion regulation strategy, mindfulness was expected to modulate the LPP earlier than more effortful downstream types of emotion regulation that focus on modifying stimulus meaning (e.g. reappraisal).

Traits that contrasted with mindfulness predicted an opposite pattern of association with the LPP, though again, in the opposite of the hypothesized direction. Two measures of uncertainty distress (IUS intolerance of uncertainty and URS emotional responses to uncertainty) and two measures of anxiety-related traits (NEO neuroticism and BDI depression) predicted attenuated LPP amplitudes elicited by aversive stimuli relative to neutral stimuli. As with mindfulness, these psychological traits interacted with stimulus valence, and not the stimulus cue, which suggests there is not sufficient evidence to conclude that individual differences in mindfulness and traits that contrast with mindfulness modulated the effect of stimulus uncertainty on a neural marker of emotional stimulus appraisal.

**Specific Aim 5. Uncertainty and Self-reported Anticipation.**

The fifth aim of the present research was to replicate past research that has demonstrated a priori and online covariation biases amplify unpleasant affect and stimulus ratings following the display of unpleasant stimuli under conditions of uncertainty, relative to certainty. The results of the present analysis suggest that heightened a priori covariation bias was associated with a general tendency to self-report more unpleasant affect (Question 5.1), and heightened perceptions of unpleasantness following the display of aversive images (Question 5.2). There was not sufficient evidence to conclude that online covariation bias modulated self-reported
appraisals (Questions 5.1 and 5.2). Higher levels of a posteriori covariation bias were associated with heightened unpleasant affect and stimulus perceptions for aversive stimuli. The effects of covariation bias measures on self-reported appraisals did not depend on whether the stimulus cue was certain or uncertain.

Prior to the aforementioned analyses assessing the influence of covariation biases on post-stimulus appraisals, evidence was found to suggest that participants’ indeed demonstrated both a priori and online covariation biases, tendencies to associate uncertainty with aversive outcomes. Participants associated uncertainty with the presentation of aversive pictures at baseline (a priori covariation bias), and as they progressed through the experimental task (online covariation bias). These findings are consistent with previous research using similar experimental paradigms (Grupe & Nitschke, 2011). At the outset of the experiment, participants had no knowledge of the actual probability that an aversive image would appear following their first exposure to an uncertainty cue. However, on average, participants’ self-reports indicated expectations that more aversive images would follow after the presentation of uncertainty cues. Participants continued to associate uncertainty with aversiveness as they progressed through the experimental task, demonstrating an online covariation bias.

There was not significant evidence to suggest that participants’ retrospective (post-experiment) estimates of the relationship between uncertain cues and aversive pictures was over the actual rate of 50%, though past research has also failed to find this effect (Grupe & Nitschke, 2011). In fact, the overwhelming majority of studies that have examined post-experiment covariation assessments have found results using phobics or high anxiety populations (deJong et al., 1992), whereas relatively few studies have found effects among a convenience sample of normative college students (Witvliet & Vrana, 2000). One likely reason the post-experiment (a
posteriori) measure of covariation bias did not reach significance is due to the high degree of variability in these post-experiment estimates (estimates ranged from 20%-80%), a finding noted in similar studies (Grupe & Nitschke, 2011).

Another aspect of the present work that was consistent with prior studies is the finding that the magnitude of online covariation bias predicted participant’s post-experiment covariation bias estimates (Amin & Lovibond, 1998; Grupe & Nitschke, 2011). The relation between online expectancy ratings and post-experiment estimates suggests that heightened expectations to associate uncertainty with aversive stimuli are linked with biases in memory about what actually occurred. When the experiment ended and participants had been exposed to every cue-picture combination - that is, when the full facts about the actual probability of uncertainty-aversive pairings was in, the tendency to anticipate that uncertainty would lead to aversive outcomes was linked with a greater degree of retrospective bias about the frequency that uncertainty was paired with aversive stimuli. Said differently, not only did uncertainty during anticipation distort perceptions of stimuli as unpleasant (Specific Aim 1), but higher tendencies to anticipate unpleasant outcomes following uncertainty also distorted retrospective appraisals of the events that actually took place during the study. This finding is further evidence that highlights the distorting influence uncertainty can have on downstream appraisal processes.

Past research has linked covariation bias with the amplification of fear (De Jong et al., 1993; 1995; Tomarken et al., 1989), and studies administering an identical paradigm to the one administered here found heightened amygdalae responses to aversive stimuli when preceded by uncertainty compared to certainty cues (Sarinopoulos et al., 2010). Covariation biases develop from the experience of anxiety when confronted with negative events, and the magnitude of the anxiety that is elicited determines the strength of the covariation bias (Pauli, Wiedemann,
Dengler, & Kühlkamp, 2001). Results from the present study suggest that uncertainty was associated with aversiveness, which provides support for the idea that uncertainty can serve as a cue signaling something unpleasant.

**Specific Aim 6. Uncertainty and a Cortical Measure of Anticipation.**

The sixth specific aim of the present study was to determine whether emotional anticipation as indexed by the SPN is largest for certain-aversive and uncertain stimulus cues compared to certain-neutral stimulus cues. Evidence from region of interest analysis did not indicate significant evidence to conclude an SPN component was isolated in the present study. While visual inspection of the SPN waveforms indicated the EEG signal was higher for uncertainty cues during the appropriate time window and at the electrode locations consistent with past research, there was no statistical evidence to suggest the SPN was modulated by the emotional information provided by the stimulus cues. This failure to isolate the SPN precluded the examination of Specific Aim 8, which sought to examine the influence of mindfulness on variability in the SPN, so the planned analyses for these tests were not conducted.

One possibility for this lack of effect is that the cued image task was not designed to measure the SPN, and I decided to assess the component post-hoc. As such, there was a crucial barrier in the trial parameters that could have added considerable noise to the SPN measure. That is, the interstimulus interval (ISI) between the participant expectancy ratings and the onset of the emotional picture was a random interval ranging between 4 and 10 seconds, which is the period during which the SPN is captured. Typically, the late component of the SPN is measured as the period just prior to a stimulus onset, and the period between a stimulus cue (S1) and the stimulus (S2) is static interval, rather than a random interval. To overcome this I operationalized the SPN as the average EEG activity during a 200ms time period prior to the earliest possible
image onset (4 seconds), but it is likely that the random interstimulus interval during this anticipatory period contributed to the lack of significant finding of an SPN component. Subsequent research using this cued image task to explore questions relating to the SPN should implement a constant interstimulus interval between S1 and S2.

**Specific Aim 7: Mindfulness and Self-reported Anticipation.**

Several tests were conducted to explore whether trait mindfulness would predict lower levels of a priori covariation bias and lower online expectancies for aversive images to follow from uncertain (online covariation bias) and aversive cues, relative to neutral cues. Measures of trait mindfulness were not predictive of a priori covariation bias, and neither were any of the traits that contrast with mindfulness (Question 7.1). However, both measures of trait mindfulness were significantly correlated with lower expectations for unpleasant outcomes following aversive cues. This finding is consistent with a previous study that found a state mindfulness induction reduced negativity bias and promoted more positive appraisals of novel stimuli during attitude formation (Kiken & Shook, 2011).

Several traits that contrast with mindfulness were related to exaggerated covariation biases. Two measures of uncertainty distress -- intolerance of uncertainty, and emotional responses to uncertainty-- were associated with heightened expectations for unpleasant stimuli to follow after uncertainty cues. Neuroticism was associated with a general tendency to expect aversive outcomes, irrespective of the type of stimulus cue. This finding is consistent with the nature of neuroticism as a personality trait associated with heightened interpretation of situations as threatening (Matthews & Deary, 1998) and is consistent with research relating covariation biases and clinical anxiety (Barlow, 2000; Borkovec, 2002) and heightened anxiety and fear (Davey & Dixon, 1995).
Limitations

This study was designed to examine the influence of uncertainty on self-reported and cortical measures of emotional stimulus anticipation and appraisal, and particularly the modulation of these effects by dispositional mindfulness. The target sample size for the study was estimated at 60 participants (to achieve a power of .80), but data from 10 participants was not usable due to procedural non-compliance, or poor quality EEG signal, leaving a sample of \( N = 52 \) for analysis. Thus, the study was statistically underpowered, which suggests the present study might have had a higher than ideal rate of type 2 errors. That is, some the effects that didn’t reach statistical significance (e.g., marginally significant results) might have been detected with an adequate sample size.

Second, I am not aware of past research that has used this cued image task to investigate variability in LPP amplitudes elicited by emotional picture stimuli. The presentation of cueing information on the LPP clearly influenced the amplitude of the LPP, but more research is necessary to uncover how pre-stimulus information influences psychological processes that modulate the LPP. An important next step would be to include multiple types of certain and uncertain stimulus cues that convey information associated with varying degrees of stimulus probability as well as the degree of unpleasantness for stimulus outcomes.

Third, the present study was designed to examine the association between dispositional mindfulness and variability in LPP responses to emotional stimuli. Attempts were made to increase confidence that the results were specific to mindfulness by also examining the influence of psychological traits antithetical to mindfulness. However, it is possible that the correlational results described here could be due to a third variable, and future studies should be conducted using experimental manipulations of mindfulness, such as mindfulness training or state
inductions of mindfulness to determine whether observed relations between mindfulness and the
LPP are causal in nature.

Finally, the cued image task was not designed to measure the SPN appropriately in the
current study, and the decision was made to assess the component after data had been collected
with the paradigm. In the present design, the interstimulus interval (ISI) between the participant
expectancy ratings and the onset of the emotional picture was a random interval ranging between
4 and 10 seconds, which is the period during which the SPN is captured. To be consistent with
previous studies that have investigated the SPN during emotional anticipation, the period
between a stimulus cue (S1) and the stimulus (S2), which is the time period in which the SPN is
isolated, should us a constant interval.

Concluding Remarks.

This study was designed to examine the influence of uncertainty on self-reported and
cortical measures of emotional stimulus anticipation and appraisal, and the modulation of these
effects by dispositional mindfulness. The study replicated and extended prior research on the
effects of anticipatory uncertainty for both emotional anticipation and appraisal processes.
Uncertainty during stimulus anticipation was found to increase unpleasant stimulus perceptions,
and this was corroborated with cortical evidence indicating that uncertainty increased LPP
amplitudes elicited by emotional stimuli relative to the same stimuli presented under conditions
of certainty. Together these findings suggest informational uncertainty during anticipation can
exert a potent downstream influence on emotional appraisal processes.

Individual differences in depression and worry were associated with heightened
unpleasant appraisals. Evidence was not found to suggest dispositional mindfulness influenced
self-reported appraisals, but mindfulness and several traits that contrast with mindfulness, were
found to modulate the LPP in opposing directions. The direction of the modulating influence of these traits on the LPP was opposite of what was expected, and potentials explanations derived from mindfulness theory were discussed to inform future research.

Participants demonstrated biased expectations for uncertainty to be associated with aversive outcomes, both at baseline (a prior covariation bias) and throughout the task (online covariation bias), and online covariation bias was associated with distorted retrospective (a posteriori) appraisals of the uncertainty-aversive pairings. A priori covariation bias predicted a general trend for higher unpleasant affect and greater unpleasant perceptions of the emotional stimulus content, and a posteriori covariation bias predicted heightened unpleasant affect following the display of aversive stimuli, as well as heightened perceptions of aversive stimuli as unpleasant.

Two measures of dispositional mindfulness were associated with reduced expectations for unpleasant outcomes following aversive cues, while traits that contrast with mindfulness were associated with greater online covariation bias, and general expectations for emotional stimuli to be aversive. The evidence described in the present study contributes to a growing body of evidence linking uncertainty during anticipation with biased expectancies for aversion, and higher unpleasant stimulus appraisal, and advances our understanding of the important role that individual differences play in event-related neural variability.


Tritt, S. M., Peterson, J. B., & Inzlicht (under review). The uncertainty bias: Brain evidence that ambiguity is more captivating than threat or reward.


Appendix A

Mindful Attention Awareness Scale

Day-to-Day Experiences

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

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<td>1</td>
<td>Almost Always</td>
<td>Very Frequently</td>
<td>Somewhat Frequently</td>
<td>Somewhat Infrequently</td>
<td>Very Infrequently</td>
<td>Almost Never</td>
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1. I could be experiencing some emotion and not be conscious of it until sometime later.  
2. I break or spill things because of carelessness, not paying attention, or thinking of something else.  
3. I find it difficult to stay focused on what’s happening in the present.  
4. I tend to walk quickly to get where I’m going without paying attention to what I experience along the way.  
5. I tend not to notice feelings of physical tension or discomfort until they really grab my attention.  
6. I forget a person’s name almost as soon as I’ve been told it for the first time.  
8. I rush through activities without being really attentive to them.  
9. I get so focused on the goal I want to achieve that I lose touch with what I’m doing right now to get there.
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<tr>
<td>10.</td>
<td>I do jobs or tasks automatically, without being aware of what I'm doing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>11.</td>
<td>I find myself listening to someone with one ear, doing something else at the same time.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>5</td>
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<tr>
<td>12.</td>
<td>I drive places on ‘automatic pilot’ and then wonder why I went there.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>13.</td>
<td>I find myself preoccupied with the future or the past.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14.</td>
<td>I find myself doing things without paying attention.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15.</td>
<td>I snack without being aware that I'm eating.</td>
<td>1</td>
<td>2</td>
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Appendix B

Five Factor Mindfulness Questionnaire

FACETS OF EXPERIENCE

Please rate each of the following statements using the scale provided. Write the number in the blank that best describes your own opinion of what is generally true for you.

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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>never or very rarely true</td>
<td>rarely true</td>
<td>sometimes true</td>
<td>often true</td>
<td>very often or always true</td>
</tr>
</tbody>
</table>

_____ 1. When I’m walking, I deliberately notice the sensations of my body moving.
_____ 2. I’m good at finding words to describe my feelings.
_____ 3. I criticize myself for having irrational or inappropriate emotions.
_____ 4. I perceive my feelings and emotions without having to react to them.
_____ 5. When I do things, my mind wanders off and I’m easily distracted.
_____ 6. When I take a shower or bath, I stay alert to the sensations of water on my body.
_____ 7. I can easily put my beliefs, opinions, and expectations into words.
_____ 8. I don’t pay attention to what I’m doing because I’m daydreaming, worrying, or otherwise distracted.
_____ 9. I watch my feelings without getting lost in them.
_____ 10. I tell myself I shouldn’t be feeling the way I’m feeling.
_____ 11. I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.
12. It’s hard for me to find the words to describe what I’m thinking.

13. I am easily distracted.

14. I believe some of my thoughts are abnormal or bad and I shouldn’t think that way.

15. I pay attention to sensations, such as the wind in my hair or sun on my face.

16. I have trouble thinking of the right words to express how I feel about things.

17. I make judgments about whether my thoughts are good or bad.

18. I find it difficult to stay focused on what’s happening in the present.

19. When I have distressing thoughts or images, I “step back” and am aware of the thought or image without getting taken over by it.

20. I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing.

21. In difficult situations, I can pause without immediately reacting.

22. When I have a sensation in my body, it’s difficult for me to describe it because I can’t find the right words.

23. It seems I am “running on automatic” without much awareness of what I’m doing.

24. When I have distressing thoughts or images, I feel calm soon after.

25. I tell myself that I shouldn’t be thinking the way I’m thinking.
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<tbody>
<tr>
<td></td>
<td>never or very rarely true</td>
<td>rarely true</td>
<td>sometimes true</td>
<td>often true</td>
<td>very often or always true</td>
</tr>
</tbody>
</table>

26. I notice the smells and aromas of things.

27. Even when I'm feeling terribly upset, I can find a way to put it into words.

28. I rush through activities without being really attentive to them.

29. When I have distressing thoughts or images I am able just to notice them without reacting.

30. I think some of my emotions are bad or inappropriate and I shouldn’t feel them.

31. I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow.

32. My natural tendency is to put my experiences into words.

33. When I have distressing thoughts or images, I just notice them and let them go.

34. I do jobs or tasks automatically without being aware of what I'm doing.

35. When I have distressing thoughts or images, I judge myself as good or bad, depending what the thought/image is about.

36. I pay attention to how my emotions affect my thoughts and behavior.

37. I can usually describe how I feel at the moment in considerable detail.

38. I find myself doing things without paying attention.

39. I disapprove of myself when I have irrational ideas.
Appendix C

Attentional Control Scale

**TASK BEHAVIORS**

**INSTRUCTIONS:** Please indicate how frequently you have the following experiences using the scale shown below.

1 = almost never  
2 = sometimes  
3 = often  
4 = always

___  1. It’s very hard for me to concentrate on a difficult task when there are noises around.

___  2. When I need to concentrate and solve a problem, I have trouble focusing my attention.

___  3. When I am working hard on something, I still get distracted by events around me.

___  4. My concentration is good even if there is music in the room around me.

___  5. When concentrating, I can focus my attention so that I become unaware of what’s going on in the room around me.

___  6. When I am reading or studying, I am easily distracted if there are people talking in the same room.

___  7. When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.

___  8. I have a hard time concentrating when I’m excited about something.

___  9. When concentrating I ignore feelings of hunger or thirst.

___ 10. I can quickly switch from one task to another.

___ 11. It takes me a while to get really involved in a new task.

___ 12. It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures.
1 = almost never  
2 = sometimes  
3 = often  
4 = always

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<td></td>
<td>13. I can become interested in a new topic very quickly when I need to.</td>
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<td></td>
<td>14. It is easy for me to read or write while I’m also talking on the phone.</td>
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<td></td>
<td>15. I have trouble carrying on two conversations at once.</td>
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<td></td>
<td>16. I have a hard time coming up with new ideas quickly.</td>
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<td></td>
<td>17. After being interrupted or distracted, I can easily shift my attention back to what I was doing before.</td>
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<tr>
<td></td>
<td>18. When a distracting thought comes to mind, it is easy for me to shift my attention away from it.</td>
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<td></td>
<td>19. It is easy for me to alternate between two different tasks.</td>
<td></td>
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<tr>
<td></td>
<td>20. It is hard for me to break from one way of thinking about something and look at it from another point of view.</td>
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Appendix D

Intolerance of Uncertainty Scale

**How I Feel**

**INSTRUCTIONS**: Please indicate the degree to which each of the following statements is characteristic of you as a person. Indicate how you really feel, and not what you think the correct response is. Please use the 5-point scale shown below.

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<tr>
<td>not at all characteristic of me</td>
<td></td>
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<tr>
<td>slightly characteristic of me</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>moderately characteristic of me</td>
<td></td>
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<td></td>
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<tr>
<td>very characteristic of me</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>entirely characteristic of me</td>
<td></td>
<td></td>
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</table>

1. Uncertainty stops me from having a strong opinion. 1 2 3 4 5
2. Being uncertain means that a person is disorganized. 1 2 3 4 5
3. Uncertainty makes life intolerable. 1 2 3 4 5
4. It’s unfair having no guarantees in life. 1 2 3 4 5
5. My mind can’t be relaxed if I don’t know what will happen tomorrow. 1 2 3 4 5
6. Uncertainty makes me uneasy, anxious, or stressed. 1 2 3 4 5
7. Unforseen events upset me greatly. 1 2 3 4 5
8. It frustrates me not having all the information I need. 1 2 3 4 5
9. Uncertainty keeps me from living a full life. 1 2 3 4 5
10. One should always look ahead so as to avoid surprises. 1 2 3 4 5
11. A small unforseen event can spoil everything, even with the best planning. 1 2 3 4 5
<table>
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<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.</td>
<td>When it’s time to act, uncertainty paralyses me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>13.</td>
<td>Being uncertain means that I am not first rate.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>14.</td>
<td>When I am uncertain I can’t go forward.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>15.</td>
<td>When I am uncertain, I can’t function very well.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>16.</td>
<td>Unlike me, others seem to know where they are going with their lives.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>17.</td>
<td>Uncertainty makes me vulnerable, unhappy, or sad.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>18.</td>
<td>I always want to know what the future has in store for me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>19.</td>
<td>I can’t stand being taken by surprise.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>20.</td>
<td>The smallest doubt can stop me from acting.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>21.</td>
<td>I should be able to organize everything in advance.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>22.</td>
<td>Being uncertain means that I lack confidence.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>23.</td>
<td>I think it’s unfair that other people seem to be sure about their future.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>24.</td>
<td>Uncertainty keeps me from sleeping soundly.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>25.</td>
<td>I must get away from all uncertain situations.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>26.</td>
<td>The ambiguities in life stress me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>27.</td>
<td>I can’t stand being undecided about my future.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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</tbody>
</table>
Appendix E

Uncertainty Response Scale

**EVERYDAY LIFE**

**INSTRUCTIONS:** Following are some statements which regard different ways of reacting to situations. Please read each one carefully and circle the one alternative which you feel is most like you. The alternatives are as follows:

1 = Never  
2 = Sometimes  
3 = Often  
4 = Always

1. I tend to give up easily when I don’t clearly understand a situation.  
2. I find the prospect of change exciting and stimulating.  
3. When I go shopping, I like to have a list of exactly what I need.  
4. Sudden changes make me feel upset.  
5. There is something exciting about being kept in suspense.  
6. I feel better about myself when I know that I have done all I can to plan my future accurately.  
7. When making a decision, I am deterred by the fear of making a mistake.  
8. The idea of taking a trip to a new country fascinates me.  
9. When uncertain, I act very cautiously until I have more information about the situation.  
10. When the future is uncertain, I generally expect the worst to happen.  
11. I like going on holidays with nothing planned in advance.  
12. I like to have things under control.
13. Facing uncertainty is a nerve-wracking experience. 1 2 3 4
14. Taking chances is part of life. 1 2 3 4
15. When I feel uncertain about something, I try to weigh up rationally all the information I have. 1 2 3 4
16. I get worried when a situation is uncertain. 1 2 3 4
17. I think you have to be flexible to work effectively. 1 2 3 4
18. Before making any changes, I need to think things over thoroughly. 1 2 3 4
19. Thinking about uncertainty makes me feel depressed. 1 2 3 4
20. I feel curious about new experiences. 1 2 3 4
21. I prefer to stick to tried and tested ways of doing things. 1 2 3 4
22. Uncertainty frightens me. 1 2 3 4
23. I like to think of a new experience in terms of a challenge. 1 2 3 4
24. I like to have my weekends planned in advance. 1 2 3 4
25. When I can’t clearly discern situations, I get apprehensive. 1 2 3 4
26. A new experience is an occasion to learn something new. 1 2 3 4
27. When I feel a situation is unclear, I try to do my best to resolve it. 1 2 3 4
28. When I’m not certain about someone’s intentions towards me, I often become upset or angry. 1 2 3 4
29. I enjoy finding new ways of working out problems. 1 2 3 4
30. I like to know exactly what I’m going to do next. 1 2 3 4
31. When uncertain about what to do next, I tend to feel lost. 1 2 3 4
32. New experiences can be useful. 1 2 3 4
33. When facing an uncertain situation, I tend to prepare as much as possible and then hope for the best. 1 2 3 4
34. I feel anxious when things are changing.  
35. New experiences excite me.  
36. I feel relieved when an ambiguous situation suddenly becomes clear.  
37. When a situation is unclear, it makes me feel angry.  
38. I think variety is the spice of life.  
39. When I feel uncertain, I try to take decisive steps to clarify the situation.  
40. I get really anxious if I don’t know what someone thinks about me.  
41. I think a mid-life career change is an exciting idea.  
42. I try to have my life and career clearly mapped out.  
43. I am hesitant when it comes to making changes.  
44. I enjoy unexpected events.  
45. I like things to be ordered and in place, both at work and at home.  
46. I easily adapt to novelty.  
47. I like to plan ahead in detail rather than leaving things to chance.  
48. Before I buy something, I have to view every sample I can find.
Appendix F

NEO-Five Factor Inventory

**Behavioral Styles**

Instructions: Please read each of the statements carefully. Using the 0 to 4 scale below, indicate to what extent you agree with each statement.

- **0 =** If you *strongly disagree* or the statement is definitely false.
- **1 =** If you *disagree* or the statement is mostly false.
- **2 =** If you are neutral on the statement, you cannot decide, or the statement is equally true or false.
- **3 =** If you *agree* or the statement is mostly true.
- **4 =** If you *strongly agree* or the statement is definitely true.

1. I often feel helpless and want someone else to solve my problems. 0 1 2 3 4
2. Sometimes I feel completely worthless. 0 1 2 3 4
3. I don't like to waste my time daydreaming. 0 1 2 3 4
4. I don't consider myself especially "light-hearted." 0 1 2 3 4
5. Sometimes when I am reading poetry or looking at a work of art, I feel a chill or wave of excitement. 0 1 2 3 4
6. I rarely feel fearful or anxious. 0 1 2 3 4
7. I have a lot of intellectual curiosity. 0 1 2 3 4
8. I am not a worrier. 0 1 2 3 4
9. I often feel as if I'm bursting with energy. 0 1 2 3 4
10. Once I find the right way to do something, I stick to it. 0 1 2 3 4
0 = If you *strongly disagree* or the statement is definitely false.
1 = If you *disagree* or the statement is mostly false.
2 = If you are neutral on the statement, you cannot decide, or the statement is equally true or false.
3 = If you *agree* or the statement is mostly true.
4 = If you *strongly agree* or the statement is definitely true.

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<tbody>
<tr>
<td>11. I often feel tense and jittery.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12. I rarely feel lonely or blue.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13. I often get angry at the way people treat me.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14. I often enjoy playing with theories or abstract ideas.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15. I am a cheerful, high-spirited person.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>16. I am a very active person.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>17. I am intrigued by the patterns I find in art and nature.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>18. I am seldom sad or depressed.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19. I have little interest in speculating on the nature of the universe or the human condition.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>20. I often feel inferior to others.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>21. I like to have a lot of people around me.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>22. I seldom notice the moods or feelings that different environments produce.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>23. I am not a cheerful optimist.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>24. At times I have been so ashamed I just wanted to hide.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>25. I believe letting students hear controversial speakers can only confuse and mislead them.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>26. I usually prefer to do things alone.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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</tbody>
</table>
0 = If you **strongly disagree** or the statement is definitely false.
1 = If you **disagree** or the statement is mostly false.
2 = If you are neutral on the statement, you cannot decide, or the statement is equally true or false.
3 = If you **agree** or the statement is mostly true.
4 = If you **strongly agree** or the statement is definitely true.

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<tr>
<td>27. Too often, when things go wrong, I get discouraged and feel like giving up.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>28. My life is fast-paced.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>29. I believe we should look to our religious authorities for decisions on moral issues.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>30. I like to be where the action is.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>31. I would rather go my own way than be a leader of others.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>32. Poetry has little or no effect on me.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>33. When I’m under a great deal of stress, sometimes I feel like I’m going to pieces.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>34. I laugh easily.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>35. I often try new and foreign foods.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>36. I really enjoy talking to people.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
Appendix G
Penn State Worry Questionnaire

**HOW I AM**

**INSTRUCTIONS:** Rate each of the following statements on a scale of 1 ("not at all typical of me") to 5 ("very typical of me"). Please do not leave any blank items.

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Not at all typical of me</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. If I do not have enough time to do everything, I do not worry about it.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. My worries overwhelm me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. I do not tend to worry about things.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. Many situations make me worry.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. I know I should not worry about things, but I just cannot help it.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. When I am under pressure I worry a lot.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. I am always worrying about something.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. I find it easy to dismiss worrisome thoughts.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9. As soon as I finish one task, I start to worry about everything else I have to do.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10. I never worry about anything.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>11. When there is nothing more I can do about a concern, I do not worry about it anymore.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
12. I have been a worrier all my life.  1  2  3  4  5
13. I notice that I have been worrying about things.  1  2  3  4  5
14. Once I start worrying, I cannot stop.  1  2  3  4  5
15. I worry all the time.  1  2  3  4  5
16. I worry about projects until they are done.  1  2  3  4  5
Appendix H

Beck Depression Inventory

THOUGHTS, EMOTIONS, AND BEHAVIOR

DIRECTIONS: On this questionnaire are groups of statements. Please read each group of statements carefully. Then choose the one statement in each group which best describes the way you have been feeling during the PAST WEEK, INCLUDING TODAY. Fill in the number on the scantron sheet to indicate your choice. Be sure to read all the statements in each group before making your choice.

Question 1.

1 I do not feel sad
2 I feel sad
3 I am sad all the time and I can’t snap out of it
4 I am so sad or unhappy I can’t stand it

Question 2.

1 I am not particularly discouraged about the future
2 I feel discouraged about the future
3 I feel I have nothing to look forward to
4 I feel that the future is hopeless and that things cannot improve

Question 3.

1 I do not feel like a failure
2 I feel I have failed more than the average person
3 As I look back on my life, all I can see is a lot of failures
4 I feel I am a complete failure as a person
Question 4.

1. I get as much satisfaction out of things as I used to
2. I don’t enjoy things the way I used to
3. I don’t get any real satisfaction out of anything anymore
4. I am dissatisfied or bored with everything

Question 5.

1. I don’t feel particularly guilty
2. I feel guilty a good part of the time
3. I feel quite guilty most of the time
4. I feel guilty all of the time

Question 6.

1. I don’t feel I am being punished
2. I feel I may be punished
3. I expect to be punished
4. I feel I am being punished

Question 7.

1. I don’t feel disappointed in myself
2. I am disappointed in myself
3. I am disgusted with myself
4. I hate myself

Question 8.

1. I don’t feel I am any worse than anybody else
2. I am critical of myself for my weaknesses or mistakes
3. I blame myself all the time for my faults
4. I blame myself for everything bad that happens
Question 9.

1 I don’t cry any more than usual
2 I cry more now than I used to
3 I cry all the time now
4 I used to be able to cry, but now I can’t cry even though I want to

Question 10.

1 I am no more irritated by things than I ever am
2 I am slightly more irritated now than usual
3 I am quite annoyed and irritated a good deal of the time
4 I feel irritated all the time now

Question 11.

1 I have not lost interest in other people
2 I am less interested in other people than I used to be
3 I have lost most of my interest in other people
4 I have lost all of my interest in other people

Question 12.

1 I make decisions about as well as I ever could
2 I put off making decisions more than I used to
3 I have greater difficulty in making decisions than before
4 I can’t make decisions at all anymore

Question 13.

1 I don’t feel that I look any worse than I used to
2 I am worried that I am looking old or unattractive
3 I feel that there are permanent changes in my appearance that make me look unattractive
4 I believe that I look ugly
Question 14.

1 I can work about as well as before
2 It takes an extra effort to get started at doing something
3 I have to push myself very hard to do anything
4 I can’t do any work at all

Question 15.

1 I can sleep as well as usual
2 I don’t sleep as well as I used to
3 I wake up 2-3 hours earlier than usual and find it hard to go back to sleep
4 I wake up several hours earlier than I used to and cannot get back to sleep

Question 16.

1 I don’t get more tired than usual
2 I get tired more easily than I used to
3 I get tired from doing almost anything
4 I am too tired to do anything

Question 17.

1 My appetite is no worse than usual
2 My appetite is not as good as it used to be
3 My appetite is much worse now
4 I have no appetite at all anymore

Question 18.

1 I haven’t lost much weight, if any, lately
2 I have lost more than five pounds
3 I have lost more than ten pounds
4 I have lost more than fifteen pounds

Note: Choose “1” if you have been purposely trying to lose weight
Question 19.

1 I am no more worried about my health than usual
2 I am worried about physical problems such as aches and pains, or upset stomach, or constipation
3 I am very worried about physical problems, and it’s hard to think of much else
4 I am so worried about my physical problems that I cannot think about anything else

Question 20.

1 I have not noticed any recent change in my interest in sex
2 I am less interested in sex that I used to be
3 I am much less interested in sex now
4 I have lost interest in sex completely
Appendix I

Medical History Information Form

MEDICAL HISTORY INFORMATION FORM

Section 1

Please indicate if you currently or in the past have experienced any of the following:
(If you check yes, state when)

I. Neurological conditions:
   □ Epilepsy
   □ Head injury
   □ Hemorrhage
   □ Meningitis
   □ Migraine
   □ Multiple Sclerosis
   □ Parkinson’s
   □ Seizures
   □ Stroke
   □ Shingles
   □ Posttherapeutic neuralgia
   □ Other

When

II. Have you ever undergone any form of brain surgery?
   Yes    No

III. Are you currently taking any medications for a problem associated with a neurological condition, attention-related condition, or mental health condition?
   Yes    No

IV. Do you currently have problems with alcohol or drugs (excluding tobacco or social use of alcohol)?
   Yes    No

V. Are you currently in treatment for alcohol or drug use?
   Yes    No

VI. Are you currently being treated for a psychological or psychiatric condition?
   Yes    No
VII. Have you ever experienced brain trauma (e.g., an accident that left you unconscious for more than 10 minutes)?

Yes  No

Section 2

I. Current weight:  

II. Current height:  


Appendix J

RESEARCH SUBJECT INFORMATION AND CONSENT FORM

TITLE: Psychological Correlates of Neurological Responses

VCU IRB #: HM13858

This consent form may contain words that you do not understand. Please ask the study staff to explain any words that you do not clearly understand. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision.

PURPOSE OF THE STUDY
This study seeks to understand neurological patterns (brain waves) associated with several key psychological states. You are being asked to participate in this study because you are an undergraduate student at Virginia Commonwealth University. The research project will be conducted in one session lasting approximately 3 hours. Participation is voluntary, and all responses will remain strictly confidential.

DESCRIPTION OF THE STUDY AND YOUR INVOLVEMENT
If you decide to be in this research study, you will be asked to sign this consent form after you have had all your questions answered and understand what will happen to you. You will then be asked to complete a form about your past medical history, and a series of psychological questionnaires that ask about various experiences you may have. After this you will be asked to sit quietly while non-invasive, painless neurological recordings are made using a sensor cap (similar to a swim cap). This procedure does not alter or disrupt brain activity in any way. You will then be asked to sit quietly for eight periods of one minute. After this we will ask you to play a game on the computer that involves looking at pictures on the computer screen, and answering questions about your experience viewing them, like how they influence your mood. Some of the pictures are of everyday items and other pictures are of an unpleasant nature.

This study will take approximately 3 hours to complete. You do not have to answer any questions, or participate in any activities you do not wish to. You may withdraw from the study at any time, without penalty. We plan to enroll 60 VCU students in our study.

Significant new findings developed during the course of the research which may relate to your willingness to continue participation will be provided to you.

RISKS AND DISCOMFORTS
The physical risks involved in this study are minimal and are related to wearing the sensor cap. We will use a snug-fitting cap that fits like a swim cap and is embedded with sensors that detect electrical brain activity on the surface of the scalp.

If you choose to participate in this experiment, you will be asked to complete measures of your medical history, personality, and emotional well-being, you may also experience feelings of distress while participating in this study. You will also see a variety of pictures that have been judged to be neutral or unpleasant. The risks are not greater than the risks associated with daily living. However, if participating in this study causes you to feel upset or you become concerned about your psychological state or your current life situation, the study staff will provide you with contact information for resources available on campus that can help you address these issues, including:
University Counseling Services, which offers free counseling for VCU students; phone 828-6200 (Monroe Park Campus) or 828-3964 (Medical Campus).

University Student Health Services (also free for VCU students); phone 828-8828 (Monroe Park Campus) or 828-9220 (Medical Campus).

Center for Psychological Services and Development, which offers counseling services on a sliding fee scale; phone 828-8069.

Should you need services other than those provided by VCU University Counseling Services or University Student Health Services, fees for such treatment will be billed to you or to appropriate third party insurance.

**BENEFITS TO YOU AND OTHERS**
You may not get any direct benefit from this study, but, the information we learn from people in this study may help us better understand the processes under study.

**COSTS**
There are no costs for participating in this study other than the time you will spend on the tasks and filling out questionnaires.

**ALTERNATIVES**
The alternative to participating in this study is to not participate.

**CONFIDENTIALITY**
The data collected in this study will not be personally identifiable, as no name, birth date, or other potentially identifiable information will be collected. Data is being collected only for research purposes, identified only by an anonymous study ID number, and stored separately from the consent form in a locked research area. All information will be kept in password protected electronic files. Hard copy questionnaires will be kept in a locked file cabinet for 3 years after the study ends and will be destroyed at that time. Electronic files of the study data will be kept indefinitely. Access to all data will be limited to study personnel. A data and safety monitoring plan is established.

We will not tell anyone the answers you give us; however, information from the study and the consent form signed by you may be looked at or copied for research or legal purposes by the sponsor of the research, or by Virginia Commonwealth University. Personal information about you might be shared with or copied by authorized officials of the Federal Food and Drug Administration, or the Department of Health and Human Services (if applicable). What we find from this study may be presented at meetings or published in papers, but your name will not ever be used in these presentations or papers.

**IF AN INJURY OR ILLNESS HAPPENS**
Virginia Commonwealth University and the VCU Health System (also known as MCV Hospital) do not have a plan to give long-term care or money if you are injured because you are in the study. If you are injured because of being in this study, tell the study staff right away. The study staff will arrange for short-term emergency care or referral if it is needed. Bills for treatment may be sent to you or your insurance. Your insurance may or may not pay for taking care of injuries that happen because of being in this study.

**VOLUNTARY PARTICIPATION AND WITHDRAWAL**
You do not have to participate in this study. If you choose to participate, you may stop at any time without any penalty. You may also choose not to answer particular questions that are asked in the study. Withdrawal from the study will not affect you present or future University relationship.
Your participation in this study may be stopped at any time by the study staff without your consent. The reasons might include:
- the study staff thinks it necessary for your health or safety;
- you have not followed study instructions;
- administrative reasons require your withdrawal.

QUESTIONS
In the future, you may have questions about your participation in this study. If you have any questions, complaints, or concerns about the research, contact:

Kirk Warren Brown, PhD
Virginia Commonwealth University
808 W. Franklin Street, Room 202
P.O. Box 982018
Richmond, VA 23284
Telephone: 804-828-6754

If you have any questions about your rights as a participant in this study, you may contact:

Office for Research
Virginia Commonwealth University
800 East Leigh Street, Suite 113
P.O. Box 980568
Richmond, VA 23298
Telephone: 804-827-2157

You may also contact this number for general questions, concerns or complaints about the research. Please call this number if you cannot reach the research team or wish to talk to someone else. Additional information about participation in research studies can be found at http://www.research.vcu.edu/irb/volunteers.htm.

CONSENT
I have been given the chance to read this consent form. I understand the information about this study. Questions that I wanted to ask about the study have been answered. My signature says that I am willing to participate in this study. I will receive a copy of the consent form once I have agreed to participate.

Participant name printed
Participant signature
Date

Name of Person Conducting Informed Consent
Discussion / Witness (printed)

Signature of Person Conducting Informed Consent
Discussion / Witness
Date

Principal Investigator Signature (if different from above)
Date
Vitae

Robert J. Goodman was born on August 2, 1979 in Charleston, South Carolina, and is an American citizen. He graduated from Milford High School in Milford, Ohio in 1997. He received an Associates of Applied Business in Computer Information Systems from the University of Cincinnati, Batavia, Ohio, in 2003. In 2007 he received his Bachelor of Arts in Religious Studies and Bachelor of Arts in Psychology from Cleveland State University, Cleveland, Ohio. He received his Master of Arts in Experimental Psychology from Cleveland State University, Cleveland, OH in 2009.