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The Role of Mindfulness in Self-view Investment: Neural and Subjective Indicators

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

by

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Abstract

Self-concept is strongly influenced by beliefs about one's personal psychological attributes, and these beliefs are held with varying degrees of confidence and consequence. Hence, it is *investment* in self-views of those attributes that helps to regulate and maintain stable self-concept. Self-view investment is relevant to numerous self-related functions, but high self-view investment can also contribute to maladaptive self-views. Theory suggests that mindfulness cultivates a less personal, more objective perception of one's thoughts, emotions and behaviors, and training in mindfulness has been shown to alter self-referential processing. The current pilot study (N=21) investigates the possible role of dispositional mindfulness in two forms of self-view investment, epistemic certainty and emotive importance, as indicated by self-reported and neural (functional magnetic resonance imaging-based) indicators of investment. Results indicated that dispositional mindfulness was positively associated with self-reported epistemic certainty but not emotive importance. Trait mindfulness was associated with activity in the amygdala and parahippocampal gyrus during judgements of both epistemic certainty and emotive importance. Caudate activity was positively associated with trait mindfulness specifically for judgements of emotive importance.

Keywords: self-view, epistemic investment, emotive investment, mindfulness, functional magnetic resonance imaging

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The Role of Mindfulness in Self-view Investment: Neural and Subjective Indicators

The psychological concept of self is difficult to define (Baumeister, 1991), but most researchers agree that the self is not a unitary phenomenon. The self is commonly divided into two broad categories: the experiential self, also called the first-person-self (Libby & Eibach, 2002) and the I-self (James, 1890); and the narrative self (Gallagher, 2000; Gallagher & Frith, 2003), also called the third-person-self (Libby & Eibach, 2002) and the me-self (James, 1890). The experiential self refers to our first-person perception of moment-to-moment events and enables processes such as a sense of agency and sensory awareness. In contrast, the narrative self refers to the ‘me’ that is the object of our attention. Rather than being tied to momentary experiences, the narrative self extends across time, accumulating conceptual knowledge about the self (Gallagher, 2013). The scope of the narrative self is easily demonstrated through the practice of self-reflection. Completion of a simple personality assessment (e.g., McCrae & Costa, 1997) will show that most adults can identify their predominant characteristics with high confidence. In many cases, we have reason for this confidence; either we have obtained extensive experience confirming these personal tendencies or have friends that have affirmed our possession of these traits. Notwithstanding the origin or accuracy of our self-views, these self-views are clearly present, salient, and accessible.

Self-views are imperative to any cognitive functioning that assumes working knowledge of the self (Neisser, 1997). For example, behavior regulation applies self-knowledge to determine if a prospective action fits the values and expectations of ‘who you are’ (Spreng, Mar, & Kim, 2009). You may avoid parties because you see yourself as introverted. When given the opportunity to cheat, you may balk at the notion because you believe you are honest. When

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offered to work an extra shift you might seize the opportunity because you consider yourself ambitious or want to avoid appearing lazy. Such examples illustrate the adaptive functioning of self-views while highlighting their social, moral, and behavioral implications. It should be noted, however, that self-views are equally implicated in maladaptive functioning. Excessive preoccupation with self-views is emblematic of fragile self-esteem and narcissism (Campbell, Rudich, & Sedikides, 2002), and negative self-views are central to affective disorders (e.g. anxiety and depression) (Watkins & Teasdale, 2001; Watkins, 2004). Self-views may also harm interpersonal relations by increasing social anxiety (Mellings & Alden, 2000) or contributing to group-based biases and aggression when group-level traits are applied to oneself (Inzlicht & Kang, 2010; Wann, 1993).

The rigidity or flexibility of self-views is largely determined by one's identification with such views and is subject to cognitive and affective influence. Self-views are prone to bias for a myriad of potential reasons, including self-enhancement (Brown, 1986) and self-verification motives (Swann, 2011). Thus, it is erroneous to assume that self-views are factual or based purely on evidence. Nevertheless, many of us experience our self-views as the truth about ourselves, even if other people refute the veracity of our claims. Particularly robust self-views are often revealed in people's "self-talk." For example, someone with poor body image may persistently think "I am fat" despite being of average size or being told otherwise. In theory, these fixed self-views are maintained by the "stake" or investment held in such claims (Pelham, 1991). The example above demonstrates that while self-specific beliefs can be cognitively inferred from objective evidence, it is equally common to believe in a self-view without proof *if* one's emotional and motivational goals are tied to this belief. Hence, self-views are jointly maintained by *cognitive rationales and subjective meaning*. Pelham refers to these two concepts

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as epistemic and emotive self-view investment, reflecting the degree of certainty one has in a self-view, and the importance one places on a self-view, respectively; however, this paper refers to the two forms of self-view investment as *epistemic certainty* and *emotive importance*. The epistemic certainty and emotive importance of self-views are distinctively relevant to psychological outcomes, and incipient neuroimaging research on self-views is beginning to elucidate this unique influence.

Neuroscience of self-views

Over the last two decades, neuroscientific methods have attempted to clarify the nature of the self by identifying distinct biological substrates of self-related phenomena. An accumulation of neuroimaging research has examined the neural correlates of ‘self-referential processing,’ defined as the cognitive processing of stimuli that are experienced as being related to or relevant to oneself (e.g., personality traits). Self-referential tasks recruit activity from various cortical-subcortical midline structures, including the medial orbitofrontal cortex, ventro- and dorsolateral prefrontal cortex, lateral parietal cortex, bilateral temporal poles, insula, colliculi, periaqueductal gray (PAG), and hypothalamus/hypophysis regions (Northoff & Bermphol, 2004; Northoff et al., 2006). Functional specificity of these cortical-subcortical midline structures (CSMS) has been extensively studied, and meta-analyses suggest that functional specialization of the CSMS is not guided by cognitive or perceptual principles, but rather is determined by the meaning of (i.e., investment in) self-related stimuli (Northoff et al., 2006). The ventral (BA 10/32) and dorsal (BA 9/32) subdivisions of the medial prefrontal cortex (mPFC) appear to be particularly critical for encoding the investment quality of self-related stimuli, given that the emotive importance of self-related stimuli has been linked to vmPFC engagement and has shown to be inversely related to dmPFC activation.

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Relative to the dmPFC, the vmPFC is distinguished by its functional connectivity to subcortical nuclei (Kober et al., 2008) and this connectivity facilitates the generation of affective meaning (Roy, Shohamy, & Wager 2012), otherwise known as valuation (D'Argembeau, 2013). In contrast, the dmPFC is ostensibly related to the reappraisal and logical analysis of self-related stimuli (Flagan & Beer, 2013). This functional specificity of the dmPFC and vmPFC has been further established by research on the self-evaluation of personal characteristics (i.e., self views) (Kircher et al., 2000; Kelley et al., 2002; Kjaer, Nowak, & Lou, 2002; Fossati et al., 2004; Macrae et al., 2008; Schmitz et al., 2004). Although multiple studies have linked dmPFC activity to certainty of evaluations (Krain et al., 2006; Bhanji et al., 2010; Eldaief et al., 2012) and vmPFC activity to emotive importance of evaluations (Levy & Glimcher, 2011; Levy & Glimcher, 2012; Kim & Johnson, 2015; Wlodaski & Dunbar, 2016), only one study to date has explicitly examined the dissociation of dmPFC and vmPFC activity in relation to the degree of epistemic and emotive investment in self-views (D'Argembeau et al., 2011). While undergoing functional magnetic resonance imaging (fMRI) participants viewed a series of psychological traits and were asked to judge: a) how much did this trait describe them; b) how certain they felt about possessing this trait (i.e., epistemic certainty); and c) how important it was for them to have (or not have) this trait (i.e., emotive importance). Analyses of the mPFC revealed a dorsal-ventral functional gradient with dorsal regions relating to epistemic investment and ventral regions relating to emotive investment. These results suggest that self-views are neurally represented as a factor of subjective value, with vmPFC activation encoding for the presence of emotive value. This view has since been formalized as the Valuation Hypothesis (D'Argembeau, 2013), which proposes that the vmPFC plays a crucial role in connecting subjectively important stimuli to self-representations. Relative to the vmPFC, there is less consensus regarding the

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specific role of the dmPFC, given that dmPFC activity is related to both self- and non-self-related processes (van der Meer, Costafreda, Aleman, & David, 2010). It been suggested that dmPFC engagement may broadly mediate epistemic judgements through derivation of social and memory-based information (Lieberman, Jarcho, & Satpute, 2004). Other researchers advocate for the dual role of the vmPFC and dmPFC and suggest that simultaneous vmPFC *activation* and dmPFC *deactivation* jointly encode for self-related information with emotional importance (Northoff et al., 2009). Although further research of mPFC functionality is necessary to resolve these theoretical discrepancies, it can reasonably be assumed that the vmPFC and dmPFC are distinctly associated with the generation and maintenance of self-views.

Clinical cases of maladaptive self-views shed light on the role of the mPFC within broader neural networks. The dmPFC and vmPFC show extensive structural connectivity with limbic areas (e.g., amygdala, hippocampus, pericarpal cortex) and visceral control areas (e.g., hypothalamus, periaqueductal gray area)—regions implicated in evaluative learning—and irregular activation from mPFC regions has been associated with heightened emotional response (Sheline et al., 2009) and poor self-regard in major depressive disorder (Lemogne, Delaveau, Freton, Guionnet, & Fossati, 2012). Moreover, changes in vmPFC engagement have been associated with reduced endorsement of negative self-views following cognitive behavioral therapy (Yoshimura et al., 2013). Together, this evidence suggests that modification of vmPFC activity may underlie changes in self-views via adjustments to emotive investment. However, no studies have directly questioned if it is possible to adjust emotive (or epistemic) investment in self-views, and no studies have investigated if these adjustments relate to changes in positive or negative self-regard.

Mindfulness and self-views

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Maladaptive self-views are resistant to change and standard efforts to correct for biased and/or harmful self-views – via direct feedback (Vazire, Mehl, & Carlson, 2010) or introspection (Pronin, 2009) – are often ineffectual. It may be possible to challenge self-views indirectly through mitigation of self-view investments; however, informational and motivational barriers may impede the ability to accurately discern the thoughts and feelings responsible for maintaining self-views (Vazire, 2010). In other words, people typically lack the perspective and objectivity to recognize their investment in particular self-views. It is plausible, however, that this limitation can be overcome via the application of mindfulness. Mindfulness is canonically described as a sustained, receptive attention to and awareness of present moment occurrences (Brown & Ryan, 2003). By definition, mindfulness is non-judgmental—because it tempers the evaluation of emotional and other stimuli—and applies to both internal (i.e. within the individual) and external events. It is hypothesized that mindfulness may overcome informational and motivational barriers to self-knowledge by improving awareness of thoughts, feelings, and behaviors while reducing biases due to evaluative judgements (Carlson, 2013). Thus, it is plausible that mindfulness may foster the non-biased observation of self-views.

Predominant theories of mindfulness suggest that bringing awareness to habitual states of mind allows one to “decenter” or “de-fuse” from one’s subjective experiences (e.g., Safran and Segal, 1990; Bernstein et al., 2015; Bernstein, Hadash, & Fresco, 2019; King & Fresco, 2019). As a mechanism-of-action in mindfulness, decentering has been defined as a mental phenomenon comprised of three interrelated metacognitive processes: *meta-awareness* (i.e., awareness of the contents of internal events), *disidentification from internal experience* (i.e., experiencing internal events as separate from one’s self), and *reduced reactivity to thought content* (i.e., reduced impact of internal events on other thought processes) (see Bernstein et al.,

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2015; Metacognitive Process Model of Decentering). Although decentering is a natural metacognitive capacity, the mind does not necessarily engage in decentering by default. People can easily lose meta-awareness and become immersed in the contents of consciousness without awareness of the mental processes that serve as context. This type of “experiential fusion” is especially common in clinical affective disorders (e.g., depression and anxiety) in which individuals have difficulty disengaging with negative patterns of thought. Similarly, a lack of meta-awareness can also promote “cognitive reification”, defined as the “experience of thoughts, emotions, and perceptions as being accurate depictions of reality” (Dahl, Lutz, & Davidson, 2015). In this way, self-views become subject to cognitive reification when an individual is unaware of the thoughts and feelings in support of self-views (i.e., self-view investments). For example, a person may say, “I am stupid” rather than acknowledge that this is (just) a thought (“There is a thought here of being stupid.”). Mindfulness is thought to foster awareness of such self-views and possibly disrupt identification with them. Early evidence supports this idea, showing that maladaptive self-views can be altered as a consequence of mindfulness training (Farb et al., 2007; Goldin, Ramel, & Gross, 2009; Thurston, Goldin, Heimberg, & Gross, 2017), and research has supported the role of decentering as a mechanism of mindfulness’ salutary effects (Shoham et al., 2017).

Neural mechanisms of mindful decentering

Mindfulness practice has been associated with reliable and enduring changes in neural activity (Holzel et al., 2011), and evidence suggests that mindfulness-related changes in neural coordination and connectivity correspond with the different metacognitive processes of decentering (Tang, Holzel, & Posner, 2015; King & Fresco, 2019). Mindfulness has been shown to increase within-network activity of the salience network (SN), namely the dorsal anterior

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cingulate (dACC), insula, and amygdala (Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou 2012), all associated with directing attention from internal to external stimuli; and the frontoparietal control network (FPCN, bilateral dorsolateral PFC (dlPFC), and posterior parietal cortex (PPC)(Allen et al., 2012; Taren et al., 2017), associated with executive functioning (Baxter & Chiba, 1999). Together, increased coordination of the SN and FPCN networks may indicate improvements in meta-awareness capacities (King & Fresco, 2019). Mindfulness also reduces activity and within-network connectivity in the default mode network, including the posterior cingulate cortex (PCC) and vmPFC, regions that have previously been associated with narrative self-processing (Watkins & Teasdale, 2001; Farb et al., 2007). Researchers suggest that PCC-vmPFC engagement during mind wandering may indicate reflexive identification with internal experiences (Bernstein et al., 2015). Hence, findings suggest that mindfulness instills *disidentification* via reductions in PCC-vmPFC activation. If mindfulness is capable of modifying investment in (i.e., identification with) self-views, it is probable that such changes are subserved by PCC-vmPFC activity.

Investigation of self-views in the context of mindfulness has yielded results consistent with the metacognitive model of decentering. In one fMRI study (Farb et al., 2007), participants were asked to apply narrative or experiential self-focus while viewing a series of personality traits. Experiential self-focus refers to the observation of moment-to-moment experiences and is a construct closely related to meta-awareness. The alternative condition, narrative focus, instructed participants to evaluate the self-descriptiveness of each personality trait, and is conceptually similar to the default, narrative mode of self-view investments. As anticipated, narrative self-focus elicited activity from cortical midline structures, including the mPFC and PCC. When engaging in experiential self-focus, the mindfulness-trained group demonstrated

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reductions in vmPFC and dmPFC activity, suggesting that those trained in mindfulness were able to disengage from self-view representations associated with narrative self-focus. These results suggest that meta-awareness imbued by mindfulness subserves experiential self-focus and potentially undermines habitual representations of self-views.

The impact of mindfulness on maladaptive self-views has been examined in patients with social anxiety disorder (SAD) (Goldin et al., 2009). Patients who completed mindfulness training reported greater endorsement of positive personality traits and lower endorsement of negative traits, and changes in positive self-views were associated with reductions in vmPFC and dmPFC engagement. Although changes in negative self-views did not correlate with reductions in cortical midline activity, reductions in negative self-views were associated with greater recruitment from attentional networks (left inferior parietal lobule and medial precuneus). It is possible that recruitment from attentional networks is indicative of enhanced attentional capacities implicit to meta-awareness, and that mindfulness-trained SAD patients were implementing attentional control to disengage from habitual thought patterns associated with negative self-views. These study findings partly corroborate the results of Farb and colleagues (2007), and together, both studies support the crucial role of the vmPFC and dmPFC in narrative representations of self-views. However, the accumulation of research on mindfulness and self-views is unclear on the differential function of the vmPFC and dmPFC. It is plausible that mindfulness modifies self-views via dissociable mechanisms targeting epistemic and emotive investment in self-views respectively, but this hypothesis requires further investigation.

The present study

The two forms of investment in self-views, epistemic certainty and emotive importance, are relevant for intrapersonal and interpersonal wellbeing and inform the neurological

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underpinnings of self-representation. There is evidence suggesting that mindfulness can alter maladaptive self-views via awareness of self-related thoughts and feelings, and prior research supports that mindfulness targets neurological regions associated with self-view investments (i.e., vMPFC, dmPFC, and PCC). Together this evidence provides a foundation for the exploration of mindfulness and its impact on factors that appear to help sustain self-views, namely, epistemic certainty and emotive importance. The current pilot study had four specific aims. Aims 1 and 2 examined these factors in terms of behavioral outcomes. Specifically, aim 1 explored the relations of dispositional mindfulness with endorsement of positive and negative self-views, operationalized as personality traits (e.g., friendly, arrogant, faithful), and aim 2 investigated the relations between dispositional mindfulness and the degree of self-reported emotive importance and epistemic certainty in positive and negative self-views. Aims 3 and 4 investigated these factors in terms of neurobiological mechanisms. Mindfulness has been shown to influence neural processes during active judgement of self-views (Farb et al., 2007; Goldin et al., 2009), and mindfulness-related changes in negative self-views have been linked to off-task, resting state activity (Vago & David, 2012; Doll, Boucard, Wohlschlager, & Sorg, 2015). Thus, aim 3 examined whether dispositional mindfulness was related to neural indicators of self-view epistemic certainty and emotive importance, and aim 4 examined the mediating role of resting state functional brain activation in the relation between mindfulness and endorsement of negative traits.

To address these questions, participants first completed a well-validated self-report measure of dispositional mindfulness. Blood-oxygen level-dependent (BOLD) signal recordings were then obtained using whole-brain functional magnetic resonance imaging (fMRI) while participants rated a series of positive and negative personality traits in a self-description task.

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After scanning, participants rated the degree of epistemic certainty and emotive importance in having or not having each of these personality traits.

Methods

Participants

Participants were 21 healthy, meditation-naive adults recruited from the Richmond, Virginia area. Participants were excluded if they met any of the following criteria: major uncorrected sensory impairments or cognitive deficits, pregnancy, left-hand dominance, diagnosis of medical or psychiatric illness within the last three months, hospitalization within the last three months, change in medication regimen within last 8 weeks, self-reported current drug abuse, presence of MRI safety risks (e.g., ferromagnetic implants, body weight > 300 lbs.), or a history of head trauma or seizures. All participants provided written informed consent to take part in the study, which was approved by the Institutional Review Board of Virginia Commonwealth University.

Materials and Methods

Mindful attention awareness scale (MAAS; Brown & Ryan, 2003)

Trait mindfulness was measured using this 15-item scale assessing receptive attention to, and awareness of present moment stimuli. Participants rated items on a scale from 1 (“almost always”) to 6 (“almost never”), with higher scores indicating higher levels of mindfulness. Dispositional mindfulness was calculated from the average of the 15 items. In previous reports, the MAAS has shown strong internal consistency and test-retest reliability, and has shown to be significantly associated with enhanced self-awareness (e.g., Brown & Ryan, 2003).

Self-description task (D’Argembeau et al., 2012)

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In the validated self-description task (D'Argembeau et al., 2011; Moran, Macrae, Heatherton, Wyland, & Kelley, 2006), participants were instructed to rate a series of personality traits for self-descriptiveness (To what extent does this trait describe you?), epistemic certainty (How certain are you that you possess or do not possess this trait?), and emotive importance (How important is it for you to possess or not possess this trait?) using a Likert-type 4-point scale (1 = "not at all"; 4 = "very much"). Participants were presented with 40 positive, desirable traits (e.g., sincere) and 40 negative, undesirable traits (e.g., untrustworthy), balanced for meaningfulness, word length, and number of syllables (Kim & Johnson, 2014).

Procedure

Pre-scan survey

After providing written informed consent, participants completed a Qualtrics software-housed battery of self-report measures including the MAAS. This survey battery was completed prior to laboratory assessment at the brain imaging facility.

Self-description task (D'Argembeau et al., 2012)

Upon arrival at the brain imaging facility, participants were provided a brief training to familiarize themselves with the brain imaging procedure and to practice the self-description task. After orienting to the scanner, participants underwent fMRI and completed an anatomical scan and a resting state functional scan before completing the self-description task while undergoing fMRI (and two other, unrelated tasks). In this study the task used 80 adjectives and 20 null events (fixation cross) presented in random order. Trait adjectives in this study were presented for 3509 ms and fixation crosses were presented for variable durations (mean duration = 1000 ms). Participants were instructed to indicate how much or how little each trait described them

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using a 4-point scale (1 = not at all, 4 = very much). This task took approximately 22 minutes to complete.

Post-scan questionnaire

After task completion in the scanner, participants were escorted to a behavioral assessment room to complete the post-scan self-description task described above (D'Argembeau et al., 2011). This second part of the self-description task was completed within 15-30 minutes of completing the first part of the self-description task in the scanner.

MRI acquisition and preprocessing

Imaging was performed using a 3.0-T Phillips Ingenia MRI scanner. Blood oxygen level dependent (BOLD) signals were acquired using a T2*-sensitive echoplanar sequence with a repetition time (TR) = 1000 msec, echo time (TE) = 75 msec, flip angle = 90°, matrix size = 80 x 79, and field of view (FOV) = 240 mm. Each volume contained 36 3.0-mm-thick parallel transverse slices. Structural scans were acquired using a T1-weighted MP-RAGE sequence (1 mm³ isotropic voxel size, TR = 8 msec, TE = 3.7 msec, flip angle = 6°, matrix size = 240 x 256, FOV = 240 mm) to facilitate registration to native space. Analysis of Functional NeuroImages (AFNI) software (Cox, 1996; Cox, 2012) was used to conduct all preprocessing and fMRI analyses. Individual time series datasets were despiked to compensate for motion artifacts, corrected for head motion (3dvolreg), warped out to common stereotactic reference space (Montreal Neurological Institute; MNI), and spatially smoothed to uniform 6 mm full-width half maximum Gaussian kernel.

Statistical Analyses

Behavioral Data Analyses. The current study aimed first to examine the relation of dispositional mindfulness to the endorsement of positive and negative self-views, operationalized as

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personality traits (e.g., friendly, arrogant, faithful). This first aim was tested by computing bivariate correlations between trait mindfulness and the average value of self-descriptiveness for each of positive and negative traits. The variables of interest met the assumption of univariate normality and were submitted for analysis without pre-treatment.

The second aim of this study was to investigate the relation between dispositional mindfulness and self-reported epistemic certainty and emotive importance for both positive and negative self-views. This aim was tested by computing bivariate correlations between trait mindfulness and 4 different variables: epistemic certainty for negative traits, epistemic certainty for positive traits, emotive importance for negative traits, and emotive importance for positive traits. Variables of interest met the normality assumption and were submitted for analysis without pre-treatment. Bivariate correlations were then calculated between each of these variables and trait mindfulness.

MRI data analysis. The third aim of this study was to examine whether BOLD responses to epistemic certainty and emotive importance in self-views varied as a factor of dispositional mindfulness. Specifically, aim 3 was to examine the neural substrates of mindfulness-related differences in epistemic certainty and emotive importance operationalized as percent signal change in volumes of interest (VOIs). To test this aim, fMRI data from the self-description task was analyzed using a two-level linear modeling approach.

First level (within-participants) analysis

Data were analyzed using GLM as implemented by AFNI's program, 3dDeconvolve (Cox, 1996; Cox, 2012). I estimated a GLM that including a regressor for the presentation of stimuli and realignment parameters to account for any residual movement-related effects.

Contrasts were generated comparing responses to negative versus positive (negative > positive)

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personality traits. In two parallel analyses, adjective-presentation events were amplitude modulated (AM) using self-reported ratings of epistemic certainty and emotive investment to model canonical hemodynamic responses at the individual event level. Statistical models coding for each parametric modulation (epistemic certainty and emotive importance) were constructed for each participant, linearly registered to native space structural volumes, and then normalized to MNI stereotaxic space for second-level analysis. Masks were generated for individual time series using AFNI's 3dClipLevel program (Cox, 1996; Cox, 2012) with a cutoff value of 40% intensity. Masks were manually inspected, and cutoff intensity was adjusted as necessary. Masks were warped into stereotaxic MNI space to constrain illuminated voxels exclusively to brain tissue in second level analyses.

Second level (between-participants) analysis

Groupmaps were calculated in AFNI using 3dMEMA (Cox, 1996; Cox, 2012), a program that incorporates within-subject and cross-subject variability, and here with mindfulness entered as an individual difference regressor. To examine regional activation related to judgement of negative versus positive traits, group analyses were performed on individual contrasts (negative > positive) and submitted to paired t-tests with participant identification (ID) numbers entered as a random effect. To assess the relation between mindfulness and epistemic certainty and emotive importance, group analyses were performed on individual amplitude-modulated images and submitted to paired t-tests, again with participant IDs entered as a random effect. Region activation and statistical power was estimated using AFNI's AlphaSim (Cox, 1996; Cox, 2012), a program which implements Monte Carlo simulations to calculate individual voxel probability thresholding and minimum cluster size thresholding. Activations in groupwise maps were

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reported at the maxima of activated voxel clusters, with uncorrected $p < .001$ and FDR-corrected $p < .05$.

Volume of interest (VOI) analyses

To test aim 3, volumes of interest were selected based on previously reported associations with self-view investment (D'Argembeau, et al., 2011). Masks were generated for individual amplitude-modulated time series using a 3mm spheric voxel corresponding to activation maxima of the dorsal mPFC (MNI -6, 55, 22), ventral PFC (MNI 6, 48, -6), left middle temporal gyrus (-56, -16, -16), right insula (40, -12, 6), and the right inferior parietal lobe (MNI 52, -52, 34). Beta weights (standardized regression coefficients) indicating percent signal change in each region were correlated with trait mindfulness scores and epistemic certainty and emotive importance ratings for negative and positive traits.

Functional Connectivity Analyses

To test aim 4, a functional connectivity analysis of default mode resting state activity was conducted. The vmPFC seed region (-2, 50, -6) was selected from the meta-analytical maxima for the term “default mode” from open source platform, neurosynth.org (Yarkoni et al., 2011). First, functional connectivity maps were generated between the seed region and all other brain voxels. Then, interregional (ROI-ROI) correlations for each participant were computed using the vmPFC seed region and PCC target (0, -50, 27).

Results

Behavioral Results

To test aim 1 of the thesis, bivariate correlations were computed to examine the relation between mindfulness and endorsement of negative and positive personality traits (see Table 1). Results revealed no relation between mindfulness and endorsement for negative or positive traits.

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Bivariate correlations were then computed to examine the relation between mindfulness and epistemic certainty and emotive importance in self-views. Results indicated that mindfulness was not significantly associated with emotive importance; however, mindfulness was significantly related to epistemic certainty of one's self-views, $r(19) = .65, p < .001$.

To test aim 2, four values were calculated to measure degree of epistemic certainty and emotive importance in negative and positive views. Bivariate correlations between these values and trait mindfulness revealed that mindfulness was positively associated with epistemic certainty in positive, $r(19) = .675, p < .01$, and negative traits, $r(19) = .649, p < .001$. Mindfulness was not related to self-reported emotive importance for either positive or negative traits. Figures 1 and 2 illustrate the relation between mindfulness, epistemic certainty, and emotive importance for negative traits and positive traits, respectively.

Table 1.

Bivariate correlations between mindfulness, endorsement of negative traits and positive traits, and ratings of certainty (epistemic investment) and importance (emotive investment)

| | 1 | 2 | 3 | 4 |
|--------------------|--------|---------|-------|------|
| 1. MAAS | | | | |
| 2. Negative Traits | -.248 | | | |
| 3. Positive Traits | .387 | -.687** | | |
| 4. Certainty | .651** | -.271 | .527* | |
| 5. Importance | .250 | -.023 | .519* | .288 |

| | 1 | 2 | 3 | 4 |
|---------|---|---|---|---|
| 1. MAAS | | | | |

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| | | | | |
|----------------------------------|--------|--------|-------|-------|
| 2. Certainty of Negative Traits | .675** | | | |
| 3. Certainty of Positive traits | .649** | .817** | | |
| 4. Importance of Negative Traits | .270 | .247 | .254 | |
| 5. Importance of Positive Traits | .211 | .213 | .498* | .495* |

* P <.01
 ** P <.001

Note. MAAS = Mindful Attention Awareness Scale.

Figure 1.

Results of bivariate correlations between mindfulness and epistemic certainty and emotive importance in negative self-views. 3D plot rotation is available at <https://plot.ly/~rahrihm/5/>

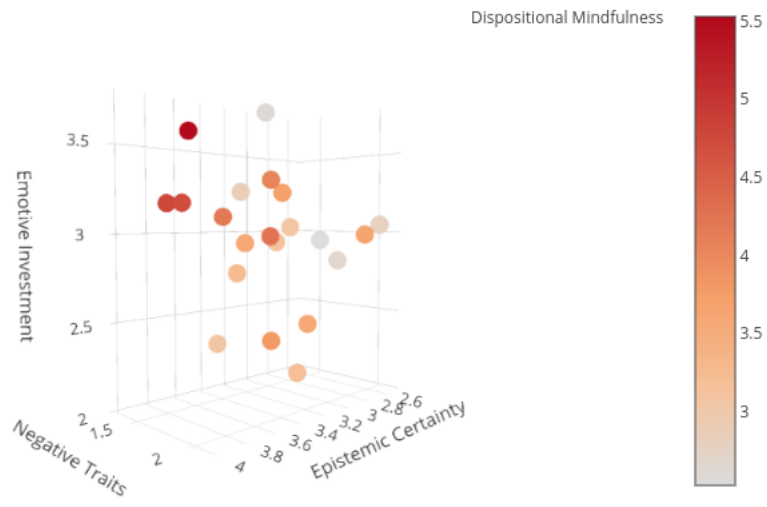
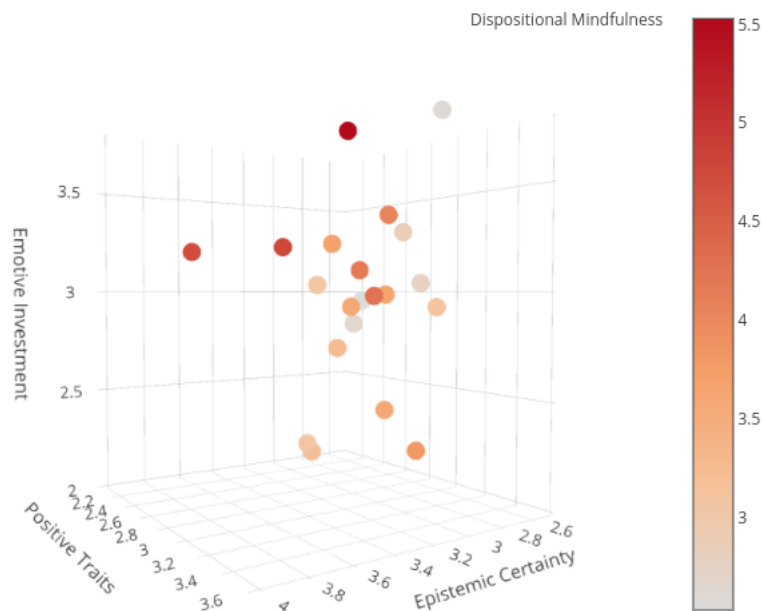


Figure 2.

Results of bivariate correlations between mindfulness and epistemic certainty and emotive importance in positive self-views. 3D plot rotation is available at <https://plot.ly/~rahrihm/7/>

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Neuroimaging Results

Aim 3 of the thesis examined BOLD responses for epistemic certainty or emotive importance in self-views in relation to dispositional mindfulness. Whole-brain group-wise regression of amplitude-modulated adjective trait events revealed no regional activation differences in terms of epistemic certainty or emotive investment (see Figure 3). Full results are reported in Table 2.

Table 2.

Brain regions significantly related to judgements of both epistemic certainty and emotive investment. FDR corrected $p < .05$

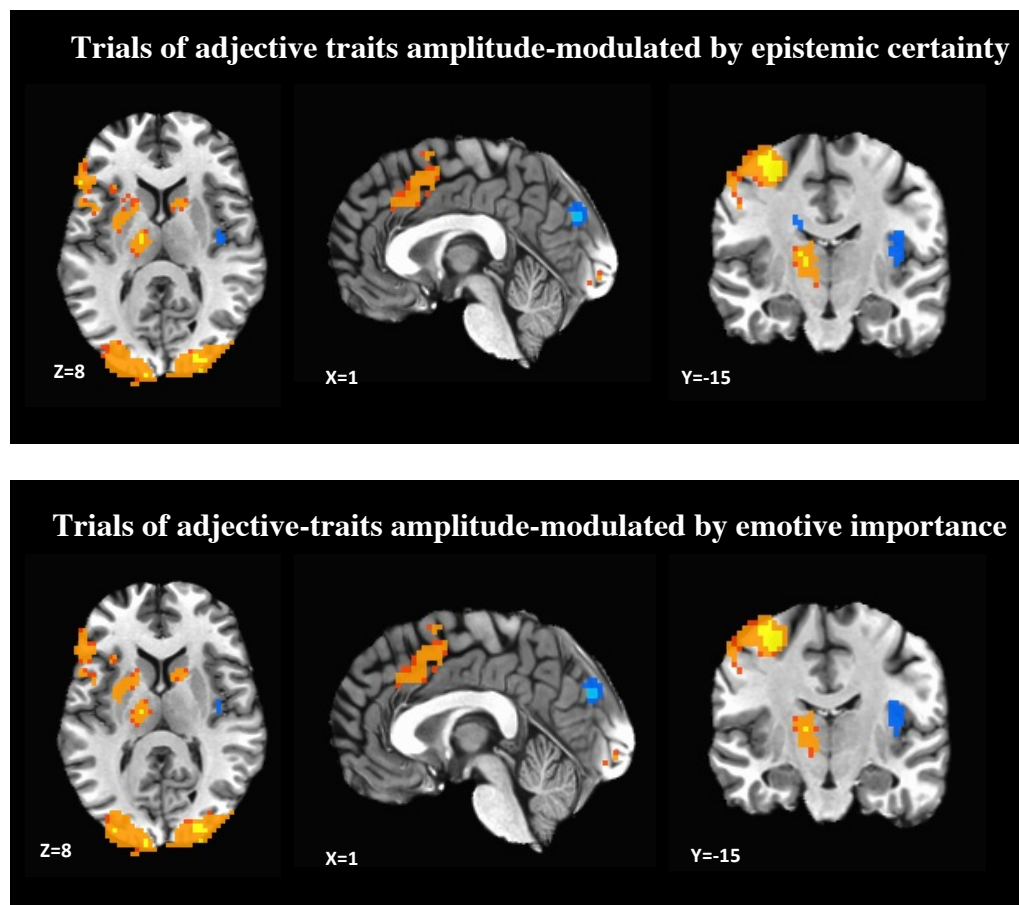
| MNI Coordinates | | | | | |
|-----------------|----------|----------|----------|----------------|----------------|
| Brain Region | <i>x</i> | <i>y</i> | <i>z</i> | <i>t-score</i> | <i>P-value</i> |
| Thalamus | -13 | -19 | 12 | 3.96 | <.05 |

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| | | | | | |
|--------------------------|-----|-----|-----|------|-------|
| Anterior Cingulate | -13 | 13 | 44 | 3.96 | < .05 |
| Ventral striatum | 18 | 12 | -1 | 4.85 | <.05 |
| Orbitofrontal cortex | -26 | 23 | -15 | 3.96 | <.05 |
| Cuneus | 0 | -84 | 28 | 4.85 | <.05 |
| Medial prefrontal cortex | -5 | 57 | 33 | 6.17 | <.05 |
| Insula | 42 | -2 | -3 | 3.96 | <.05 |

Figure 3.

BOLD signal responses to adjective traits amplitude-modulated according to self-reported epistemic certainty (top panel) and self-reported emotive importance (bottom panel). Displayed at FDR adjusted $p < .05$

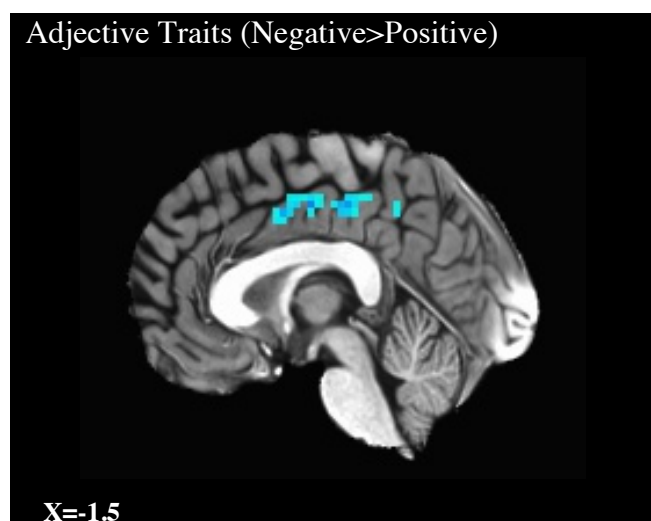


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Whole-brain groupwise regression of negative trait adjective versus positive trait adjective events (negative > positive) revealed deactivation localized at the midcingulate cortex (MCC) (peak $t = 3.90$, $p < .10^{-3}$, peak MNI = 1, -17, 42; see Figure 4). To further examine the source of this contrast, beta weights of activation for negative and positive trait adjective events were examined singly to determine their likely contribution to contrast-elicited deactivation. Results suggested that midline deactivation by the negative > positive contrast was determined by trials containing negative traits, with peak deactivations localized within the precuneus (peak $t = 3.88$, $p < .001$, peak MNI = -8, -36, 49) and the posterior insula (peak $t = 3.88$, $p < .001$, peak MNI = 38, -17, 8). Trials containing positive traits did not elicit greater activations from these regions, however judgement of positive traits was associated with greater activation of the right caudate (peak $t = 3.87$, $p < .001$, peak MNI 14, 10, 8).

Figure 4.

BOLD signal deactivation evoked by negative vs positive adjective traits. Displayed at uncorrected $p < .1^{-4}$

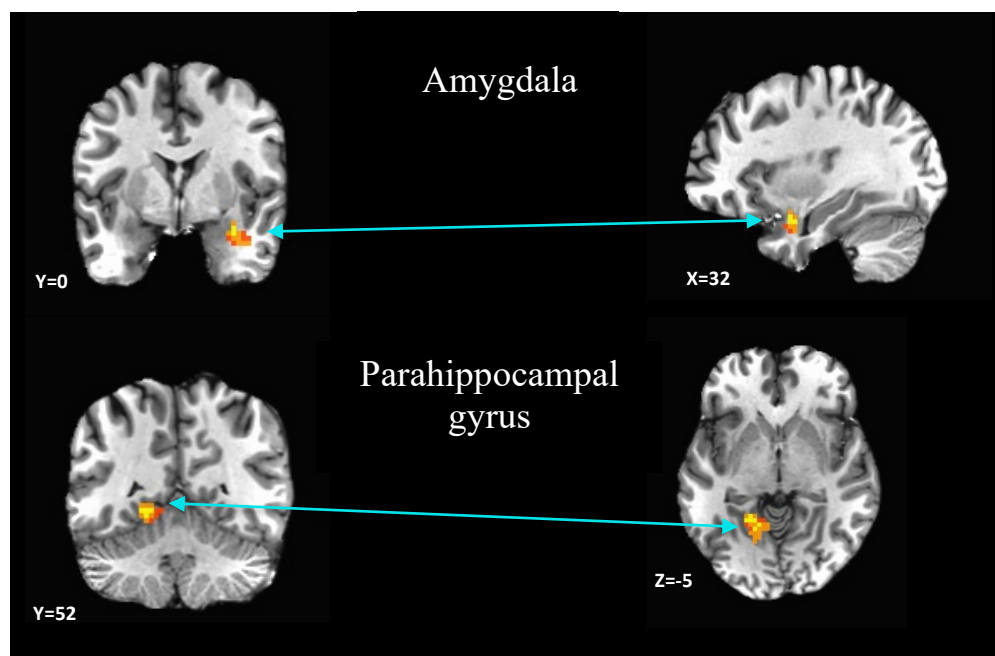


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After determining group-wise regional associations of epistemic certainty and emotive importance, I next examined if trait mindfulness contributed to differences in region-specific activation. To specifically address aim 3, mindfulness was modeled as a covariate in two parallel whole-brain regressions of the amplitude-modulated adjective trait events. The model indicated that trait mindfulness was positively related to activity in the amygdala (peak $t = 4.23$, uncorrected $p < .001$, MNI $x = 33, y = 0, z = -24$) and parahippocampal gyrus (peak $t = 4.36$, uncorrected $p < .001$, MNI $x = -18, y = -49, z = -24$) during judgements of epistemic certainty (see Figure 5), and emotive importance (see Figure 6). Trait mindfulness was positively related to activity in the caudate (peak $t = 4.27$, uncorrected $p < .001$, MNI $x = 35, y = -17, z = 0$) only for judgements of emotive importance (See Figure 6).

Figure 5.

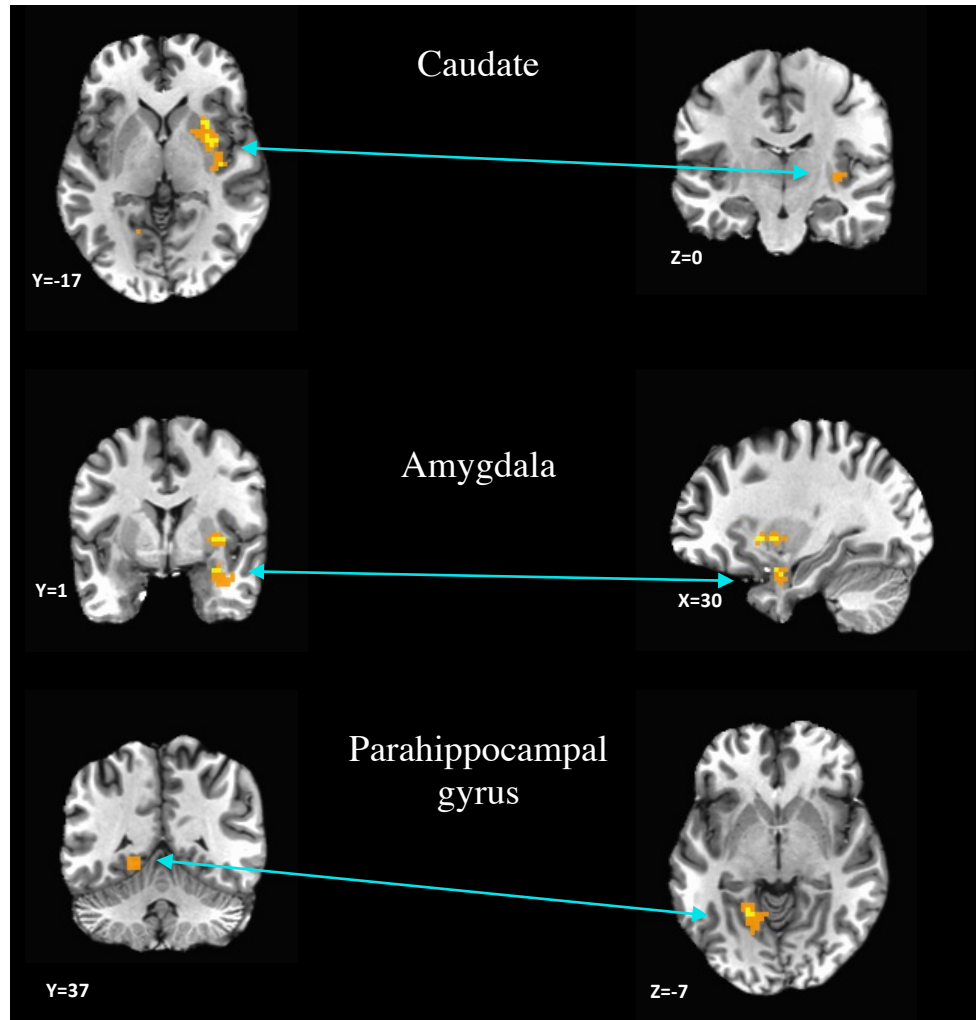
Mindfulness-related activation to epistemic certainty of self-views.
Displayed at uncorrected $p < .001$.



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Figure 6.

Mindfulness-related activation to emotive importance of self-views.
Displayed at uncorrected $p < .001$.

*Voxel of Interest (VOI) analyses*

In addition to whole-brain regressions, I addressed aim 3 by restricting analyses to regions previously implicated in self-view investment. VOI analyses were conducted to investigate the relation between mindfulness-related BOLD signal activations elicited by epistemic and emotive self-view investments. Bivariate correlations between trait mindfulness, epistemic certainty and emotive importance ratings, and beta (standardized regression)

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coefficients of VOIs revealed that trait mindfulness was not significantly correlated with activation in regions related to epistemic investment; however, trait mindfulness was positively associated with activation in the left middle temporal gyrus during judgements of emotive importance, $r = .56, p < .001$ (see Figure 8). All zero-order correlations between certainty-modulated VOIs and importance-modulated VOIs are reported in Tables 3 and 4 respectively.

Table 3.

Zero-order correlations between mindfulness, ratings of negative traits and positive traits, and certainty-modulated VOIs

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-----------------------------------|--------|--------|-------|---------|--------|---------|-------|
| 1. MAAS | | | | | | | |
| 2. Negative traits | .675** | | | | | | |
| 3. Positive traits | .649** | .817** | | | | | |
| 4. Dorsal mPFC | -.309 | -.436 | -.427 | | | | |
| 5. Ventral mPFC | .149 | .456* | .287 | -.765** | | | |
| 6. Left middle temporal gyrus | -.131 | -.326 | -.246 | .908** | -.854 | | |
| 7. Right insula | .273 | .513* | .468* | -.791 | .936** | -.828** | |
| 8. Right inferior parietal lobule | .098 | -.061 | -.266 | .123 | -.042 | .051 | -.174 |

* $P < .05$

** $P < .001$

Note. MAAS = Mindful Attention Awareness Scale.

Table 4.

Zero-order correlations between mindfulness, ratings of negative traits and positive traits, and importance-modulated VOIs

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| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-----------------------------------|---------------|--------|-------|--------|-------|------|-------|
| 1. MAAS | | | | | | | |
| 2. Negative traits | .27 | | | | | | |
| 3. Positive traits | .211 | .495* | | | | | |
| 4. Dorsal mPFC | .011 | -.451* | -.247 | | | | |
| 5. Ventral mPFC | .126 | .527* | .136 | -.269 | | | |
| 6. Left middle temporal gyrus | .561** | .371 | .376 | .203 | -.278 | | |
| 7. Right insula | .369 | .464* | .414 | -.452* | -.068 | .304 | |
| 8. Right inferior parietal lobule | .184 | -.126 | -.363 | .249 | .356 | .01 | -.329 |

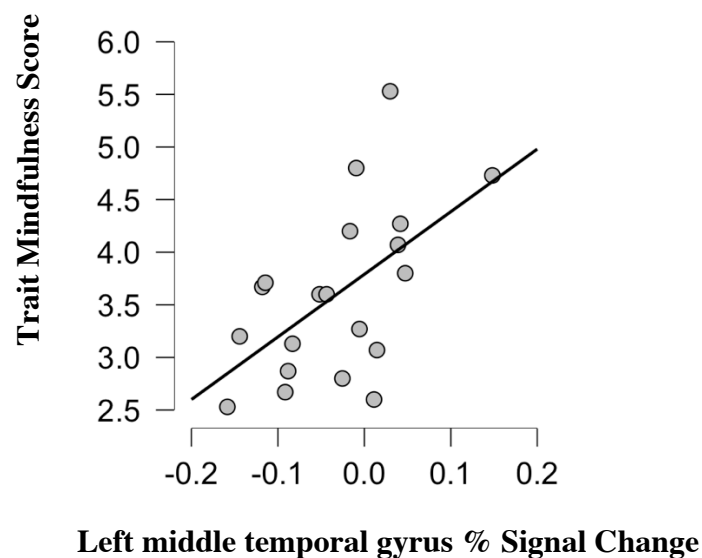
* P < .05

** P < .001

Note. MAAS = Mindful Attention Awareness Scale.

Figure 7.

Correlation between trait mindfulness and left middle temporal gyrus activity during judgements of emotive importance of self-views



Functional Connectivity Analysis

The fourth aim of the study was to examine whether resting state connectivity of the vmPFC seed with the PCC would mediate the effect of mindfulness on endorsement of negative personality traits. Preliminary analyses demonstrated that mindfulness was negatively correlated with endorsement of negative traits ($r = -.25, p = .12$) and resting state functional connectivity between the vmPFC and PCC ($r = -.21, p = .37$). However, vmPFC-PCC functional connectivity was not correlated with endorsement of negative traits ($r = .56, p = .82$). Given that the mediator (vmPFC-PCC connectivity) was not related to the outcome (endorsement of negative traits), the variables did not meet criteria for a mediation relationship (Baron & Kenny, 1986), so no mediation analysis was performed.

Discussion

The self-concept is sustained by both cognitive and affective factors (Pelham, 1991), and these factors have previously been associated with activation from cortical-subcortical midline structures (CSMS) (Roy et al., 2012; D'Argembeau, 2013). Maladaptive self-views are characterized by identification with negative traits, but it is possible that the metacognitive distancing fostered by mindfulness may mitigate maladaptive self-views by altering epistemic and emotive investment in personality traits. The present exploratory study investigated the relation between trait mindfulness and self-views in healthy, meditation naïve adults. I examined whether a basic form of trait mindfulness was related to self-descriptions of negative and positive traits, and epistemic certainty or emotive importance in self-views, as indexed by self-reported responses. I also examined BOLD signal recordings obtained during a self-description task to

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determine if dispositional mindfulness was related to neural indicators of epistemic or emotive investment.

Addressing the first aim of the thesis, the relations between mindfulness and self-descriptions of personality traits were statistically nonsignificant ($ps > .05$). Concerning the second aim of the thesis, namely examining the relations between mindfulness and emotive importance and epistemic certainty for both negative and positive traits, results revealed large effect-sized associations between mindfulness and epistemic certainty in both positive and negative self-views. The magnitude of the two correlations were very similar, suggesting that mindfulness-related certainty applied equally to both negative and positive personality traits. Although the findings are preliminary, these findings suggest that mindfulness may improve non-biased awareness of self-views.

Neuroimaging analyses first examined neural indicators of epistemic and emotive investment in negative and positive self-views before analyzing mindfulness-related differences specific to aim 3. Neuroimaging results demonstrated that judgements of epistemic certainty and emotive importance for a series of personality traits elicited activation from cortical-subcortical midline regions (i.e., medial prefrontal cortex, anterior cingulate cortex, striatum, and thalamus). Of particular interest to the third aim of this thesis, dispositional mindfulness was related to investment-specific differences in activation, with those scoring higher in mindfulness eliciting activation from the amygdala and parahippocampal gyrus when encoding for epistemic certainty and emotive importance. This pattern may indicate that those scoring higher in mindfulness are more likely to engage limbic regions when encoding epistemic certainty or emotive importance for self-views. Such interpretation possibly suggests that mindfulness support semantic knowledge of the self via viscerosomatic awareness (as opposed to strictly cognitive processes).

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Results also indicated that mindfulness was related to greater caudate activation during judgements of emotive importance, but not epistemic certainty. These findings, particularly concerning caudate and amygdala activation, suggest that those scoring higher in mindfulness recruit from reward associated regions when considering the emotive importance of self-views. Such an explanation may elucidate the finding showing associations between mindfulness and positive self-concept (high endorsement of positive self-views and low endorsement of negative self-views) and is consistent with research linking mindfulness to relatively high self-esteem (Thompson & Waltz, 2008).

Previous research on self-view investment has shown epistemic investment to be specifically related to the dorsal mPFC and left temporal gyrus, and emotive investment to be specifically related to the ventral mPFC, right insula, and right inferior parietal lobe (D'Argembeau et al., 2011). In specifically addressing the third aim of the study, I conducted VOI analyses to examine if mindfulness was associated with epistemic or emotive investment in these regions. Results showed that mindfulness was significantly associated with left middle temporal gyrus activity when encoding for emotive importance, but not epistemic certainty of self-views. This result is interesting considering that the left middle temporal gyrus has previously been associated with certainty of self-views (D'Argembeau et al., 2011). One explanation for this finding is that those higher in mindfulness made judgements of valuation by recruiting from regions typically utilized for cognitive judgements. The left middle temporal gyrus has previously been implicated in social processing and mentalization (Ross & Olson, 2010). Thus, it is possible that those higher in mindfulness were employing a form of cognitive distancing when evaluating important self-views, as represented via activation from the left middle temporal gyrus. Further investigation of this region is necessary to make stronger

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conclusions regarding its role in representing self-views and determine if it is a possible target of mindfulness.

Judgements of negative personality traits elicited significant deactivation from the midcingulate cortex. Previous research has suggested that dysphoric emotions may divert activity from the salience network and increase blood flow to the medial prefrontal cortex (Liotti, Mayberg, McGinnis, Brannan, Jerabek, 2002), but researchers note that this response is indicative of poor meta-cognitive awareness of emotion (Fresco, Segal, Buis, Kennedy, 2007). Research indicates that mindfulness may ameliorate symptoms of depression by improving meta-cognitive awareness of unpleasant emotions via insular activation (Farb et al., 2010). The findings here suggest that participants responded to negative self-views as if they were responding to unpleasant emotions. Because those higher in trait mindfulness demonstrated greater certainty of possessing or not possessing negative self-views, it is possible that mindfulness reduces cognitive processing that would have otherwise been allocated to emotional appraisal.

Aim 4 of the thesis was to examine whether resting state connectivity of the vmPFC seed with the PCC mediated the relation between mindfulness and endorsement of negative personality traits. The vmPFC seed region and PCC mask were selected *a priori* based on research identifying the vmPFC and PCC as central hubs of the default mode network (Davey, Pujol, & Harrison, 2016) and research linking PCC-vmPFC connectivity to rumination behaviors (Hamilton, Farmer, Fogelman, & Gotlib, 2015); since vmPFC-PCC connectivity was not significantly related to negative personality trait endorsement, mediation analysis was not performed.

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The failure to observe a relation between resting state connectivity and negative self-views may be due to the sample demographics, which included healthy adults without clinical levels of anxiety or depression. Future research in populations with internalizing disorders may determine if mindfulness improves maladaptive self-views via changes in resting state functional connectivity. In summary, further research is necessary to determine the contribution of the unique role of default mode network connectivity in valuation of positive and negative self-views.

Limitations and Future Directions

This study was limited by its small sample size, making statistical significance of the relations explored more difficult to achieve. However, this exploratory study provides preliminary evidence suggesting the impact of mindfulness on maladaptive self-views via mechanisms of affective and cognitive processing. Additionally, I chose to operationalize mindfulness using a validated self-report scale of dispositional mindfulness (Brown & Ryan, 2003). Trait mindfulness has been related to greater self-awareness and improvements in emotional and cognitive functioning (Brown & Ryan, 2003), however, a one-occasion self-report measure lacks the predictive power of experimentally manipulating mindfulness via mindfulness training. To make stronger conclusions, future research should use randomized control trial designs to experimentally test the effects of mindfulness training on subjective and neural indices of self-view endorsement and investment. Prior research has established the ameliorative impact of mindfulness training on maladaptive self-views (Farb et al., 2007; Goldin et al., 2009), so it is possible that mindfulness treatment may be leveraged to better understand self-view-related neural mechanisms associated with internalizing and other disorders.

Conclusion

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Mindfulness is theorized to improve maladaptive self-views via disidentification with thoughts and feelings. Previous research shows that mindfulness training mitigates negative self-views by fostering meta-cognitive awareness, however this is the first study to investigate how mindfulness relates to epistemic and emotive investment in positive and negative self-views. This research provides preliminary evidence that mindfulness may influence self-views via differences in self-reported epistemic certainty and emotive importance. These findings provide a starting point to further examine how beliefs about one's traits are modulated by mindfulness training.

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