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Cognitive and Neural Mechanisms of Stress Cognition:
Becoming Immersed in Stress and Disengaging from It with Mindful Attention

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Doctor of Philosophy

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M.A. Emory University, 2010

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An abstract of
A dissertation submitted to the Faculty of the James T. Laney School of Graduate Studies
of Emory University in partial fulfillment of the requirements for the degree of
Doctor of Philosophy
in Psychology
2014

Abstract

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Because chronic stress is linked to decreased well-being, establishing the processes that both produce and disable stress is important. We focus on how people attribute stressfulness to events, the subjective realism of stressful cognition, and one means of blocking subjective realism, mindful attention. In article 1, we present a Grounded Theory of Stress Cognition, explaining how people attribute stressfulness to events. According to this theory, when people experience stress, they store situated conceptualizations in memory that typically include features related to expectancy violation, threat, efficacy, peripheral physiology, emotion, rumination, coping, and metacognition. Later, new events are categorized as stressful when they are similar to situated conceptualizations established for prior stressful events. To assess this theory, participants evaluated features of stressful and non-stressful situations. In a multilevel regression model, situational features explained 85% of the variance in perceived stressfulness, supporting our hypothesis that people use situated conceptualizations of previous experiences to categorize current stressful events. When an event is perceived as stressful, it often seems real, as if they were happening in the moment. One possibility is that this subjective realism results from simulating the self engaged in a situation (immersion). If so, then disengaging the self—decentering—should reduce the subjective realism associated with immersion, and therefore stressfulness. In a brief intervention outlined in article 2, we taught participants a strategy for disengaging from events, simply viewing their thoughts as fleeting mental states (mindful attention). Neural activity was measured as participants subsequently imagined stressful and non-stressful events during mindful attention vs. immersion. Mindful attention showed greater activity in brain areas associated with perspective shifting and effortful attention, whereas immersion showed greater activity in areas associated with self-processing and visceral states. These results suggest that, through shifts of perspective, mindful attention produces decentering by rapidly disengaging embodied senses of self from stressful situations so that affect doesn't develop. Together findings from both articles provide a more nuanced understanding of mechanisms that contribute to reenacting stressful events, how participants categorize events as stressful, why stressful thoughts feel so real, and why mindfulness has a therapeutic effect.

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ACKNOWLEDGEMENTS

This dissertation rests on the shoulders of many individuals who have supported me on this journey. First, my deepest thanks to my advisor, Larry Barsalou, for his scientific guidance, mentorship, and introduction to the world of precise tea preparation. He has pushed me to think deeper, write stronger, and science better. Larry is not afraid to "Robert Frost it," and take the scientific road less traveled by. He has shown me it is possible to succeed in the academic world as a generous, humble soul. Working with Larry has truly been transformative, and as he has assured me, this is only the beginning.

I am grateful to my committee members, including Lisa Feldman Barrett, Robyn Fivush, James Rilling, and Kim Wallen. Their feedback, and counsel has pushed my thinking to new levels. I am also grateful to my past committee members for their insightful perspectives, including Edward Craighead, Marshall Duke, David Edwards, Rob Hampton, and Stella Lourenco. I thank the National Center for Complementary and Alternative Medicine, and the Emory Laney Graduate School for their financial support. I am also grateful to Paula Mitchell for her generosity and guidance, along with the rest of the Emory Psychology Department Staff.

Before Emory, I benefited immensely from the encouragement and guidance of several individuals at the University of Notre Dame, including Anita Kelly, David Smith, Anre Venter, and Kevin Whelan. And in particular, a thanks to my honors thesis advisor, G.A. Radvansky, whose final advice I can finally assure him I have followed.

I am indebted to my Barslaou lab siblings, including Jing Chen, Jonathan Drucker, Wendy Hasenkamp, Christine Wilson-Mendenhall, and Kyle Simmons. I have benefited greatly from your guidance, support, and shared laughter throughout my time at Emory. The research in this dissertation and other manuscripts would not have been possible without the assistance of many undergraduate research assistants over the years, including Taryn Colton, Hailey Friedman, Julie Kim, Jessica Lake, Rob St Louis, Yesenia Mares, Moses Tincher, and Bridget Warren. I am thankful for their hard work.

I am appreciative of the chance to learn from many great minds through recent collaborations, including Kaundinya Gopinath, Chris Hertzog, Esther Papies, George Slavich, and Karen Quigley. I thank you for your time, patience and teaching. A special thanks to Esther Papies for bringing much happiness to the Barsalou Lab.

I have been unbelievably lucky to spend my time in Atlanta with a group of amazing friends. A special thank you to Carolina Campanella for sharing your witty intellectualism, support, enthusiasm for life, Latin dance moves, and above all, your friendship. A special thank you also to my Atlanta musical family, The Ballybeg Band, Owen Devine, James Dunning, and Ken Shearer. For every gig in which audience members joked that you would be the topic of my dissertation, finally, you can rest easy that, in fact, you are not. And to Jim Flannery who took me on my first foray into the Irish music scene in Atlanta, and whose encouragement and insight have made me a better person.

I am incredibly grateful to my McDonough and Lebois family. Your ears, advice, and late night group texts have carried me through this adventure. Finally, I would like to thank my husband, Evan, for his unwavering love, support, and mirth. You make

everyday like Christmas. I can't wait to transition from The Future Drs Lebois to The Drs Lebois.

I dedicate this dissertation to my parents, Patrick and Geraldine McDonough. You have worked tirelessly to provide me with the best opportunities. Your example and belief in me has made all this possible.

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Stress is linked to decreased mental and physical well-being (Zautra, 2003), being associated with increased risk for many ailments, including depression, anxiety, and heart disease (Brosschot, Gerin, & Thayer, 2006; Sapolsky, 2004; Zautra, 2003). Although many techniques (e.g., mindfulness, exposure therapy, cognitive behavioral therapy) exist to help manage stressful experiences, stress remains an integral element of life, and a significant financial and personal burden in our society. Given the situation, it is important to both understand what factors make something stressful, and how to ameliorate stress when it becomes dysfunctional. This dissertation addresses both these points. At its core, it contains two articles, the first presenting and testing a Grounded Theory of Stress Cognition, and the second, establishing the neural bases of decentering in mindfulness and immersion while imagining stressful events.

To begin, the general introduction provides a brief overview of significant gaps in our present understanding of stress cognition and its mechanisms, motivating our Grounded Theory of Stress Cognition, and exploring the neural correlates of stress and mindful attention. Next, I provide an overview of the cognitive, neural, and physiological systems involved in the stress response to situate our article on the Grounded Theory of Stress Cognition. This section finishes with an introduction to the concept of subjective realism, an element of stressful cognition that we hypothesize is key to some of its detrimental effects.

Next, I address one way to block the subjective realism of thoughts, mindfulness. This section provides an overview of the benefits and mechanisms of mindfulness. Much previous and current mindfulness research focuses on expert and experienced meditators, considering mindfulness in novices, however, could be very beneficial to understanding its basic mechanisms. I review mindfulness research that has addressed brief mindfulness interventions, motivating the topic of our second article.

Finally, I conclude the general introduction with an overview of the two articles. Again, article one provides a Grounded Theory of Stress Cognition, and an initial test of this theory, whereas article two compares neural activity during immersion vs. mindfulness with a specific emphasis on decentering. Following the two articles, I end the dissertation with a general discussion. This section includes additional results not presented in the two core articles, an integration of key findings from each article, and a discussion of their relation to the concept of self. Limitations and future directions are also addressed.

Preface: Addressing Unresolved Issues

Sitting alone in your office, your mind wanders to a presentation you gave recently, and the one question you were unable to answer. You mentally reenact the event - what was asked, how uncomfortable you felt, what you could have said, the answer you fumbled through instead, and how you clenched your fist around your laser pointer through the awkward silence that followed. Every time you think about the incident, it still feels subjectively real, as if you were there again. Days later, you still feel anxious, continuing to ruminate on the event, with your blood pressure rising just by recounting the incident in your thoughts. I will refer to experiencing one's thoughts in this manner as "subjective realism" (see also, "cognitive fusion," Hayes, 2003, 2004). Subjective realism in the context of stressful cognition is the sense that the experience of a stressful thought seems so real it triggers a stress response and negative emotion in the moment. "Real" refers to the idea that the thought is experienced almost as if the event were actually happening in the present moment; as if one had time travelled to the imagined event. Arguably, the subjective realism of these stressful thoughts contributes to their stressfulness (a similar idea can be found in Acceptance and Commitment Therapy (ACT); Biglan, Hayes, & Pistorello, 2008).

Classic research by Cannon, Selye, Lazarus, and Ellis, among many others, has shaped our conceptualization of stress for decades (Cannon, 1914; Ellis, 1994; Lazarus, 1999; Selye, 1979). We have a greater understanding of its impact on human functioning, its associated physiological response, and how the interaction between an individual's characteristics and appraisal strategies determine whether an event is experienced as stressful. A great deal of research has explored the biochemical processes of the stress response, in particular, the hypothalamic-pituitary-adrenal axis (Herman et al., 2003; Schwabe, Haddad, & Schachinger, 2008). Similarly, much of the stress literature is devoted to the process of categorizing an event as stressful by determining whether it affects one's values, goals, beliefs, or self-concept (Almeida, 2005; Higgins, 1989; Lazarus, 1993, 1999).

Nonetheless, stress research appears relatively limited at an important explanatory level that, in the long run, has potential to significantly inform its measurement and treatment. Expressly, the specific cognitive mechanisms underlying stressful thoughts are not well understood, including their computational properties, subjective qualities, and neural correlates. Studies that do examine cognitive processes of stress do so at a rather descriptive, non-mechanistic level, incorporating stressor characteristics (e.g., frequency, content), subjective appraisal, and the resilience and vulnerability factors of individuals (Almeida, 2005). Additionally, researchers often arbitrarily separate processes of cognition and emotion at various stages (Almeida, 2005; Lazarus, 1993), which may unduly limit our understanding of stress and its underlying mechanisms. In the following two articles, we examine the subjective qualities and neural correlates of stressful thoughts, and one stress regulation technique, mindfulness. Ultimately, understanding these mechanisms has the potential to inform the assessment and treatment of stress.

Stress: Overview Cognitive, Neural, and Physiological Mechanisms

A combination of cognitive, neural, physiological, and behavioral reactions make up one's stress response. In the following sections, I will briefly overview the cognitive, neural, and physiological mechanisms associated with stress. Although stress is sometimes associated with positive feelings (e.g., challenge), I focus here on stress in negative, undesirable contexts, because of their known health implications (e.g., Keller et al., 2012; Sapolsky, 2004).

Stress is the intricately entwined psychological, physiological, and behavioral reactions to internal or external events categorized as a threat or harm to one's goals or self-concept (Lazarus, 1993, 1999). In a broad sense, this categorization often occurs when there is a mismatch between the outcome one anticipates and the world's existing circumstances (Ursin & Eriksen, 2004). Together with this violation of expectations, a combination of factors makes an event stressful, in particular: perceived self-threat, perceived lack of efficacy, stressor characteristics, the individual's resilience and vulnerability, neuroendocrine responses, and negative emotion (Almeida, 2005; Almeida, Wethington, & Kessler, 2002). Stress can be a reaction to a present event, worry about a past event, or anticipation of a future event (Sapolsky, 2004; Watkins, 2008).

When stressful thoughts perseverate in an individual's mind (e.g. rumination, worry), they repeatedly elicit a stress response that can affect mental and physical health over time (Brosschot et al., 2006; Zautra, 2003), thereby steadily increasing allostatic load (McEwen, 1998). Subjective features of experience also contribute to the stressfulness of an event, including the experience of stressful bodily states and immersion in the perceived reality of thought related to the event (subjective realism). While acknowledging the complexity of how and why individuals experience stress, these features of stressful thoughts and their subjective realism are of particular interest for this dissertation.

Overview of grounded cognition and Conceptual Act Theory. According to grounded cognition, all the multimodal aspects of situational experience, including audition, vision, gustation, tactition, olfaction, internal bodily states and action, have neural correlates that become stored in memory (Barsalou, 1999). In recent theories of grounded cognition, patterns of neural activation associated with experiencing these bodily states, tactition, vision etc. are reenacted in the context of a specific thought (Barsalou, 1999; Barsalou, Niedenthal, Barbey, & Ruppert, 2003). For example, when ruminating about your inability to answer the question during your presentation, you mentally time travel to that instance (context). You simulate the bemused faces of the audience (vision), you hear the awkward shifting of chairs during your silence (audition), you feel your jaw tighten (action), and your stomach clench (internal bodily states), as you search for an answer. Using some different examples, when one thinks about a color or an action, brain areas similar to those operating when one actually perceives color or performs an action become active (Hauk, 2004; Simmons, et al., 2007). Thoughts (i.e., simulations), however, are not full reenactments of the original perception or experience. They are partial re-activations of previous experience that are dynamic and context-dependent.

According to Conceptual Act Theory, the conceptual system links together these context-dependent reenactments of multimodal experience (action, vision etc.) into a "situated conceptualization" that categorizes the instance as stressful (Barrett, Wilson-Mendenhall, & Barsalou, in press; Lebois, Wilson-Mendenhall, Simmons, Barrett, & Barsalou, submitted; Wilson-Mendenhall, Barrett, Simmons, & Barsalou, 2011). These categorizations further produce associated bodily states (sweaty palms), inferences about possible consequences ("I will lose respect among my colleagues if I don't answer"), and potential actions (jaw tightening, the search for answers). Thought can also influence experience in a top-down manner. After categorizing your presentation experience as stressful, for example, you may link your perception of the audience's disapproval with a sense of self-threat, and see the audience's, bemused faces as increasingly irritated and judgmental.

Neural correlates of stressful cognition. As stated earlier, stress is a complex combination of behavioral, cognitive, neural, and physiological responses to a stressor. Of particular interest to the second article in this dissertation are the neural correlates of stressful cognition. According to Conceptual Act Theory, the neural activity underlying a particular emotion is tailored to the current context. Specifically, a consistent set of neural areas is implicated in emotional processing, but different subsets of the circuit are activated depending on what is currently relevant (Kober et al., 2008). I will briefly overview how these regions may work together and in conjunction with other responses in the experience of emotion with a focus on stress.

The anterior insula, amygdala, orbitofrontal cortex (OFC), and their reciprocal connections to sensory areas help determine the relevance of a particular stimulus to the individual (Barrett, Mesquita, Ochsner, & Gross, 2007; Ganzel, Morris, & Wethington, 2010). The OFC, in particular, is involved in the integration of internal and external sensory information (Barrett et al., 2007; Dedovic, Duchesne, Andrews, Engert, & Pruessner, 2009; Dedovic, Rexroth, et al., 2009; Ganzel et al., 2010). It may also play a role in intentional emotion regulation, and in the maintenance of possible future consequences' value (Dedovic, D'Aguiar, & Pruessner, 2009). The OFC may help initially categorize an event as stressful, and facilitate its perseveration in one's mind (Dedovic, D'Aguiar, et al., 2009; Dedovic, Duchesne, et al., 2009), perhaps contributing to the subjective realism of the thought.

Coupled with representations of a stimulus's value, anterior cingulate cortex, the amygdala, and dorsomedial and ventromedial prefrontal cortex (dmPFC and vmPFC, respectively) help form an appraisal of the stimulus's personal significance, emotional intensity, and valence (Barrett et al., 2007; Dedovic, Duchesne, et al., 2009; Dedovic, Rexroth, et al., 2009; Ganzel et al., 2010). Interestingly, the mPFC in particular appears to be heavily involved in self-focused attention (Amodio & Frith, 2006; Mitchell, Banaji, & MacRae, 2005; Northoff & Bermpohl, 2004; Van Overwalle, 2009).

Hypothalamic-pituitary-adrenal axis regulation. Neuroendocrine activity in response to stress is one of the most thoroughly studied topics in the stress literature. I will briefly review the current understanding of one feedback loop in the stress response, the hypothalamic-pituitary-adrenal (HPA) axis, and the neural structures involved in HPA axis regulation.

Through connections with the hypothalamus and brainstem, the aforementioned brain activations influence physiological, hormonal, and behavioral responses to stress (Barrett et al., 2007; Chida & Hamer, 2008; Dedovic, D'Aguiar, et al., 2009; Greenberg, Carr, & Summers, 2002; Sapolsky, 2004). A number of areas seem to be directly involved in regulating the neuroendocrine stress response through the HPA axis (described in detail shortly). The hippocampus, for example, may help evaluate how deeply the stressor affects one's goals and self, that is, the "intensity" of the stressor (Dedovic, D'Aguiar, et al., 2009). Both the hippocampus and the mPFC can inhibit the HPA axis (Dedovic, D'Aguiar, et al., 2009). When these areas are deactivated, they disinhibit the HPA axis, thereby initiating the cascade of stress hormone release.

The amygdala can also trigger HPA axis activation. In contrast to the inhibitory role of mPFC and hippocampus, the amygdala potentiates HPA axis activation (Dedovic, D'Aguiar, et al., 2009). This potentiation can occur through two main pathways: one pathway involves cortico-amygdala connections; the second is a 'shortcut' via thalamo-amygdala connections (Rodrigues, LeDoux, & Sapolsky, 2009). The thalamo-amygdala pathway can initiate a rapid stress response through direct efferent connections with the hypothalamus and brainstem, without (conscious) input from cortical processing (Rodrigues et al., 2009). The amygdala, however, is not always consistently active during stressful cognition. Certain contexts may be more likely to activate the amygdala compared to others. Ganzel et al. (2010) posit that the amygdala may be more involved when an individual fears physical or social threat, though this delineation requires further research.

HPA axis. Once an event or stimulus is consciously or unconsciously categorized as stressful, it begins a cascade of stress hormone release. Neural network activation, for example, causes the medial parvocellular division of the paraventricular hypothalamic nucleus (PVN) to release corticotrophin-releasing hormone (CRH) (Dedovic, D'Aguiar, et al., 2009; Herman et al., 2003; Sapolsky, 2004). The medial PVN receives input from bodily pain receptors, visceral afferents, and other sensory pathways, which allows it to activate the stress response quickly (Herman et al., 2003). This prompts the pituitary to emit andrenocorticotrophin hormone (ACTH). ACTH release, in turn, results in the discharge of glucocorticoids from the adrenal cortex, epinephrine and norepinephrine (catecholamines) from the adrenal medulla, and norepinephrine from other bodily nerve endings (Herman et al., 2003; Rodrigues et al., 2009). Among their many roles, epinephrine, norepinephrine, and glucocorticoids help keep energy in circulation to be used in the stress response and recovery (Herman et al., 2003; Sapolsky, 2004). This can prompt a host of physiological and behavior changes, for example, increased heart rate and blood pressure.

These changes also feed back and influence hormone and neural activity (Ganzel et al., 2010; Greenberg et al., 2002; Herman et al., 2003). Glucocorticoids, for example, bind to receptors in the hippocampus, amygdala, and PFC to regulate the stress response further (Dedovic, D'Aguiar, et al., 2009; Dedovic, Duchesne, et al., 2009). This feedback loop can have both short-term and long-term modulatory effects on memory and emotion processing (Muehlhan, Lueken, Wittchen, & Kirschbaum, 2010). These effects may manifest, in part, through changes in the morphology and excitability of the neurons in these neural structures. Chronic stress response activation, for example, can reduce the spine count and lead to fewer dendritic branches on neurons in the hippocampus (Rodrigues et al., 2009). In short, the neuroendocrine stress response is a dynamic process with many potential adaptive and maladaptive consequences.

Importantly, this is just one example of many possible cascade effects in the stress response. Many of these activations can change depending on the sex of the individual, the specific context, and the experimental task required (e.g., generate stressful experiences, view International Affective Picture System photos, complete the Stroop color-word interference task, give a speech in front of an audience, solve difficult math problems; Dedovic, D'Aguiar, et al., 2009). One unresolved debate, for example, revolves around the activation vs. deactivation of limbic structures (medial orbitofrontal cortex, anterior cingulate cortex, hippocampus, hypothalamus) in the stress response. Whereas some studies report activations of these structures during the stress response (e.g. Ganzel et al., 2010), others report deactivations (e.g. Pruessner et al., 2008). Pruessner et al. (2008) posit that this discrepancy exists because of differences in stressor characteristics. Physical stressors that threaten bodily harm, for example, especially engage the amygdala and other limbic structures. In contrast, stressors that threaten social status tend to engage the hippocampus and deactivate other limbic structures.

Limbic activation or deactivation may also be contingent on when psychophysiological measurements are taken in the stress response time course. Perhaps initially there is heightened activation in OFC and mPFC as the individual perceives and categorizes a stimulus as stressful (Ganzel et al., 2010). Once this conceptualization occurs, these regions may be deactivated, thereby disinhibiting the PVN of the hypothalamus, and prompting the release of stress hormones through the cascade described above (Dedovic, D'Aguiar, et al., 2009). Depending on when neural activation is measured, researchers may find differing patterns of activation.

Grounded cognition and Conceptual Act Theory also predict these discrepancies in activation over the course of stress responses in different contexts. According to these theories, the experience of subjective stress emerges from the combination and integration of distributed neural network activation (neural), categorization using stress-related concepts (cognitive), triggered bodily states (physiological), and actions (behavioral). This overall set of processes is experienced as a unified thought (Barrett et al., 2007). Importantly, this process is continuous and can be activated in any order—no particular sequential order is required (Barrett et al., 2007). All these components interact, shape, confine, and feed back on one another as tailored to a specific situation.

Thus, it is possible for the different components to vary in their involvement across different contexts. The same emotion category could consist of many different neural activation patterns for different situated forms of the emotion, and the same brain areas could contribute to very different subjective experiences within and across individuals (Barrett, 2009; Lebois et al., submitted; Wilson-Mendenhall et al., 2011). Further research is necessary to understand these patterns more completely. Keeping the nuances of context, time course, and feedback loops in mind, these bidirectional relations between cortical and limbic structures help create an affective representation of the stimulus, and assist in responding effectively to the situation (Barrett et al., 2007; Ganzel et al., 2010; Greenberg et al., 2002).

Subjective realism of stressful thoughts. For reasons not yet well understood, mental simulations of stressful events often feel very real. Subjective realism associated with stressful thoughts may arise because the integration of physiological, behavioral, neural, and cognitive mechanisms involved create the experience of space, time, bodily states, negative emotion, and a sense of self, together producing an experience that the self is engaged in the current situation. It is perhaps the combination of these qualities that creates the feeling of "being there," even when you are just sitting at your desk thinking about it.

As evident in the second article of this dissertation, an embodied sense of self-engagement may be a key factor in the experience of subjective realism. Arguably, though, both the content of these simulations and their subjective realism contribute to their stressfulness. Thoughts are not treated as thoughts, or passing mental states (Papies, Barsalou, & Custers, 2012), but instead, as vivid transportations through time, in which one relives the mentally simulated event almost as if one were engaged with it in the current moment.

Blocking the Subjective Realism of Thoughts

Nevertheless, one does not necessarily have to be fully immersed in an imagined situation and experience it as subjectively real. Other experiences of these mental states are possible. Instead of being there in the simulation, one can have other relations with it as well; for example, one can regard it from the perspective of mindfulness. Western conceptualizations operationalize mindfulness as "nonelaborative, nonjudgmental, present-centered awareness" (Bishop et al., 2004; Kabat-Zinn, 1990).

There is continued debate as to whether mindfulness is a unidimensional (e.g. Brown & Ryan, 2003) or multidimensional construct (e.g. Baer et al., 2008; Bishop et al., 2004), but most agree it comprises specific ways of attending to and shifting perspective on thoughts and reactions (e.g., Bishop et al., 2004). The two-component model proposed by Bishop et al. (2004) emphasizes two mechanisms: (1) attention to the present moment without elaboration of thoughts, and (2) a shift in perspective toward one's thoughts that is "open" and "accepting." Individuals refrain from elaborating on or becoming immersed in the details of where a thought came from, what it means, how it is related to oneself and one's goals (Bishop et al., 2004).

One outcome of this shift in perspective to thoughts is that one can regard thoughts as exactly what they are: only thoughts, not as seemingly real events (Biglan et al., 2008; Bishop et al., 2004; Williams, 2010). The mode of processing that views thoughts as impermanent, passing mental states is called decentering, and is a key element of our brief mindful attention intervention described shortly (Papies et al., 2012; also see Bishop et al., 2004; Safran & Segal, 1990; Teasdale, Segal, & Williams, 1995). For the related construct of "reperceiving," see Shapiro, Carlson, Astin, and Freedman (2006); for "cognitive defusion," see Hayes (2004); for "deautomatization," see Deikman, (1982), and also Safran and Segal (1990).

With this shift in perspective comes the realization that thoughts are not necessarily true reflections of the self, events, and the world (Bishop et al., 2004; Teasdale, 1999a, 1999b; Teasdale, Segal, Williams, & Mark, 1995; Teasdale et al., 2000; Williams, 2010). If you were to treat the thought of your fumble during the presentation as a transient mental state, for example, it would not spark a stress response after the fact.

A diverse collection of research on mindfulness demonstrates that it reduces perceived stress and the symptoms of stress, including rumination, anxiety, depression, anger, negative thought avoidance, over-general autobiographical memory, memory for negative stimuli, emotional reactivity including to instances of social rejection, attempts to defensively protect the self-concept in response to threat, and experience of physical pain. Mindfulness is also associated with improved sustained attention, sustained working memory ability during stressful events, emotion regulation, positive affect, sense of spirituality, forgiveness, empathy, connectedness, self and other compassion, life satisfaction, quality of romantic relationships, and immune response. There is also growing evidence it is a buffer against cognitive decline with aging (Gard, Hölzel, & Lazar, 2014). For reviews of these findings, see Bishop et al. (2004), Brown, Ryan, and Creswell (2007), Chiesa and Serretti (2010), Keng, Smoski, and Robins (2011), Lutz, Slagter, Dunne, and Davidson (2008), and Tang, Rothbart, and Posner (2012).

Many clinical and laboratory interventions have incorporated aspects of mindfulness and seated meditation practice to foster benefits. Important examples of these interventions include Mindfulness Based Stress Reduction, MBSR (Grossman, Niemann, Schmidt, & Walach, 2004), Acceptance and Commitment Therapy, ACT (Biglan et al., 2008), Dialectical Behavioral Therapy, DBT (Öst, 2008), and Mindfulness Based Cognitive Therapy, MBCT (Kuyken et al., 2008; Teasdale et al., 2000). Various adaptations of these techniques combat depression (Teasdale et al., 2000), anxiety (Walsh et al., 2009), cigarette addiction (Kober, Kross, Mischel, Hart, & Ochsner, 2009), eating disorders, and attention disorders, further reducing symptoms and hospitalizations related to these ailments (for reviews, see Grossman, Niemann, Schmidt, & Walach, 2004; Rubia, 2009; Hofmann, Sawyer, Witt, & Oh, 2010).

Brief Mindfulness Interventions

In accumulating literature, very brief interventions from 12 min to a week have found immediate modulatory and beneficial effects of mindfulness and its components. Several of these studies focus just on the attention mechanism of mindfulness (component 1 in Bishop et al.'s, 2004, two-component model). Delizonna, Williams and Langer (2009), for example, found that after a week of practice monitoring their heartbeat, participants could better regulate its speed during an experimental task compared to a control group. In Ditto, Eclache, and Goldman (2006), twenty minutes of guided body scan meditation resulted in healthier autonomic nervous system activity (increased respiratory sinus arrhythmia), and increased sympathetic arousal compared to a control group. In Arch & Craske (2006), fifteen minutes of focused breathing produced more positive responses to neutral stimuli and less negative affect to negative stimuli compared to a worry condition. In Farb et al. (2007), a simple attention shift to more present-centered awareness decreased activation in areas associated with self-referential (PCC, mPFC) and visceral state processing (sgACC). Finally, in Dickenson, Berkman, Arch, and Lieberman, (2013) a brief breath-focused meditation recruited more areas involved in internal state awareness (insula) and in attentional control and shifting (dlPFC, AG) compared to a mind wandering condition, especially in participants high in trait mindfulness.

Other brief intervention research has examined both the attentional and perspective shifting components of mindfulness together, instead of just the attentional component. In Alberts and Thewissen (2011), participants receiving a brief 12 min mindfulness intervention remembered fewer negative words in a memory recall test compared to controls. In several related studies, twenty minutes of mindfulness practice for 3-4 days improved sustained attention, visuospatial processing, working memory, and executive functioning, while reducing fatigue, anxiety, heart rate, subjective experiences of pain and pain sensitivity, compared to controls and sham meditation groups (Zeidan, Johnson, Diamond, David, & Goolkasia, 2010; Zeidan, Gordon, Merchant, & Goolkasian, 2010; Zeidan, Johnson, Gordon, & Goolkasian, 2010). Still other studies have found that brief mindfulness interventions in the laboratory improve mood after a negative mood induction compared to distraction and rumination conditions (Broderick, 2005; though see Kuehner, Huffziger, & Liebsch, 2009 for conflicting results), while decreasing negative reactions to unpleasant events (Singer & Dobson, 2007). Finally, after training a mindfulness group with brief written instructions before an fMRI scan session, Lutz et al. (2013) found that mindfulness was associated with greater emotion regulation (increased superior mPFC) in anticipation of negative pictures**,** and decreased emotional responding during perception of emotional pictures (decreased amygdala, and parahippocampal gyrus activity) compared to a control group.

Only a handful of brief intervention studies have also included an explicit decentering instruction, in addition to either attentional and/or a more general perspective shifting instructions. In Papies et al. (2012) a 15 min mindful attention induction modulated implicit reactions to desirable, unhealthy foods. In Tincher, Lebois, and Barsalou, (forthcoming), a 20 min mindful attention induction implicitly modulated biased stereotype reactions to in-group and out-group members. In Erisman and Roemer

(2010), an experimentally-induced mindfulness group experienced more positive affect after viewing positively valenced film clips, less negative affect after viewing affectively mixed film clips, and higher levels of decentering on a mindfulness scale, relative to a control group who listened to educational radio clips in lieu of mindfulness training. Finally, Kross et al. (2009) found less self-referential, emotion, and visceral state integration (e.g., mPFC, sgACC) in response to negative autobiographical memories in a mindful condition compared to a ruminative condition.

The growing evidence for modulated behavior and benefits following very short mindfulness-based interventions supports the idea that individuals have basic mindfulness abilities without extensive training (Brown & Ryan, 2003; Brown, Ryan, & Creswell, 2007; Goldstein, 2002; Kabat-Zinn, 2003; Taylor et al., 2011). This makes it possible to study the component mechanisms of mindfulness in laboratory studies of non-meditators. In addition, it becomes possible to examine how these components contribute to stress reduction without the drawbacks of studying expert meditators, where self-selection, together with preexisting physiological, genetic, and neural differences, can complicate the interpretation of results.

Mindful attention. In the second article of this dissertation, we adapted a brief mindfulness intervention from Papies et al. (2012) that focused largely on the perspective shifting mechanism of mindfulness, specifically decentering. Participants were trained to maintain awareness of their present state, while recognizing that their thoughts were passing mental events that do not necessarily represent the situation they were thinking about. This allowed their simulations of events to simply arise and dissipate without sustaining an emotional or stress response in the moment (Kross & Ayduk, 2008).

Previous work, reviewed above, often lacks this specific focus on decentering, and none has emphasized decentering in the context of stressful cognitions.

By contrasting the cognition associated with immersion vs. mindful attention, we hoped to establish the mechanisms that make simulated events seem subjectively real and stressful, and conversely, the mechanisms that make them seem less real and engaging. Ultimately, this work has the potential to inform identification and reduction of subjective realism in stressful thoughts that become increasingly dysfunctional, as in chronic anxiety and Post Traumatic Stress Disorder.

Overview

As I have reviewed, stress is a complex combination of behavioral, cognitive, neural, and physiological responses to a stressor with potential serious health implications if chronically active. Of particular interest to this dissertation is: (1) how people attribute stressfulness to events, (2) the subjective realism associated with stressful cognition, and (3) one means of blocking subjective realism, mindful attention.

Article 1 addresses the first goal. In a Grounded Theory of Stress Cognition, we attempt to explain how people attribute stressfulness to thoughts and events. This theory builds on existing theories in the stress and psychology literatures to provide a cognitive and neural account of the mechanisms underlying stress cognition. According to this theory, experiences of stress are stored in memory as situated conceptualizations, and partially reactivated in the context of similar stressors. The Grounded Theory of Stress Cognition further postulates that situated conceptualizations associated with an individual's general category of stress consistently include certain features related to expectancy violation, threat, efficacy, peripheral physiology, emotion, rumination, coping, and metacognition.

The second half of this article provides an initial test of the Grounded Theory of Stress Cognition. Participants rated a large sample of stressful and non-stressful events for involvement of the aforementioned key features. If these features are consistently present in individuals' situated conceptualizations of stressors, then they should predict the amount of stress in a particular situation. This initial test of the theory grew out of a norming study completed to select the best materials for the experiment outlined in the second article.

Article 2 addresses aforementioned goals 2 and 3. As discussed earlier, we hypothesize that a key component of cognition that underlies stress is subjective realism, while further hypothesizing that it is possible to block subjective realism by adopting a mindful attention perspective on stressful thoughts. In this experiment, we used a short mindful attention intervention to block subjective realism that utilizes people's pre-existing ability to decenter. First, we briefly trained participants to both immerse and mindfully attend to stressful and non-stressful events. Next, participants immersed and mindfully attended to blocks of stressful and non-stressful events in a functional magnetic resonance imaging (fMRI) scanner. We then compared neural activity when individuals were immersed in events to neural activity when they were mindfully attending to events. We predicted that immersion would activate regions associated with emotion, visceral state (e.g., sgACC), and self-referential processing (e.g., mOFC/vmPFC), as participants engaged in elaborative thinking about the events. In contrast, we predicted that mindful attention would activate regions associated with effortful attention, regulation (e.g., lPFC, mPFC), and perspective shifting (AG), as participants attempted to disengage from stressful thoughts (decentering).

Article format. A brief note about formatting is in order so that it's clear why the articles take their specific forms. The first article was recently submitted to *Clinical Psychological Science* as a theoretical article with a 15,000-word maximum, and with a limit of four total figures and tables. The second article will be submitted to *Psychological Science* as a research article. This journal has no restriction on the word limit for the methods and results sections, but the introduction and discussion section together may not exceed 2,000 words. Both articles have supplemental materials for readers who would like more detail than provided in the main texts.

A Grounded Theory of Stress Cognition

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28 May 2014

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Abstract

We present a Grounded Theory of Stress Cognition that explains how people attribute stressfulness to events. According to this theory, when people experience stress, they store situated conceptualizations in memory that typically include features related to expectancy violation, threat, efficacy, peripheral physiology, emotion, rumination, coping, and metacognition. On later occasions, new events are categorized as stressful when they are similar to situated conceptualizations established for prior stressful events. To test this account, participants evaluated features of stressful and non-stressful situations that they would be likely to experience. In a multilevel regression model, situational features of stressful experiences explained 85% of the variance in perceived stressfulness (including random effects for individual differences), supporting our hypothesis that people use situated conceptualizations of previous stressful experiences to categorize current events as stressful. These findings have implications for how perceived stressfulness is related to health, neural activity, peripheral physiology, and individual differences.

The question of what makes some situations more stressful than others has long been debated. At the most distal level, certain life events may have specific characteristics that make them especially impactful (e.g., Almeida, 2005; Keller, Neale, & Kendler, 2007; Kendler, Hettema, Butera, Gardner, & Prescott, 2003; Slavich, O'Donovan, Epel, & Kemeny, 2010; Slavich, Thornton, Torres, Monroe, & Gotlib, 2009). Physical stressors, for example, may include violence, maltreatment, abuse, or neglect, posing a threat to the physical self. Similarly, social stressors may include isolation, rejection, shame, or humiliation, threatening a person's social status, value, and connections (Kemeny, 2009). Cognitive appraisals of the situation and oneself also play critical roles in producing stress (e.g., Lazarus, 1999; Folkman, Lazarus, Dunkel-Schetter, DeLongis, & Gruen, 1986; Ellsworth, & Scherer, 2003; McEwen, 2007; McEwen, & Wingfield, 2010). Whereas some individuals may perceive a life event as threatening, other individuals experiencing the same event may appraise it as non-threatening, or as a challenge, and believe that they have enough resources to cope (Blascovich, & Mendes, 2000; Crum, Salovey, & Achor, 2013; Tomaka, Blascovich, Kelsey, & Leitten, 1993; Tomaka, Blascovich, Kibler, & Ernst, 1997). Biological processes also play central roles in stress responses. Situations perceived as stressful may upregulate the cardiovascular, respiratory, autonomic, endocrine, and immune systems, which feed back on the brain to influence the appraisal of stressors (e.g., Irwin & Cole; 2011; Kemeny, 2003; McEwen, 2007; McEwen & Sapolsky, 1995; McEwen, & Wingfield, 2010; Sapolsky, Romero, & Munck, 2000; Slavich, Way, Eisenberger, & Taylor, 2010). Finally, genetic factors and personality traits shape perceptual, cognitive, neural, and peripheral responses to the social environment (e.g., Cohen, & Edwards, 1989; Conway et al., 2011; Conway, Slavich, & Hammen, 2014; Slavich, & Irwin, 2014).

Although a complete understanding of stress must ultimately take all levels of analysis into account, we focus here on the role of cognition. Specifically, we present a novel approach to stress cognition that reflects three themes. First, we build on the strengths of appraisal theories. Second, we adopt the theoretical perspective of grounded cognition. Third, we develop a theory that integrates the accumulated wisdom of the stress literature with the grounded perspective. Finally, we conduct an initial test of our theory and explore its implications for stress cognition.

Building on Appraisal Theories

Since the landmark contributions of Lazarus (1991, 1993, 1999) more than two decades ago, researchers have generally assumed that stress cognition takes the form of appraisal. From this perspective, stressors are evaluated on a variety of dimensions, including the relevance of a stressor for an agent, and the agent's ability to cope with it. Once these appraisals are made, they play central roles in causing whatever stress is experienced (e.g., Blascovich & Mendes, 2000).

More generally, appraisal has played central roles in theories of emotion (Gross & Barrett, 2011), with stress often characterized as an emotion. In some theories, appraisal is viewed as a central cause of emotion (e.g., Frijda, 1988; Lazarus, 1991), although whether appraisal actually causes emotion or simply describes its meaning remains a controversial topic (e.g., Moors, 2013; Parkinson, 1997). In other theories, the specific responses associated with an emotion (e.g., physiological, facial, attentional, motoric) reflect the specific collection of appraisals used to produce it (e.g., Roseman, 2013; Scherer, 2001). In still other theories, appraisals refine initial undifferentiated affect to an affective stimulus into a differentiated emotion (e.g., Clore & Ortony, 2008; Cunningham & Zelazo, 2007).

Although the construct of appraisal has played central roles in understanding stress and emotion, it is limited in several ways. First, appraisal theories often focus on relatively general descriptions of appraisals and the appraisal process (what Marr, 1982, called the "computational" level of analysis; see Moors, 2013). Although some theories stipulate that appraisals are cognitive mechanisms, these theories essentially describe appraisals made under various circumstances, not the underlying cognitive and neural processes that produce them (what Marr referred to as the "algorithmic" and "implementation" levels). Second, appraisal theories do not capture the categorization and inference processes that constructivist theories propose are central for producing emotion (e.g., Barrett, 2006, 2013; Wilson-Mendenhall, Barrett, Simmons, & Barsalou, 2011). Third, appraisal theories do not describe how emotions are learned, and thus do not explain how individuals develop different emotional styles (e.g., Lebois, Wilson-Mendenhall, Simmons, Barrett, & Barsalou, submitted).

The Grounded Theory of Stress Cognition that we develop here builds on the insights of appraisal theory. Specifically, our theory offers cognitive and neural accounts of the mechanisms underlying stress cognition. Additionally, our theory explains how categorization and inference contribute to stress cognition, and how individuals learn idiosyncratic forms of stress cognition as a consequence of their specific stress experiences.

Grounded Cognition

Several constructs from grounded cognition—situated conceptualization, pattern completion inference, and simulation—are central to the Grounded Theory of Stress Cognition that we develop in the next section. We address each in turn.

Situated conceptualization. We assume that the brain is a situated processing architecture (Barsalou, 2003, 2009; Barsalou, Niedenthal, Barbey, & Ruppert, 2003; Lebois et al., 2014; Wilson-Mendenhall et al., 2011; Yeh & Barsalou, 2006). As a person perceives, cognizes, and acts in a situation, multiple neural systems process different situational elements in parallel, generating complementary streams of information. Specifically, different neural systems process the current setting (parietal lobe, parahippocampal gyrus, retrosplenial cortex), objects in the setting (the ventral stream), other agents who are present (temporal poles, FFA, mPFC, PCC, STG, EBA), self conceptions and self relevance (mPFC, PCC), physical actions in the environment (motor and somatosensory cortices, cerebellum, basal ganglia), and a wide variety of cognitive, affective, and interoceptive responses to the situation (lPFC, ACC, mPFC, PCC, OFC, amygdala, insula).

Over time, each of these neural systems produces a continuous stream of perceptual experiences (qualia) for its respective situational content, along with corresponding conceptual interpretation. If you are reading this article in a coffee house, for example, some of these neural systems may be producing streams of perceptual and conceptual information about the space you're in, its furniture, and the other agents present. Another neural system may continually establish the self-relevance of events as they unfold, reflecting your identity, values, and goals. Other neural systems may control actions related to reading, drinking coffee, and interacting with others, along with somatosensory and visual feedback. And yet other neural systems may be producing continual thoughts about the article and your coffee house experience, along with affective responses and associated bodily states.

As each of these systems processes its respective situational information, other systems integrate these streams of “local” information “globally” (Lebois et al., 2014; Wilson-Mendenhall et al., 2011). As a result of this integration, coherent perceptual experiences of the situation result, along with coherent conceptual interpretations of the complex events constituting the situation. At the level of global interpretation, for example, you might experience finishing your coffee and feel ready to begin reading your article, while realizing that a friend across the room just recognized you. We refer to the combined local and global conceptualizations of a situation as a *situated conceptualization.* At a given point in time, a situated conceptualization interprets what is occurring in the current situation at multiple levels of analysis, while simultaneously controlling relevant actions and producing related cognition, affect, and bodily states.

As a situated conceptualization is constructed, associative mechanisms establish a statistical trace of it in long-term memory (Barsalou, 2003, 2009, 2013; Barsalou et al., 2003; Yeh & Barsalou, 2006). To the extent that a particular type of situation occurs repeatedly, the situated conceptualizations that result become integrated into a category of “exemplars” that represents this situation (cf. Medin & Schafer, 1978; Nosofksy, 2011). An individual who has coffee with a co-worker on many occasions, for example, may develop a category of situated conceptualizations for this repeated situational experience.

Pattern completion inferences. When a local or global element of an earlier situation is reencountered on a later occasion, a situated conceptualization that was previously stored may be retrieved in a Bayesian activation process (Barsalou, 2011; Clark, 2013). As the reencountered local or global element is processed currently in the relevant processing stream(s), it projects onto all situated conceptualizations in memory that share the same perceptual and conceptual content. Essentially, the brain is attempting to categorize the type of situation currently being experienced. When the best matching situated conceptualization is found, it becomes active and categorizes the current situation as a similar type of situation. On many occasions, the best matching situated conceptualization may come from a category for a familiar repeated situation; on others, it may come from a specific memory of a relatively unique situation. On rare occasions, no matching situated conceptualization may be available in memory, and the situated conceptualization constructed to represent the current situation functions on its own.

When a stored situated conceptualization becomes active, it produces inferences about what is likely to happen in the current situation, based on the inferential process of pattern completion. Content in the activated situated conceptualization that has not yet been perceived is inferred as being likely to occur. When you walk into the same coffee house again, for example, a situated conceptualization from a previous visit may become active from the category for this repeated event, preparing you to drink coffee, read, and converse with friends.

We further assume that emotion often ensues from pattern completion inferences; namely, experiencing an object or event previously associated with an emotional situation begins to construct a similar emotion again (Barrett, 2006, 2013; Lebois et al., 2014; Wilson-Mendenhall et al., 2011). As described shortly, we similarly believe that pattern completion inferences often underlie the production of stress.

Simulation. We assume that the local and global concepts used to construct situated conceptualizations are grounded in the neural and peripheral bodily systems that produce perception, action, and internal states (Barsalou, 1999, 2008). When representing an object in its absence, such as a strawberry, brain systems associated with perceiving the object's shape, color, and motion become active to represent this information conceptually (e.g., Kiefer & Barsalou, 2013; Martin, 2001, 2007). When representing potential actions on the object, brain areas associated with executing actions become active to anticipate them (e.g., Pulvermüller, 2005). When representing abstract qualities of the object, such as its reward value and associated mental states, brain areas associated with these qualities become active (e.g., Simmons, Martin, & Barsalou, 2005; Wilson-Mendenhall, Simmons, Martin, & Barsalou, 2013). Notably, representing an object in its absence across these systems can occur unconsciously, not just consciously.

In general, the grounded approach to cognition assumes, first, that when an *actual* object, event, or abstract quality is processed in the current situation, activity in relevant neural systems is stored and integrated into evolving conceptual knowledge. When consuming strawberries, for example, memories of their red color, sweet taste, and juicy texture are stored in the visual, gustatory, and somatosensory systems used to process these perceptions. Analogously, memories of the actions used to grasp, chew, and swallow strawberries are stored in the motor system, and memories of the subsequent pleasure and reward in motivational systems. Over time, multimodal memories of strawberries on different occasions become increasingly entrenched in the neural systems that perceive, control, and evaluate experiences of consuming them, integrated in higher-order association areas.

Entrenched knowledge about strawberries becomes active on later occasions when conceptual inferences about them are required (e.g., reading the "word" strawberry and establishing its meaning; seeing pictured strawberries on a menu and imagining what it would be like to eat them). From the grounded perspective, the process of simulation underlies these conceptual inferences. Specifically, conceptualizing what a strawberry is (in response to a word or picture) involves reactivating the relevant neural systems for interacting with it, such that the color system simulates the strawberry's red color, the gustatory system simulates its sweet taste, the motor system simulates appropriate eating behaviors, and motivational systems simulate pleasure and reward. In other words, conceptual knowledge about the strawberry results from re-experiencing it in the relevant neural systems used to actually experience real strawberries.

We further assume that simulation underlies the process of pattern completion inference. When something in the current situation reactivates a situated conceptualization stored in memory, the pattern completion inferences that result are expressed as simulations. When entering a familiar coffee house and expecting to drink coffee, read an article, and converse with friends, these pattern completion inferences are produced as simulated events. Anticipating the coffee, for example, produces relevant simulations of drinking, tasting, and reward. We further assume that these neural simulations often produce associated embodiments, such as anticipated feelings of arousal on consuming caffeine, and smiling on possibly seeing a friend.

A Grounded Theory of Stress Cognition

We assume that the situated processing architecture underlying cognition in general also underlies stress as a special case. When a stressful situation is encountered (or imagined), the basic situational architecture just described processes the situation. The neural systems in this architecture perceive and conceptualize the setting, objects, agents, self, actions, and mental states in parallel streams, producing situated conceptualizations that contain both local and global conceptual interpretations. Imagine, for example, meeting a close friend at a coffee house, who begins telling you that he is dying from cancer. During the conversation, situated conceptualizations are stored that capture your experience, including perceptions of the physical setting, perceptions of your friend telling you his news, the threat he feels about losing his life, the threat that you feel at the prospect of losing him, the ineffectiveness that you experience from not knowing what to do, and the powerful bodily states generated by cognitive upheaval, negative thoughts, and intense emotions.

Now imagine that you return to the same coffee house later in the week by yourself. Perceiving the setting activates earlier situated conceptualizations established when you learned of your friend's illness. As a result, pattern completion inferences become active that reinstate the feelings of threat, ineffectiveness, and shock that you experienced earlier, along with the accompanying emotion and bodily states. Over the next hour, you replay in your mind the original conversation and its ramifications, ruminating about it until you leave.

Similarly, imagine losing your mother to cancer when you were a child, such that many situated conceptualizations associated with your loss become established in memory. When experiencing social exclusion in later years (e.g., not being included when some friends attend the theater), the loss of social connection activates these earlier situated conceptualizations, producing similar cognitive, affective, and bodily states as pattern completion inferences (e.g., Beck, 1967, 2008). Even though stressful feelings associated with losing your mother are hardly appropriate for being excluded from a theater excursion, they nevertheless could become active.

When various kinds of stressful events are experienced repeatedly, they may become entrenched in memory as a category (e.g., difficult interactions with a neighbor, frequent car problems, chronic back pain). From experiencing each type of situation repeatedly, a category of situated conceptualizations becomes established. On later occasions, similar stressful situations are categorized into the best fitting category of stress experiences. In each case, situated conceptualizations in the category become active that anticipate and shape the stressful experience to follow.

Finally, just experiencing negative thoughts and moods may be enough to activate entrenched stress categories (e.g., Beck, 1967, 2008; Slavich & Cole, 2013). Because the situated conceptualizations in these categories are highly available in memory, they may become active and engage biological stress responses with minimal environmental cuing.

Stress cognition results from general cognitive mechanisms. From this theoretical perspective, stress cognition utilizes the same basic systems that underlie cognition in general, rather than resulting from stress-specific systems (Sanislow et al., 2010). Chronic and extreme stress may be associated with dysfunctional behavior of these systems, but the same basic systems responsible for cognition in general also underlie stress cognition more specifically.

When a stressor occurs or is imagined, the same situational architecture that processes many kinds of objects and events becomes active to produce stress responses, and to perceive and conceptualize the stress experienced. As a result, memories of stressful situations become established that are similar in their situated structure to memories for non-stressful situations (e.g., eating, tool use, social interaction). Furthermore, situated conceptualizations from stressful experiences become organized into categories, just like experiences of objects and events, more generally.

When activated by a current situation, situated memories of stressful experiences produce the same basic kind of pattern completion inferences that occur for many other diverse categories. Similar to how activating situated conceptualizations of previously eating strawberries produces anticipatory eating simulations, activating situated conceptualizations of previous stress experiences produces anticipatory stress responses.

Characterizing the general category of stressful experiences and its associated features. Recent research suggests that the perception of stress is related to well-being (e.g., Keller et al., 2012). The more frequently people perceive stress in their lives (together with the belief that stress is related to well-being), the more their physical and mental health suffer. Whether or not people categorize events as stressful thus has important implications for health. The Grounded Theory of Stress Cognition offers an account of how people perform these categorizations, with the potential to inform interventions for changing them.[1]

Although stress cognition may share much with general cognition, certain features distinguish stress cognition from other kinds of experiences. We suggest that stress cognition is associated with a unique combination of features that underlies an individual's general category of stressful experiences, much like other unique combinations of features underlie categories for animals, tools, foods, emotions, and so forth (e.g., Murphy, 2002; Lebois et al., submitted). From the grounded perspective, the unique features that distinguish stressful experiences from other categories reflect the local and global conceptualizations that become active to process stressful situations, and that later represent them in situated conceptualizations.[2]

We adopted two heuristics for generating hypotheses about what the features associated with stressful situations might be. First, we examined the diverse literatures on stress, using the established wisdom in them to develop hypotheses about the likely features of these situations. Second, from the perspective of grounded cognition, we examined the stressful situations that people experience, as catalogued in life events inventories (e.g., Adrian, & Hammen, 1993; Almeida, 2005; Almeida, Wethington, & Kessler, 2002; Brown & Harris, 1978; Slavich & Epel, 2010). As we examined these situations, we asked ourselves what local and global features are likely to be established in situated conceptualizations for them, and to later be simulated as pattern completion inferences during stressful rumination. Finally, we combined the results of these heuristics to establish an integrated account of the cognitive processing associated with stressful situations.

Figure 1 presents our account. As can be seen, we propose that a situation is perceived as stressful when three core conditions are satisfied: (1) a discrepancy exists between an expectation and an actual or simulated event (e.g., Higgins, 1989), (2) a threat to self is experienced (e.g., Lazarus, 1993), and (3) a perceived lack of efficacy exists for acting effectively to remove the discrepancy and the associated threat, which could reflect control, power, self-efficacy, available coping strategies, etc. (e.g., Bandura, 1997; Lazarus, 1993; Scherer, 2001). These three local conceptualizations of a situation are necessary for perceiving an experience as stressful, along with the global conceptual structure that integrates them. Together these local and global conceptualizations are typically sufficient for producing stress. Importantly, we do not assume that these core features are abstract symbolic descriptions, but that they are grounded in important ways. Thus, threat might be experienced as simulated harm to the body or as simulated social exclusion; similarly, inefficacy might be experienced as the inability to produce effective bodily or social action.

As Figure 1 further illustrates, once the three core conditions for a perceiving a situation as stressful occur, they have consequences for negative emotion and peripheral physiology. The realization that one cannot act to remove a threat increases negative emotion (Lazarus, 1993), and produces activity in peripheral physiological systems (Kemeny, 2003; McEwen & Sapolsky, 1995; McEwen & Wingfield, 2010). From the perspective of grounded cognition, emotion and peripheral physiology are central aspects of situated activity, in general, that become stored in situated conceptualizations (Barrett, 2005, 2013; Lebois et al., submitted; Wilson-Mendenhall et al., 2011). Specifically for stress, negative emotion may take the form of anxiety, displeasure, fear, anger, sadness, disgust, and so forth, whereas peripheral physiology may reflect activity in the cardiovascular, respiratory, autonomic, endocrine, and immune systems. Additionally, negative emotion and peripheral physiology may interact with discrepancy, threat, and inefficacy, contributing to the experience of these core factors, and motivating secondary stress responses, as described next.[3]

As Figure 1 illustrates, secondary stress responses may result from attempting to manage the core causes of stress, along with the immediate affective and bodily responses that follow. Because these secondary responses play central roles in experiencing and coping with stressful situations, they constitute important aspects of the situated conceptualizations that become established during them. Perhaps most importantly, extensive rumination and worry about the stressful situation may persist, as long as the threat, inefficacy, and associated bodily alarm remain (Nolen-Hoeksema, 1991; Nolen-Hoeksema, Morrow, & Fredrickson, 1993; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Watkins, 2008). We assume that this type of perseverative thought typically results from experiencing the stressful event, together with the inability to cope with it effectively. Again, rumination and worry may produce strong emotional and bodily responses (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Watkins, 2008). To the extent that coping responses occur, they too may become established as features of the resulting situated conceptualizations, along with their consequences (e.g., Lazarus, 1993; 1999). Finally, a wide variety of metacognitions about one's stress responses, regulatory activities, and coping abilities may also become features of situated conceptualizations (e.g., Beer & Moneta, 2010; Dragan et al., 2012; Wells, 2008).

In summary, Figure 1 integrates features of stressful situations abstracted from the stress literature that are compatible with viewing these situations from the perspective of grounded cognition. Statistically speaking, we assume that an individual's general category of stressful situations typically include the features of stress included in Figure 1, integrated with the global structure illustrated there. Certainly, variations on this structure may occur, with some features absent in some stressful situations, and with additional features included in others. Nevertheless, our central hypothesis is that Figure 1 captures the statistical regularities typically associated with what people perceive as stressful situations. From the perspective of grounded cognition, we predict that the situated conceptualizations established during stressful situations tend to include these regularities.

Study Overview

If Figure 1 represents the situated structure of the experiences that an individual has previously categorized as stressful, then this structure should determine people's categorizations of whether future situations are stressful or not. To the extent that a future situation matches this structure, the situation should be categorized as stressful; to the extent that the situation does not match, it should categorized as not stressful. How people identify stressful situations should reflect the situated structure in Figure 1.

To test this hypothesis, we presented participants with 572 brief descriptions of stressful and non-stressful events that could occur in their daily lives (e.g., "Your professor just accused you of cheating on an exam"). We then asked them to judge the perceived stressfulness of each event, without specifying what we meant as stress, leaving it open ended. If the situated structure of stress in Figure 1 provides a tenable account of the experiences that an individual has categorized as stressful, then memories of stressful events, stored as situated conceptualizations, should contain the features embedded in this structure. Moreover, prototypical memories of stress should tend to have high values for these features, whereas atypical memories should tend to have low values (Barsalou, 1985; Wilson-Mendenhall, Barrett, & Barsalou, 2014). As a result, participants should judge events with high values as stressful, and events with low values as non-stressful.

To the extent that a specific feature in Figure 1 is associated with past stressful events, it should predict the perceived stressfulness of judged events. We therefore asked participants to evaluate how much each event contained a discrepancy, a threat, action inefficacy, negative affect, arousal, and perseverative thought like rumination and worry. If these features are typically present in stressful memories, then their presence should predict stress, whereas their absence should predict lack of stress. Furthermore, these features are likely to be highly correlated, together constituting a unitary construct of stress. When people decide that an event is stressful, all these features should tend to be present as a group; analogously, when an event is not stressful, these features should tend to be absent as a group.

Four additional factors noted in various literatures could also potentially influence the perceived stressfulness of an event: familiarity, imagery, realism, and certainty. First, familiarity and past experience with a stressor could be associated either positively or negatively with its perceived stressfulness (Bandura, 1997). On the one hand, the more often people fail to effectively manage a stressor, the more stressful it may seem. On the other hand, increased familiarity with a stressor may enhance one's belief that it can be handled effectively, making it seem less stressful. Second, imagery could be related to perceived stressfulness (D'Argembeau, & Van der Linden, 2006). As visual, auditory, motor, and bodily imagery increases when imagining a stressor, the stress experienced could increase as well. Third, the plausibility and subjective realism of a stressor could be related to its perceived stressfulness (e.g., Papies, Barsalou, & Custers, 2012). As an imagined stressor becomes increasingly realistic, perceptions of threat and inefficacy may seem increasingly compelling. Fourth, uncertainty could potentially be associated with stressfulness. As people become more uncertain about what is happening in a stressful event, what they can do to cope with it, or what the eventual outcome will be, perceived stress may increase. In the study to follow, we hypothesized that these four factors would be relatively peripheral to those in Figure 1, playing a minor role in predicting perceived stressfulness.

Finally we hypothesized that individual differences in judgments of perceived stress would occur. Because participants have different experience with stressors, they establish different populations of situated conceptualizations for their respective categories of stressful situations in memory. In the study here, these different categories of stressful memories may produce differences in judging the perceived stressfulness of events. Specifically, participants' overall levels of stress may differ, as may the range of stressfulness they perceive and the events they find stressful.

Methods

Participants

Because our aim was to perform idiographic analysis on a small number of individuals, we examined detailed judgments for a small sample across a large set of life events. Thus, participants were 12 Emory University students (6 females), ranging in age from 23 to 38 ($M = 27.5$). The sample was predominately Caucasian (66.7%), with 25% Asian and 8.3% Hispanic. Participants were native English speakers with normal or corrected vision, and received $100 compensation.

Study Design

Each participant performed 20 ratings of 572 life events in a repeated-measures design with no grouping variables, for a total of 11,440 ratings. Participants received each life event a total of six times, once in each of six rating groups. For a given rating group, each participant received the 572 events in a different random order. However, the order of the six rating groups, and also the sequence of ratings within each group, followed a set order to prevent certain ratings from being affected by earlier ratings. Experience and Familiarity ratings, for example, were completed first to ensure that viewing the events previously for other ratings did not produce carry-over effects on these memory judgments. Other ratings were grouped and positioned sequentially for similar reasons. Additionally, the fixed order of ratings within each group made the task easier for participants, allowing them to settle into a response rhythm as they performed the ratings for group in a constant order across the 572 events. Table 1 presents the order of the six groups, together with the order of ratings within each.

Materials

Life events. We constructed 572 one-sentence descriptions of life events that our participant population could plausibly experience (286 stressful, 286 non-stressful). To make the stressful life events ecologically valid, two sampling strategies were used. First, stressful events were drawn from Almeida, Wethington and Kessler's (2002) nation-wide sample of stressful events database. Second, student research assistants helped develop a sample of stressful events relevant for the student population. The Supplementary Material (SM) provides a complete list of these events.

All stressful life events depicted interpersonal tensions relevant to college life (e.g., "Your professor just accused you of cheating on an exam"). For each stressful event, a matched non-stressful event was constructed that included similar characters and settings, but that focused on a non-threatening interpersonal interaction (e.g., "Your professor just passed out lecture notes in preparation for the next class"). Each sentence describing an event contained second person ("you") references to promote participant engagement. Including a broad range of stressful and non-stressful life events provided sufficient variability to establish whether the features in Figure 1 predict perceived stressfulness, across a broad range of events. All event sentences were analyzed using the Linguistic Inquiry and Word Count database to ensure that stressful and non-stressful scenarios were comparable on irrelevant variables, such as sentence length and tense.

Procedure

As Table 1 illustrates, participants performed the six groups of ratings in the following order: (1) experience and familiarity, (2) stress and plausibility of experience, (3) core stress features, (4) imagery, (5) valence and arousal, and (6) certainty. Before beginning each group, the experimenter first read participants detailed instructions about the ratings. During these instructions, participants were shown the ratings and associated rating scales, illustrated with an example life event. Participants then received one practice event, evaluating it on all the rating scales for the group. During the instruction period, participants had the opportunity to ask the experimenter questions.

Participants received additional instructions relevant to particular ratings. For the Experience group, participants could indicate they had experienced a particular life event even if their experience was not identical to the event described. For the Imagery group, participants were told that bodily imagery is anything going on in one’s body (e.g., sensing your heart beat, your face getting red), whereas verbal imagery is hearing people talking in the situation. For the valence and arousal group, participants were told: (1) valence is the degree of pleasant or unpleasantness in an event, (2) arousal is the degree to which one feels awake and reactive during an event, (3) a distinct difference exists between them (e.g., high arousal can be both pleasant or unpleasant; Wilson-Mendenhall, Barrett, & Barsalou, 2013).

Once participants understood the judgments that they were to make for a particular group, they received the 572 life events in a random order and evaluated them on the rating scales for that particular group in a fixed order. On each trial, a sentence describing an event appeared at the top of the computer screen, with the first rating question and scale directly below it. Participants had as much time as needed to read the sentence and make their rating. Once the participant entered their judgment for the first rating question, the next rating question appeared immediately, while the same event remained at the top of the screen. This process continued until the participant had answered all rating questions in the current group for the sentence. At this point, participants had two options: (1) If they felt they had made an error, they could press the SPACE bar, go back, and change their responses, or (2) if they were ready to perform the same ratings on the next event, they pressed the ENTER key and moved on. After judging life events for 15-20 min, participants had the option to continue with another 15-20 minute batch of ratings, to take a break, or to stop for the day.

Participants took a total of 10 to 19 sessions to complete the experiment, ranging over a period of 37 to 51 days. The time spent on the experiment for a given day ranged from 30 min to 120 min. A participant always completed a 15-20 min batch of ratings before stopping for the day. This procedure continued for every group of ratings until each participant completed all 20 ratings on each of the 572 scenarios (11,440 ratings total). Table 1 presents the mean and standard deviation for each of the 20 ratings.

Statistical Method

Treating life events as the unit of analysis, we used exploratory factor analysis to evaluate the number of distinct dimensions that underlay the participant-rated event features in Figure 1. A common factor analysis was run on the 19 relevant predictor variables, excluding stressfulness (which would serve as the dependent variable in subsequent regression models). Unweighted least squares factor extraction indicated that 4 factors underlay the 19 predictors (by visual inspection of a scree plot of the correlation matrix eigenvalues). The four factors were transformed by an oblique (correlated factors) promax rotation of 4 with Kaiser normalization to make them more interpretable. We then generated factor scores for the four factors using the standardized regression method, and treated these derived variables as predictors of the perceived stressfulness for each life event.

Finally, we used multilevel regression modeling (e.g., Snijders & Boskers, 2012) to address how the four derived factors predicted variation in perceived stress. These models estimated the proportion of variance that reflected between-event differences in perceived stress, while also evaluating fixed and random effects associated with the four factors (from the factor analysis) in perceived stress. For these models, life event was treated as the Level 1 unit of analysis, and the fixed effects estimated the average influence of each derived factors on perceived stress, aggregated over different event scenarios. Participant served as the Level 2 unit of analysis. We used maximum likelihood estimation with the SPSS Mixed procedure (version 20; see Heck, Thomas, & Tabata, 2014). The covariance structure for random effects was specified as orthogonal variance components. Significance tests on random effects for regression slopes and intercept were evaluated by likelihood-ratio χ^2 tests and also by the normal-deviate Wald test (ratio of the variance estimate to its estimated standard error).

Three nested models were used to generate the likelihood ratio tests for random effects (with the difference in -2LL fitting functions for the maximum likelihood estimation being asymptotically distributed as a χ^2 variate with *df* equal to the number of parameters added to the model). First, a model estimated only fixed effect regression coefficients for the derived factors and a random regression residual. Second, we added a random intercept to test for individual differences in average level of perceived stress. Third, we added random effects for the slope of the first factor to assess whether individual participants differed in the first factor's relationship to perceived stressfulness.

To calculate the percent of explained variance in perceived stressfulness, we compared the residual variance for a model that only had a fixed intercept specified (RES-I) to the reduction in residual variance for the three models adding fixed and random regression effects (RES-M). This generated a pseudo-R^2 statistic (Snijders & Boskers, 1998): (RES-I - RES-M)/ RES-I.

Results

As described earlier, our primary goal was to assess the features associated with people's categories of stressful experiences. Of interest was whether the features in our Grounded Theory of Stress Cognition (Figure 1) predict the perceived stressfulness of imagined events, and the extent to which these features are functionally overlapping and interdependent. We begin with results from a simple correlation analysis that assesses whether individual features in our theory predict perceived stressfulness.

Correlation Analysis

We hypothesized that the features of the situated structure in Figure 1—expectation violation, self-threat, lack of efficacy, emotion, perseveration, bodily states, and coping certainty—would be related to perceived stress. As the correlations in Table 1 illustrate, almost all of these features predicted stress significantly (see SM Table 1, for the full correlation matrix).

Negative valence, perseveration, and self-threat had the highest correlations with perceived stressfulness, and were highly inter-correlated with each other. The more threatening an event was to social self-preservation, the more negative and stressful it became, and the more it was associated with perseveration (Dickerson, Gruenewald, & Kemeny, 2004; Watkins, 2008). It does not follow that negative valence and stress are exactly the same, nor that stress is always negatively valenced. In our dataset, all the stressful life events were written to be unpleasant, such that this design feature produced a correlation between negative valence and stress.

Greater lack of efficacy in managing a situation and greater violation of expectations were both associated with greater perceived stress. Consistent with existing literature, when participants believed that they lacked the ability to effectively manage an interaction described in an event, they imagined greater stress (Bandura, 1997; Cooper & Dewe, 2004; Lazarus, 1993). The relationship between expectation violation may be central to stress, reflecting general upheaval in one's plans, goals, and aspirations for the future (Brown & Harris, 1978, 1989). Additionally, when an event violated expectations, participants reported less experience with the event and less belief in their capacity to cope effectively with it (see SM Table 1). In contrast, the more certainty participants had about the circumstances, coping, and eventual outcome of the situation, the less stress they reported experiencing. Perhaps greater certainty about these factors suggests, more generally, that a coping solution can be reached in the imagined situation.

Higher arousal and bodily imagery were associated with more stress. Greater arousal is a documented response to stressful situations, often related to activation of the hypothalamic-pituitary-adrenal axis (Ganzel, Morris, & Wethington, 2010). Among the imagery-related predictors in our dataset, bodily imagery had a much higher correlation with perceived stressfulness than the other imagery variables (visual, action, verbal). Bodily imagery may be especially important because greater bodily activity may often be associated with stressful experiences, whereas other types of experience may vary more widely across them, sometimes not being present.

Greater experience and familiarity with an event were both associated with less stress, perhaps because participants had dealt successfully with similar situations themselves. Indeed, experience and familiarity were positively correlated with certainty about one's ability to cope with the situation (SM Table 1). Additionally, as situations became more plausible, they also became less stressful, perhaps because plausibility was also positively related to experience, coping, and efficacy (SM Table 1).

Greater positive valence was related to lower stress levels. Interestingly, the negative correlation between positive valence and stress was much smaller than the positive correlation between negative valence and stress. This most likely reflects the fact that our stressful scenarios were written to be unpleasant and stressful, further reflecting the possibility that positive situations can also be stressful (e.g., planning a wedding). Additionally, as much work shows, positive and negative valence are often not perfect inverses of one another, with it being possible that an event can have both positive and negative valence (e.g., Condon, Wilson-Mendenhall, & Barrett, 2014; Wilson-Mendenhall, Barrett, & Barsalou, 2013). Although we designed our stressful events to have negative valence, some of them may have inadvertently had positive features. Another possibility is that range restriction drove the difference in predictability for positive and negative affect (*SD*s of 1.28 and 2.08, respectively). Still another possibility is that positive emotion is not generally predictive of stress, whereas negative emotion is.

Not all features tested were highly, or even moderately, correlated with the perceived stressfulness of the life events. Vicarious familiarity, being there, visual imagery, and action imagery were very weakly and negatively correlated with stress, and verbal imagery was not correlated with stress at all. Vicarious familiarity and stress were related in the expected direction: the more vicarious familiarity, the less stress. The correlation was almost negligible, however, which implies that personal experience and familiarity may be much more important than vicarious familiarity. The small negative and non-significant correlations for being there and for visual, action, and verbal imagery most likely reflect the brevity of our stimuli. Because each life event description only contained as much detail as could fit in a single sentence, the event descriptions may not have contained enough detail to produce relations between these variables and perceived stressfulness. Perhaps longer more detailed event descriptions would produce significant relations. A median split on stressfulness ratings indicated the correlation between being there and the most stressful 50% of scenarios was in the expected positive direction ($r = .22$, $p < .001$). The more participants experienced "being there" in the situation, the more stressful they found it. This suggests that "being there" may only play a role in experiencing stress when strong affect is present.

With the exception of some imagery variables and vicarious familiarity, all the hypothesized variables, expectation violation, self-threat, lack of efficacy, emotion, perseveration, bodily states, and coping certainty, were related to stressful cognition in the expected directions. This pattern provides initial support for our theory of stress cognition, demonstrating that the central features of stress in Figure 1 were associated with perceived stressfulness.

Data Reduction through Factor Analysis

The four-factor solution explained almost 60% of the variance in the factor structure of the data. Table 2 presents the factor loadings and communalities. The four factors were well defined and easily interpreted. Factor 1, labeled Core Features, was the largest factor, accounting for 40% of the item variance. Judgments of the key features in Figure 1, including threat, perseveration, negative valence, efficacy, bodily imagery, expectation violation, positive valence, and arousal, all loaded on this factor. Factor 2 (Experience) appeared to capture participants' prior and present experience with the life events, including judgments of familiarity, experience, plausibility, vicarious familiarity, and being there, and accounting for 11% of the total item variance. Factor 3 (Certainty) was defined by loadings of the three certainty judgments for situation, coping, and outcome, accounting for 5% of the total item variance. Factor 4 (Imagery) was defined by loadings for rated imagery of action, vision, and verbalization.

A potential methodological concern was that we had participants rate groups of features together (to minimize carry-over effects across ratings), which could have caused features in these groups to be correlated. The factor analysis indicates that this source of possible method variance was not a significant problem for three reasons. First, features rated in the same group often loaded on different factors. In Group 4, for example, bodily imagery primarily loaded on Core Features, whereas the other imagery factors loaded on Imagery. Second, features in different groups sometimes loaded on the same factor. Features from Groups 3, 4, and 5 loaded on Core Features. Features from Groups 1 and 2 loaded on Experience. Features from Groups 2 and 4 loaded on Imagery. Third, the overall loadings that resulted generally followed our predictions, first, that the core features of stress would load together, and second, that other groups of more peripheral features for familiarity, imagery, realism, and certainty would load on separate, less important factors.

Predicting Perceived Stressfulness with Multilevel Regression Models

Our primary goal was to establish the features that most strongly predict the perceived stressfulness of life events. If the Grounded Theory of Stress Cognition is tenable, then the core features defined a priori as relevant for distinguishing stressful experiences should be strong predictors of each life event's perceived stressfulness. Thus, we hypothesized that the Core Features factor should strongly predict the perceived stressfulness of events, with the other three factors being less important.

Table 3 summarizes the results for the models used to evaluate fixed and random regression effects. The initial intercept-only model did not fit the data well. It did indicate an intraclass correlation of $r = .06$, $p > .10$, showing that a substantial proportion of the total variance in rated stressfulness was due to within-participant variation in perceived stress across different event scenarios. This outcome justified evaluating the ability of between-event differences in the four factor score variables to predict perceived stressfulness.

Model 1. In Model 1, the fixed effects of Core Features, Certainty, and Imagery significantly predicted perceived stress, whereas Experience did not. Because all factor scores were standardized by the factor score estimation method, they were effectively scaled in the same units of measurement. As Table 3 illustrates, Core Features had a much higher fixed effect on perceived stress than did Certainty and Imagery, consistent with our hypothesis. Because the Certainty and Imagery coefficients were very small, they may not represent reliable relationships with stress in this model (as confirmed by subsequent analyses). Overall, the pseudo-R^2 statistic indicated that this model explained 75% of the variance in perceived stress.

Model 2. In Model 2, all four fixed effects were again included, along with the random effect of the regression intercept. This random effect can be conceptualized as participants varying in their average levels of perceived stressfulness across the 572 life events, with some individuals having higher average levels than others. This random effect was significant, LR $\chi 2 = 1906.35$, $df = 1$, $p < .01$, indicating that participants differed in the overall levels of stressfulness that they perceived in the events (estimated variance = .28, $SE = .12$, Wald Z = 2.45, $p = .015$).

Including this random effect of individual stressfulness in Model 2 altered the pattern of fixed effects observed in Model 1, with Experience now becoming a significant predictor, and with Certainty dropping below significance. Consistent with Model 1, Core Features still had the largest regression coefficient, whereas Experience and Imagery played much smaller roles. Adding the random effect of stress intercepts for participants increased the estimated R^2 from 75% to 81%.

Model 3. Finally, Model 3 included the parameters from Model 2, while adding a random effect for the slope of the Core Features factor. This random effect can be conceptualized as allowing participants to vary in the effect of Core Features on perceived stress (i.e., for some participants, the relationship of Core Features to perceived stressfulness could be high, whereas for other participants the relationship could be low). Adding the random effect for slopes improved fit, rejecting the null hypothesis of fixed slopes across individuals, LR $\chi^2 = 36.95$, $df = 2$, $p < .01$. Both Wald tests of random variance components were significant for Model 3; specifically, the random effect of stress intercepts (Estimated Variance = .29, *SE* = .12, Wald Z = 2.44, $p = .015$), and the random effect of Core Features slope (Estimated Variance = .13, *SE* = .06, Wald Z = 2.42, $p = .015$). SM Figure 1 illustrates these individual differences for intercepts and slopes across participants.

Including these two random effects in Model 3 again changed the pattern of fixed effects that explained perceived stressfulness. In this modeling context, only Core Features explained significant variance, while all other fixed effects failed to achieve statistical significance. Hypothetically, this outcome can be seen as reflecting the misspecification in Models 1 and 2 of failing to estimate individual differences in Core Feature slopes. Absent the random effect in slopes, Models 1 and 2 may have absorbed variance associated with Core Feature slopes into other fixed effects. According to Model 3, the features loading on Core Features (expectation violation, perceived self-threat, efficacy, valence, arousal, bodily imagery, and perseveration) captured all the explainable variance in stressfulness ratings. Adding the second random effect of Core Features slopes for participants significantly increased the explained variance from 81% to 84%.

Further analysis of the Core Features factor. Can the features that load on the

Core Features factor be differentiated further, and might this influence how subsets of core features relate to perceived stressfulness? Perhaps only a few of these features are important, with the others being much less important or not important at all. To test this hypothesis, a common factor analysis on the eight core features was performed, analogous to the factor analysis earlier. An arousal factor emerged that differed from a factor for the remaining seven core features (bodily imagery, positive valence, efficacy, expectation violation, perseveration, threat, negative valence); with these two factors being highly correlated (r = .78).

Next these two factors were used to predict stressfulness in a multilevel regression model. Importantly, both factors significantly explained unique variance, even when random effects for intercept and slope were entered as in Model 3. Based on these analyses, we conclude that all features loading on the original Core Features factor are important for explaining perceived stressfulness, and again that they are highly related to one another, approaching a unitary construct. These analyses further confirm our prediction that a core set of features underlies how people conceptualize stress.

Further analysis of individual differences. As just described, perceived stressfulness varied significantly across individuals. Besides varying in the overall levels of stress that they perceived (random intercepts), and individuals also varied in how strongly their values on the Core Features factor predicted perceived stressfulness. The low intraclass correlation mentioned earlier between participants' stress ratings further confirms substantial individual differences.

In a final analysis, we explored individual differences in the stress intercepts and slopes for the Core Features factor. As the X axis in SM Figure 2 illustrates, individuals varied widely in the standard deviations of their stressfulness judgments (from about 1.4 to 2.4). In other words, participants varied in the granularity of their stressfulness ratings, with some participants drawing finer distinctions than others. As the left panel of SM Figure 2 illustrates further, this granularity was positively related with individual intercepts for stressfulness ($r = .76$, $p = .005$). As participants' overall average or baseline for stressfulness ratings increased (i.e., higher intercepts), the granularity of their stress judgments became finer. One possible interpretation is that higher levels of perceived stressfulness lead to greater differentiation (and therefore variability) in perceiving degrees of stress.

Finally, as the right panel of SM Figure 2 illustrates, the granularity of stress judgments was also positively related to individual slopes for the Core Features factor ($r = .67$, $p = .017$). As Core Features explained more variance in perceived stress (steeper slopes), the granularity of stress judgments again became finer. A possible interpretation of this result is that greater variability in stress judgments enables greater prediction through greater range. Alternatively, greater use of the features that loaded on Core Features produced greater variability in judgments of perceived stressfulness.

Discussion

According to the Grounded Theory of Stress Cognition, people construct situated conceptualizations of the stressful situations that they encounter. As a stressful situation is processed, the brain's situation processing architecture establishes perceptual experiences and conceptual interpretations for basic aspects of the situation, including the setting, object, agents, self-relevance, actions, events, bodily states, mental events, emotions, and so forth. Not only does this situational architecture perceive and conceptualize situations, it actively supports goal pursuit by producing inferences, actions, bodily states, emotions, and other enactments. Various relational structures further integrate these "local" situational components "globally," coordinating them coherently and effectively.

As similar stressful experiences are encountered, they become integrated to form categories for specific types of stressful experiences. Because different individuals have different stressful experiences, they develop different categories. When later encountering people, objects, settings, and events associated with these categories, associated situated conceptualizations in them become active. As pattern completion inferences result, the current situation is construed similarly to previous situations, with similar stress and coping responses following. Because these inferences are implemented as simulations, previous stressful situations are partially reenacted, not only cognitively, but also perceptually and bodily.

The Grounded Theory of Stress Cognition further proposes that specific features of stressful situations underlie people's general category of stressful experiences, namely, the features in Figure 1. To test this account, we asked people to evaluate the perceived stressful of situations that they would be likely to experience, along with how much these hypothesized features of stressful experiences would be present. If the situated structure of stress in Figure 1 provides a tenable account of the experiences that an individual has previously categorized as stressful, then memories of stressful events, stored as situated conceptualizations, should contain the features embedded in this structure. As a result, participants should judge events having these features as stressful, and events not having them as non-stressful. Furthermore, if individuals vary in the situated conceptualizations that underlie their different categories of stressful experiences, individual differences in perceived stressfulness should occur.

The results from the study reported here support the Grounded Theory of Stress Cognition. All the critical features that we hypothesized as central to categorizing situations as stressful were highly correlated with perceived stressfulness (threat, perseveration, negative valence, efficacy, bodily imagery, expectation violation, positive valence, and arousal; see Table 1). Furthermore, all these features loaded highly on a "Core Features" factor that appeared to capture a relatively unitary construct of what constitutes a stressful experience (Table 2). Perhaps most importantly, these features—and only these features—explained 85% of the variance in perceived stressfulness, when random effects for the slope of the underlying factor and for the intercept of perceived stressful were taken into account (Table 3). Finally, these random effects demonstrate significant differences between individuals in their overall levels of perceived stressfulness, and in how well the Core Features factor predicts their perceived stressfulness (SM Figures 1 and 2).

Other features loaded on three additional factors for experience, certainty, and imagery. Interestingly, these features tended to be less correlated with perceived stressfulness than were the features loading on the Core Features factor. Furthermore, these factors no longer explained any unique variance in perceived stressfulness once all the fixed and random effects associated with the Core Features factor were included.

These results support our hypothesis that the features in Figure 1 underlie the situated conceptualizations that people establish in memory to represent their respective categories of stressful experiences. When a person's current experience tends to match the situated conceptualizations in their stress category, they perceive the experience as stressful. Because different individuals populate this category with different situated conceptualizations, their perceptions of stress differ.

Why is the Perception of Stress Important?

Accumulating findings indicate that the perception of stress plays central roles in people's well-being (e.g., Keller et al., 2012). To the extent that people perceive a lot of stress in their life and believe that it affects their well-being, their health declines, both physically and mentally. Our theory and supporting results offer insight into this important finding. Most basically, our theory suggests that individuals should vary in their perceptions of stress, given that they use different categories of stressful experiences to categorize life events as stressful. Furthermore, the construct of simulation in our theory has the potential to explain how the perception of stress can contribute to health decline. Once an event is categorized as stressful, a situated conceptualization associated with stress begins running in the brain and body, simulating a past stressful experience that is projected onto the current situation. Because this stressful simulation may include both negative emotion and taxing physiological responses, wear and tear on the brain and body can result. To the extent that the chronic perception of stress continues, wear and tear may accumulate, producing various declines in health and well-being (e.g., McEwen & Wingfield, 2010).

Of potential interest is the relation of the features in Figure 1 to the perception of everyday life stress. If, as in Keller et al. (2012), we assessed perceptions and beliefs about everyday stress, would they be predicted by the core features in our account, and by the individual differences measures we observed? To the extent that our account explains the perception of everyday stress, it may help motivate interventions for reducing stress. Simply informing individuals that they regularly categorize events as stressful or not, and that these categorizations have consequences for health, could lower the rate at which they categorize their life events as stressful. Further teaching individuals about the pattern completion inferences and embodied simulations that follow from stress categorization could similarly reduce perceived stress. Finally, teaching individuals about the features underlying stress categorization could provide them with even greater control over how they appraise events. Focusing, for example, on the features of threat and efficacy could orient people towards reducing threat attributions and strengthening efficacy attributions, thereby shifting categorizations of life events more towards challenges and away from threats (e.g., Blascovich & Mendes, 2000).

Stress Cognition Originates in General Cognitive Mechanisms

Earlier we proposed that the general cognitive mechanisms of situated conceptualization, pattern completion inference, and simulation play central roles in producing stress. As many stress theorists have suggested, stress is a natural response to difficult life events (Almeida, 2005; McEwen, 2007; McEwen, & Sapolsky, 1995; Monroe, 2008; Monroe & Slavich, 2007). To the extent that stress is a natural response, it is not surprising that general cognitive mechanisms play central roles in implementing it.

As we also proposed earlier, however, perceived stressfulness, as a category, is associated with unique features, analogous to how other categories are analogously associated with unique features (e.g., animals, artifacts, foods, emotions). Our findings here confirm that these features are indeed strongly associated with perceived stressfulness, explaining 85% of its variance. We suspect, however, that these features are not *individually* unique for perceived stressfulness, but are relevant to many other categories as well. Similar to how the features of emotion occur across many other categories (Lebois et al. submitted; Wilson-Mendenhall et al. 2011), so may the features of stressful experiences occur for many other categories. We simply assume that these features tend to be relatively unique *as a set* for stressful experiences, relative to non-stressful experiences.

Finally, we assume that as the perception of stress becomes increasingly dysfunctional in some manner, the mechanisms underlying stress perception operate increasingly abnormally in some way (Sanislow et al., 2010). We suspect that diverse abnormalities can occur during situated conceptualization, pattern completion inference, and simulation, causing stress perception to become dysfunctional in myriad ways. During situated conceptualization, for example, undue emphasis on high threat and low efficacy could increase neuroticism, rumination, and anxiety; thereby increasing the attribution that one is experiencing much stress (Bandura, 1989; Blascovich & Mendes, 2000; Higgins, 1989; Mathews et al., 1999; Watkins, 2008). Similarly, when pattern completions generalize too broadly beyond the situations that produced the original situated conceptualizations, stress may be produced too broadly across unlikely situations (e.g., the dysfunctional generalization that characterizes PTSD; Layton, & Krikorian, 2002; Oyarzún, & Packard, 2012; Qin, Hermans, van Marle, & Fernández, 2012). Finally, when anticipated negative outcomes are simulated intensely and repetitively, the resulting rumination can produce much more stress then warranted, leading to depression and a host of other problems (Brosschot, Gerin, & Thayer, 2006; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Watkins, 2008).

In general, the method that we have developed here for assessing a person's category of stressful experiences could potentially be extended to studying dysfunctional forms of stress, as well as to developing interventions for treating them. By measuring individuals on core stress features, we could potentially characterize how various populations experience various types of dysfunctional stress. This approach could also be used to assess whether treatments are working, and to tailor treatments to individuals as function of how they conceptualize stress in terms of specific core features at different points in time.

Relations Between Stress Cognition, Neural Activity, and Peripheral Physiology

Another direction for future work is to explore relations between core features of perceived stressfulness and other dimensions of stress responses. As the core cognitive features of stress vary, what corresponding dimensions of neural and peripheral physiology become active? Because we found that the core stress features all loaded on a common factor, this question can be framed as examining the neural and peripheral activity that correlates with an event's loading on this factor.

Individual differences in stress intercepts and core feature slopes could also be correlated with neural and peripheral activity. As people perceive higher levels of stress, how might these measures be reflected in neural activity and peripheral physiology? As core feature slopes vary, how do neural and peripheral activity covary? By examining such issues, it may become possible to develop an increasingly integrated account of stress cognition, its neural bases, and its bodily manifestations.

Further Exploring Individual Differences in Cognition

To establish initial evidence for our theory, we focused on detailed idiographic analysis in a small sample of relatively homogenous individuals. In a larger and more diverse sample, our method for measuring core features could be used in a variety of ways to better understand individual differences in perceived stressfulness. One measure of an individual's perceived stressfulness, for example, could be an individual's overall level on the Core Features factor that we identified, as obtained from having different individuals evaluate the core features across a common set of events. Similarly, stress intercepts and core features slopes could also potentially be used as measures of perceived stressfulness, either individually or combined with the other measures.

Perhaps most basically, these individual measures of perceived stressfulness could then be correlated with various personality measures to assess differences in how people having different personality types perceive stress. Analogously, variability in perceived stressfulness could be examined in individuals who live and work in different environments, who have different developmental histories, who have different cultural backgrounds, who are embedded in different social networks, who have different psychopathologies, and who receive different therapeutic treatments. Finally, perceived stressfulness could be examined in groups having different genetic profiles, exploring relations between various genes and core features of stress cognition (e.g., Conway et al., 2011, 2014).

Although the core features of stress loaded on a single factor in the study reported here, it is important to examine whether they remain integrated or disassemble as individual differences are examined more closely. In certain individuals and sub-groups of individuals, these core features may pattern differently than observed here, reflecting how different groups adapt the perception of stress to the stressful life events that they encounter, utilizing the resources available for managing them.

Conclusion

The Grounded Theory of Stress Cognition developed here offers an explanatory framework for understanding how people perceive stress. Besides providing general cognitive mechanisms for understanding stress perception, this account provides a natural means of understanding individual differences in perceived stressfulness, as well as dysfunctional forms of it. Furthermore, this account naturally affords being integrated with other dimensions of stress responses, including neural activity, peripheral physiology, and genetics. Finally, this account has the potential for stimulating new research that will move the understanding and management of stress cognition forward.

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Author Contributions. LAML and LWB developed the study concept and design. LAML played the primary role in implementing, running, and analyzing the experiment in the Barsalou Lab at Emory University. CH played a leading role in developing and implementing the analyses. LWB played central roles in implementing the experiment, analyzing the results, and managing the project. GMS played a leading role in relating the research to the stress literature. All authors contributed to interpreting the results. LAML, LWB, GMS, and CH drafted the manuscript, and all authors contributed to revising it. The project grew out of a related neuroimaging project developed by LAML, Esther K. Papies, LWB, and LFB. LWB and LFB are joint senior authors. All authors approved the final version for submission.

Acknowledgments. We are grateful to David Almeida for sharing his stressor database, Taryn Colton, Hailey Friedman, and Bridget Warren for assistance with sampling the stressful life events, and to Christine D. Wilson-Mendenhall for assistance with the valence and arousal instructions.

Declaration of Conflicting Interests. The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Funding. Work on this article was supported by an NIH NRSA award to Lauren McDonough Lebois at Emory University, and by an NIH Director's Pioneer Award DPI OD003312 to Lisa Feldman Barrett at Northeastern University, with a sub-contract to Lawrence Barsalou at Emory University.

Footnotes

[1] We focus here on the category of stressful events that are experienced as negative and undesirable, given their significant implications for health and well-being (e.g., Keller et al., 2012). As stress researchers occasionally note, however, individuals sometimes experience stress as positive and desirable. Much of what we say can be readily extended to positive stress experiences.

[2] To this point, we have used “stressor” when referring to a situational event that produces a stress response. From hereon, however, we use “stressful situation” instead of “stressor,” because “stressful situation” refers more broadly to the range of relevant situational features in Figure 1 relevant for our theory and for the experiment to follow.

[3] In Lebois et al. (submitted) and Wilson-Mendenhall et al. (2011), we argue that global conceptual structure across a situation underlies an emotion. We further argue that complex emotions, such as exhilarating fear, result from integrating global structure for multiple emotions (Wilson-Mendenhall et al., 2014). Here we similarly assume that stress typically combines emotion with other local and global structure to produce a complex global interpretation of a situation.

Table 1. Rating questions and correlations with perceived stressfulness

Questions	M (SD)	Pearson *r*
Group 1. Experience		
Experience (Exp)		
Have you ever experienced this or a similar situation yourself? (-1 to 1 scale: -1 = no, 0 = uncertain, 1 = yes)	.12 (0.95)	-.49*
Familiarity (Fm)		
How familiar are you with this scenario based on having experienced it? (1-7 scale: 1 = no, 4 = average, 7 = high)	3.19 (2.20)	-.43*
Vicarious Familiarity (VFm)		
How familiar are you with this scenario based on vicarious experience (present when someone else experienced it, read about it, seen it on TV, heard someone else talk about it etc.)? (1-7 scale: 1 = no, 4 = average, 7 = high)	3.83 (1.91)	-.09*
Group 2. Stress and Plausibility of Experience		
Stressfulness (Str)		
If you were actually in this scenario, how much stress would you experience? (1-7 scale: 1 = low, 4 = medium, 7 = high)	3.07 (2.07)	---
Being There (BT)		
From reading the description above, how much can you imagine actually “being there” in the scenario and vividly experiencing what’s taking place? (1-7 scale: 1 = none at all, 4 = moderate, 7 = high)	4.66 (1.35)	-.06*
Plausibility (Pl)		
How likely do you think it would be that you would find yourself in this situation? (1-7 scale: 1 = none at all, 4 = moderate, 7 = high)	3.85 (2.01)	-.46*
Group 3. Core Elements of Stress		

Expectation Violation (ExV)		
If you were in this scenario, to what extent does it violate your expectations about what's supposed to happen when people are acting reasonably? (1-7 scale: 1 = none at all, 4 = moderately, 7 = highly)	2.56 (1.99)	.67*
Self Threat (STh)		
If you were in this scenario, how threatened would you feel (physically, psychologically, socially etc.)? (1-7 scale: 1 = none at all, 4 = moderately, 7 = highly)	2.76 (2.05)	.78*
Efficacy (Eff)		
If you were in this scenario, to what extent do you believe that you would be able to cope effectively with the situation? (1-7 scale: 1 = none at all, 4 = moderate, 7 = high)	5.91 (1.50)	-.72*
Perseveration (Prv)		
If you were in this scenario, to what extent would you continue to worry about this situation until it was resolved? (1-7 scale: 1 = none at all, 4 = moderate, 7 = high)	2.94 (2.24)	.82*
Group 4. Imagery		
Visual Imagery (VsIm)		
As you read this scenario, how much visual imagery related to it do you experience? (1-7 scale: 1 = none at all, 4 = moderate, 7 = high)	4.22 (1.58)	-.15*
Bodily Imagery (BIm)		
As you read this scenario, how much internal bodily experience do you have (arousal, changes in heart rate, breathing, muscle tension etc.)? (1-7 scale: 1 = none at all, 4 = moderate, 7 = high)	3.24 (1.96)	.62*
Action Imagery (AcIm)		
As you read this scenario, how much do you imagine actions you could perform? (1-7 scale: 1 = none at all, 4 = moderate, 7 = high)	3.73 (1.76)	-.05*

Verbal Imagery (VrIm)	
As you read this scenario, to what extent do you hear verbalizations (your own or other people's)? (1-7 scale: 1 = none at all, 4 = moderate, 7 = high)	3.93 (1.82) .01
Group 5. Valence and Arousal	
Positive Valence (PV)	
If you were in this situation, how much positive emotion would you experience? (1-7 scale: 1 = none, 4 = medium, 7 = high)	1.89 (1.28) -.46*
Negative Valence (NV)	
If you were in this situation, how much negative emotion would you experience? (1-7 scale: 1 = none, 4 = medium, 7 = high)	3.20 (2.08) .85*
Arousal (Ar)	
If you were in this scenario, how much bodily arousal would you experience? (1-7 scale: 1 = none, 4 = medium, 7 = high)	3.98 (1.65) .63*
Group 6. Certainty	
Situation Certainty (SCer)	
How certain are you about what's really going on in this situation? (1-7 scale: 1 = very uncertain, 4 = somewhat certain, 7 = very certain)	5.44 (1.70) -.46*
Coping Certainty (CCer)	
How certain are you about what you would do to handle the situation? (1-7 scale: 1 = very uncertain, 4 = somewhat certain, 7 = very certain)	5.33 (1.71) -.65*
Outcome Certainty (OCer)	
How certain are you about what the eventual outcome of the situation would be? (1-7 scale: 1 = very uncertain, 4 = somewhat certain, 7 = very certain)	4.96 (2.00) -.65*

Note. * indicates significance at $p < .05$

Table 2. Factor loadings and communalities

	Factors				
Rating	Core Features	Experience	Certainty	Imagery	Communality
Threat	.97				.83
Perseveration	.96				.88
Valence Negative	.85				.83
Efficacy	-.81				.67
Imagery Bodily	.76			.27	.61
Expectation Violation	.71				.66
Valence Positive	-.58				.27
Arousal	.53				.44
Familiarity		.99			.93
Experience	-.20	.76			.69
Plausibility	-.27	.57			.59
Vicarious Familiarity	.22	.52			.30
Being There		.43		.31	.33
Certainty Coping			.81		.83
Certainty Outcome			.77		.82
Certainty Situation			.69		.55
Imagery Action				.79	.58
Imagery Visual				.51	.30
Imagery Verbal				.37	.15

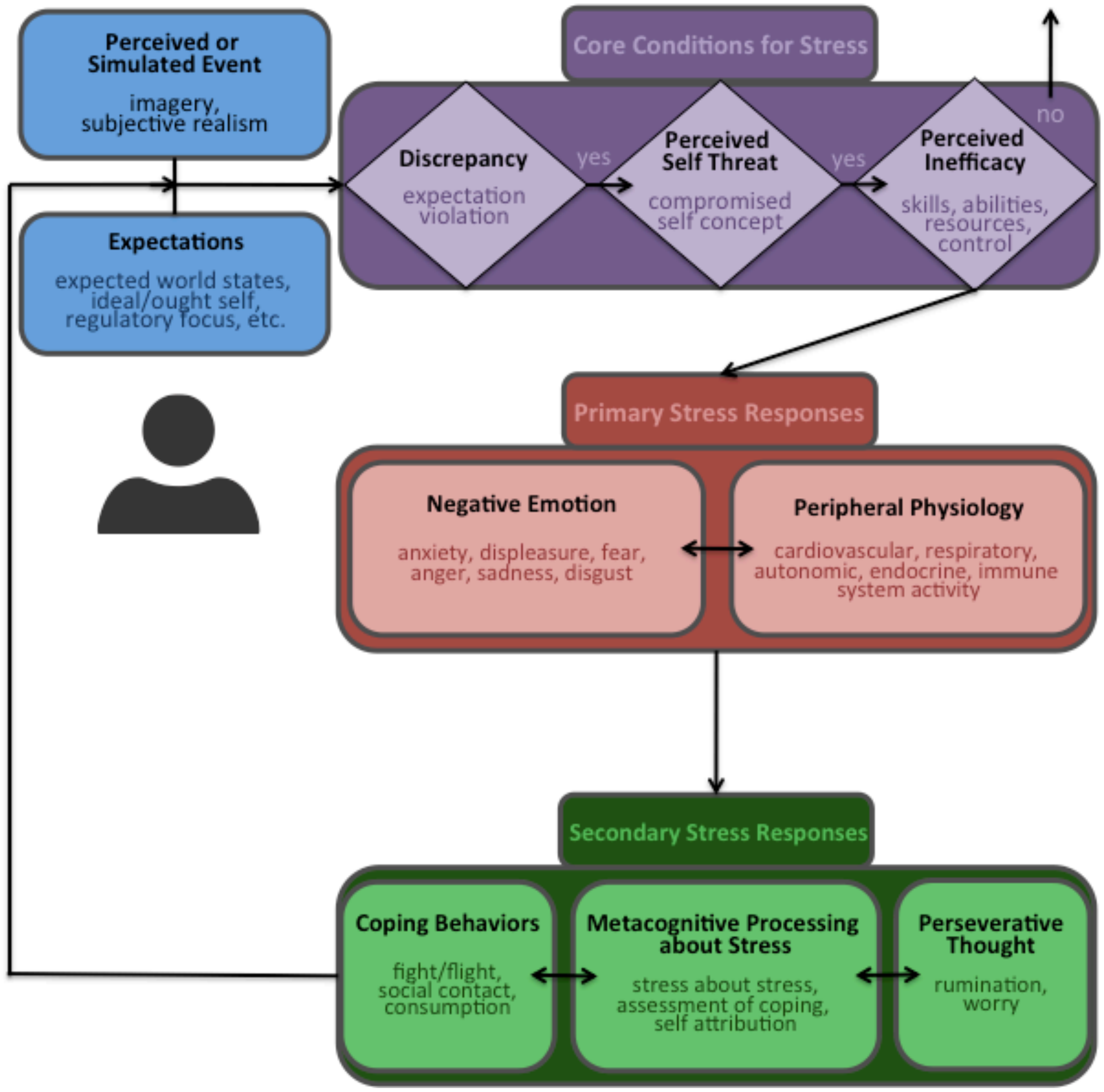
Note. Values are the pattern matrix coefficients, representing the variance in a measured variable explained by a factor's *unique* contributions. Values <.2 are suppressed. Communality is the variance in a given variable explained by all the factors (reliability). These are the extraction communalities, not the initial values.

Table 3. Percent of variance in stressfulness explained with multilevel modeling including fixed effects estimates

Model	Coeff	SE	% Variance Explained	Measures of Model Fit -2LL	Residual Variance
Model 00. Fixed Effects			--.--	29493.58	4.30
Intercept	3.07*	(.15)			
Model 0. Fixed Effects, & Random Intercept			--.--	29091.11	4.03
Intercept	3.07*	(.15)			
Random Intercept					
Model 1. Fixed Effects			75.1	19936.98	1.07
Intercept	3.07*	(.01)			
F1 Core Features	1.76*	(.02)			
F2 Experience	-.01	(.02)			
F3 Certainty	-.10*	(.02)			
F4 Imagery	-.09*	(.02)			
Model 2. Fixed Effects, & Random Intercept			81.4	18030.63	.80
Intercept	3.07*	(.15)			
F1 Core Features	1.82*	(.02)			
F2 Experience	-.05*	(.01)			
F3 Certainty	-.00	(.02)			
F4 Imagery	.04*	(.02)			
Model 3. Fixed Effects, Random Intercept, & Random F1 Slope			84.0	17093.68	.69
Intercept	3.09*	(.15)			
F1 Core Features	1.86*	(.11)			
F2 Experience	-.01	(.01)			
F3 Certainty	-.01	(.02)			
F4 Imagery	.03	(.02)			

Note. *$p < .05$. F1 is “factor 1,” F2 is “factor 2,” F3 is “factor 3,” F4 is “factor 4,” Coeff is coefficient. SE is standard error.

Figure 1. Features predicted to be included in situated conceptualizations of stressful experiences, shown with the global structure that integrates them.



Grounded Theory of Stress Cognition Supplementary Material (SM)

Lebois, Hertzog, Slavich, Barrett, & Barsalou

Materials

Stressful Events

1. You watch a mother slap her child for speaking out in public.
2. Your sibling borrowed your bike, forgot to lock it up, and now it's been stolen.
3. You’re working to help pay for school, but your boss fires you because they need someone with more availability.
4. You’re late to your summer job a second time, and your boss threatens to fire you.
5. You’re late to class and your professor will not open the locked door to let you in.
6. Your boss is away, and decides you must fire a coworker that you get along with well.
7. Your internship boss just scolded you in front of the office for inappropriate work attire.
8. Your internship boss fires you for being late to work too many times.
9. You return home to find your parents converted your bedroom into a guest room without telling you.
10. Your father is in the hospital, but your sibling decides to go on vacation anyway.
11. Your mother refuses to speak to your sibling after the incident.
12. Your parents come to your dorm room and find your roommate left it in complete disarray.
13. You told your parents about the conflict with your best friend's party, but they host the family reunion anyway.

14. Your mother breaks down because you have not been calling them while you are away.

15. Your roommate's significant other sleeps over every night in your tiny one-room dorm room.

16. Your friend asked out a long time crush of yours, even though they knew you were interested.

17. Your significant other announces they've made plans to go to dinner with an ex.

18. The conversation quiets awkwardly as you approach a group of friends.

19. You abhor your friend's significant other, and they just told you they're joining the road trip.

20. You have to tell your parents you failed a class and need to take summer school.

21. You struggle to tell your professor why you cannot attend class anymore.

22. You're the first to be notified of your father's death, and you must now tell relatives.

23. You have to tell your best friend that both their parents passed away in a car accident.

24. Your mother yells at you for not helping more while you're at home over break.

25. Your roommate has left you to clean the toilet again after your most recent party.

26. Your roommate leaves rotting food on the counter, even after many heated requests to clean up.

27. Your mom tells you the basement flooded, and you realize you left your laptop down there.

28. Your roommate accuses you of not cleaning up after yourself in front of your significant other.

29. Your TA accuses you of not trying hard enough even though you put 12hrs into the assignment.

30. Your professor says they did not receive your assignment and gives you a zero.

31. After merely skimming your report, your boss says it's incorrect, and it must be completely redone tonight.
32. You meet with your professor to discuss finishing touches on a project, and they say to start over.
33. Your professor requests a meeting, and they say your work is not at the level it should be.
34. You stay late to finish a project, and you see on Facebook your group member went to a party.
35. Your significant other says they're breaking up with you because you hardly make time for them.
36. You're working to help pay for school, but you never have time to finish group assignments.
37. During your group presentation your partner claims they came up with the entire creative idea themselves.
38. You have work to finish before this evening's deadline, but your group member leaves early for a party.
39. During the final exam you realize there is an entire section on a topic your professor didn't cover.
40. Your professor yells at you for not bringing materials they forgot to tell you to bring.
41. You are graded largely on teamwork, but your group member has stopped answering emails.
42. You find out your best friend lied to get out of going to your party.
43. You rush to a 7am group meeting, but realize your friend didn't say it was cancelled.
44. Your professor fails you on an assignment even though the instructions were not clear.
45. Your friend leaves you to pay for an expensive lunch for the second time in a row.
46. Your roommate sold the old fridge on Craig's list without including you in the profits.
47. A stranger bursts out of your apartment, and you realize you've been robbed.

48. While giving a stranger directions, you put down your bag, and when you turn around it's gone.

49. Your parents won't give you more money, and you don't have enough money in your account.

50. You arrive at school to see your roommate has taken the majority of the space for themselves.

51. Your roommate ate all the goodies from your care package while you were away over the weekend.

52. You arrive back from class to see your roommate making fun of some of your work.

53. You overhear a classmate whisper to another that you smell bad.

54. You just tidied your room when your roommate comes back and tracks mud everywhere.

55. Your friend tells you outright they did not like the dinner you cooked for them.

56. Your roommate let a friend sleep in your bed while you were away, and they vomited on the sheets.

57. Your sibling borrowed your car and got in an accident.

58. Your friend borrowed your bike to get to class, but forgot to bring it back.

59. Your roommate takes your car without asking for the 10th time.

60. You come out of the shower to find your roommate and their friend ate all of your pizza.

61. Your friend borrows your expensive textbook and loses it.

62. A friend jokingly grabs you as you bike past causing you to fall violently in front of a crowd.

63. You're on a rollercoaster when the controller announces you'll have to wait as they complete routine maintenance.

64. Your friends insist on going to the one movie you don't want to spend $12 on.

65. Your professor accuses you of being disrespectful in front of the whole class.

66. Your professor demands you leave class after people were whispering next to you.

67. Your group partner haughtily dismisses your idea for the next class project.

68. Your significant other decides it's time for you both to leave the party without consulting you.

69. Your best friend implies your opinion on the topic is immature and less important.

70. Your significant other makes a condescending remark to you while you are at a friend's party.

71. Your teacher accuses you of being disrespectful for talking during class.

72. Your close friend just told you she's decided to have an abortion.

73. The doctor tells you that you won't feel better for a couple of months.

74. Your parents tell you they won't pay for you to go to your top choice school.

75. Your parents tell you they won't continue to pay for you to go to school given the major you've chosen.

76. Your friend gloats obnoxiously over their midterm grade when they know you didn't do as well.

77. As punishment for rampant cheating, your professor assigns the class 15 page papers due next week.

78. You and your class partner argue over how to format a presentation that's due this afternoon.

79. You go to give your significant other a kiss and they pull away from you.

80. Your significant other accuses you of cheating on them.

81. You notice your significant other missed a call from their ex.

82. You notice your significant other's eyes trail an attractive individual across the room.
83. Instead of coming up to your room after dinner your significant other says they want to go.
84. Your friend confesses that they slept with your significant other.
85. You found clothing that does not belong to you or your significant other scrunched between their bed sheets.
86. You rush to practice after an impromptu late night of partying, and your coach announces there will be drug tests.
87. The university searches your dorm and finds your roommate's pot, but they lie about it being yours.
88. You're hosting a party, and a huge crowd of obnoxious people you don't know shows up.
89. The cops bust your party, and they arrest you for providing alcohol to minors.
90. You're at a party with pot smoking, and one controlled substance offense could prevent you from getting your teaching certification.
91. A friend attends a shady party against your advice, and they overdose on a drug used to spike the drinks.
92. It's the night before your final, and your friends are pressuring you to go out drinking.
93. Your friend accuses you of having a drinking problem in front of your family while you're treating them to dinner.
94. Your significant other decides they have to head home after only 30min with you.
95. Your parent is late to your graduation and misses you walking across the stage.
96. Your friend promised they would visit, but they cancel last minute after you rearranged your schedule to accommodate them.

97. Your roommate hits their snooze button 5 times each morning even though they know you don’t have to be up.

98. Your roommate slept in even though they agreed to give you a ride to class.

99. Your professor's lecture ran over and made you late for your exam in the next class.

100. You’re rushing to class after lunch, and the waiter stops to flirt before bringing back your credit card.

101. You are late to class, and your teacher yells at you in front of the entire lecture hall.

102. You are running late for a meeting, and the bus driver stops to take his break en route.

103. You arrive late and your professor interrupts the guest speaker to call you out.

104. Your drunk friend insists on driving when they've had more to drink than you.

105. Your roommate decides to watch TV instead of picking you up, and you have to take public transport at midnight.

106. Instead of catching a cab from the party, your friend calls you at 4am the night before your exam.

107. You overhear your significant other laughing with their friend about what a poor driver they think you are.

108. Your friend grabs the next taxi even though they know you’re running late.

109. You wait for your friend even though it makes you late, but they took the early shuttle without telling you.

110. You swerve to avoid a pedestrian and get in a head-on car crash.

111. You're rushing to the airport, but your taxi driver takes a wrong turn and now you're stuck in traffic.

112. Your friend stridently criticizes the way you are driving on your way to school.

113. Your roommate lied about handing in your essay while you were sick, and you got a zero.

114. Your significant other makes a snide remark about your family's religious practices.

115. Your good friend is interviewing for the same position as you behind your back.

116. You find out your classmate is suing you for stealing their project idea even though you didn't.

117. You're TAing a class, and a student threatens to sue you for discrimination.

118. You're leaving for your best friend's wedding when your parents say you received a subpoena for court weeks ago.

119. You see someone getting mugged and are forced to go to court as a witness.

120. You get jury duty during exam week, and the judge says your civic duty comes before school.

121. You're assigned jury duty during midterms, but your professor hasn't answered your email request to reschedule exams.

122. You're taking a shortcut home from the library when a cop stops you for trespassing.

123. You're having friends over, things get rowdy, and a cop knocks on your door with a noise violation citation.

124. You hear sirens, and you realize you are being pulled over by a man in an unmarked car.

125. A police officer pulls you over for speeding and gives you a hefty ticket.

126. Your friend was late, you had to park illegally to be on time, and now you have a $100 fine.

127. A cop pulls you over for going 20mph over the speed limit in a school zone.

128. You rush out to your car, and see a policeman directing the tow truck to take your car away.

129. The driver behind you is tailgating, and they rear-end you at a stoplight.

130. You’re waiting outside before class when someone rushes past you, grabbing your bag out of your hands.

131. You glance someone following you as you walk home from the library after a late-night study session.

132. You are at a crowded concert with a friend and someone steals your wallet.

133. You’re tutoring an underclassman when they accuse you of being racist.

134. You didn't make it into your top choice school, but your friend, whom you often help with homework, did.

135. You didn't get a scholarship to your top choice college, and your parents can’t afford to send you.

136. The last class you need to fulfill your requirements is full, and the professor refuses to let more people in.

137. You're processing the rejection letter from your top choice school when your friend calls to tell you they got accepted.

138. A professor writes you a curt email saying you do not qualify for their advanced course.

139. You’ve been called to the honor council because a classmate copied off you during an exam.

140. You find out after the fact that your professor had in-class exercises count for nearly half your grade.

141. You have 5 cumulative finals in three days because your professor changed your exam time to accommodate their vacation.

142. You're travelling during registration, and your friend forgets to sign you up for classes like they promised.

143. Because your group member is so inflexible you are unable to complete a project.

144. You're late and discover the professor gave a pop quiz you now only have a minute to finish.

145. Your professor tells you that because you were absent from class you're failing.

146. A construction worker aggressively yells at you for biking past the site.

147. You accidentally sleep through a test and your professor won't let you make it up.

148. Your friend refuses to help you pay for groceries after your card is declined at the checkout.

149. Looking at your bank statement, you see the cashier charged your card three times for one expensive purchase.

150. It's the end of the month, and you don't have enough money to treat your best friend to birthday dinner.

151. The electric bill is due today, but your roommate doesn't receive their paycheck until next week.

152. A waiter at a restaurant tells you that your card was declined.

153. You didn’t make enough money this summer, and now your parents say you have to take out a school loan.

154. Your parents call to tell you they're selling the house you grew up in.

155. You’ve begged your mom to stop smoking, but now she has lung cancer.

156. The day after an argument with your best friend, you get a call that they’ve attempted suicide.

157. Your friend borrows your moped without asking and gets hit by a car.

158. You’re arguing about an exam question, when your professor clutches their chest and falls.

159. A good high school friend confides in you that they have been contemplating suicide.

160. You always complain about dad's daily bacon and eggs, and you receive word he's had a heart attack.

161. Your dad tells you that he has just been diagnosed with cancer.

162. You’re sick the night before a big exam; your roommate offers cold medicine that makes it hard to concentrate.

163. You take some medicine, and you sleep through your test because your roommate didn’t wake you.

164. You begin to have major side effects from your new medication, though your doctor never mentioned these risks.

165. Your friend blocks your view, and you almost hit another car as you're switching lanes.

166. Your doctor prescribes medicine that makes you extremely nauseous.

167. Your roommate drinks from your water bottle, and then you get sick during exam week.

168. You’re in the infirmary, and the nurse insists on lights out even though you have to continue working.

169. Your doctor tells you that you must have immediate surgery.

170. Due to a complication while taking out your wisdom teeth, your dentist decides to put you under.

171. You fall while running and the doctor tells you that you need 50 stitches.

172. Your roommates had a party while you were gone, and now your landlord is threatening to evict you.

173. There’s severe water damage in the dorm, and everyone has to move out during midterms.

174. Maintenance crews need to do emergency work on your dorm, and your rector says to remove everything immediately.

175. Your landlord tells you they need next month's rent immediately, and you do not have the money.

176. You’re rushing out, but your car won’t start because your roommate didn't put any gas in it.

177. Your friend is driving you to class, and they run out of gas in the middle of a busy highway.

178. Your roommate breaks the stove right before you're getting ready to prepare a special meal.

179. You bought an expensive gift for your friend, but they act indifferent.

180. Your significant other is late, and you burn the dinner you spent hours preparing for them.

181. You have to drive two hours back to the store because the store manager gave you the wrong package.

182. While preparing a special meal with the help of a friend, they use the wrong ingredient and ruin it.

183. Your apartment management tries to cover up 7 break-ins over the holidays.

184. Your neighbor agreed to watch your apartment while you were away, but you return home to find broken windows.

185. Your neighbor was burglarized last night, and you realize you forgot to lock your front door.

186. It’s 2am and you still have to finish your essay and read for class tomorrow.

187. Your parents visit and your roommate left the room filthy even though they agreed to clean up.

188. You are forced to handle paying the bills this month because your roommate refuses to contribute.

189. You babysit your friend’s dog, but when they get back they say you did a lousy job.

190. You’re walking with your dog when a car speeds by almost hitting your pet.

191. Your friend watched your cat, and you can tell the cat hasn’t been fed for days.

192. Your sibling takes care of your pet fish, but when you return home it's died of starvation.

193. Your sibling begged to take care of the dog, but let it run away.

194. The vet tells you that your dog is very sick and will not last long.

195. The referee makes a lousy call in the last 2 min of the game, and you lose the intramural championships.

196. You’re fouled by another player, but the referee calls the foul on you.

197. You're about to relax for the first time in months when your group member demands you finish their section.

198. You made a large bet with a classmate that your favorite team would win, and your team just lost.

199. You and a competitive friend are rooting for opposing teams, and your team loses badly.

200. Your mom wants you to come home for the anniversary of your sibling’s death, but you have an exam.

201. Your significant other comes over all dressed up, and you realize you forgot about your anniversary.

202. It is the anniversary of your grandparent's tragic death, and your mom insists everyone visit the cemetery.

203. Your close friend asks you to lie on their behalf to your favorite teacher.

204. Your friend convinces you to lie about being sick to miss class, and you find out there was a pop-quiz.

205. You find out your significant other lied to you about when they broke up with their ex.

206. Your professor just accused you of cheating on an exam.

207. Your friend insists they know the way to the party, but you get lost and miss it.

208. The office misplaced your financial aid paperwork and now your loans won’t go through.

209. Your friend gives you vague directions to the party and you circle for an hour trying to find it.

210. Your friend distracted you, you missed your exit ramp in big city traffic, and now you're lost.

211. Your friend gives you incorrect directions, and you get lost in a bad part of town at night.

212. Your uncle balks loudly at the family party when you tell him your political affiliation

213. A news anchor discloses 20 people have died in a meth lab explosion in your hometown.

214. Your parents call to tell you there was a terrorist attack on the news.

215. Your roommate has started smoking regularly inside your room, and they refuse to go outside.

216. Your roommate borrowed some of your favorite clothes, wore them to a smoky party and now they reek.

217. The table next to you continues to smoke in the non-smoking section even after the waiter asks them to stop.

218. A student lights up right next to you, and haughtily blows cigarette smoke in your face.

219. You watch a man smoking next to someone's baby.

220. Your professor decides to add an oral exam to count for half of your final grade.

221. You're giving a final presentation when a late classmate interrupts, and you can't remember what comes next

222. You're giving a group presentation, but the other member doesn't show.

223. The student presenting first runs over their time, leaving only a few minutes to squeeze in your presentation.

224. You have to give a speech in front of your entire college at graduation.

225. You have to give a speech at your high school reunion in front of the entire class.

226. It's your significant other's turn to come over, but they refuse for the fourth time in a row.

227. You wait at the airport for 5 hrs because your roommate forgot to pick you up.

228. Because your sibling was late, you now have to rush home in the middle of a torrential downpour.

229. You and your friend are going on a road trip and get caught in a blizzard.

230. You forget to cover for a coworker who’s late again, and your boss fires them.

231. You fail to cover for a group member who hasn’t finished yet, and your professor fails them.

232. Because of an incident between you and a coworker at your internship, the coworker is fired.

233. Your offhand remark about the rude behavior of a coworker leads to them getting fired.

234. You let slip to your internship boss that your coworker is always late, and they get fired.

235. Before your parents drop you off at college they tell you they’re getting a divorce.

236. You’ve told your sister to lose her lousy boyfriend a thousand times, and she tells you he’s hit her.

237. Your sister refuses to tell you why her arm is all bruised.

238. You overhear your sibling screaming at their significant other in the room next door.

239. Your parents start to treat each other disrespectfully after your youngest sibling leaves for college.

240. You're very close to your sibling, and they've decided to move across the country.

241. Your significant other calls you and says they need to talk with a sobering tone.

242. Your ex calls your current significant other to tell them how selfish and inconsiderate you are.

243. Your significant other accuses you of ignoring them, and tells you they’re leaving you for your roommate.

244. A casual friend offers their condolences about a recent breakup you thought no one knew about.

245. You need to break up with your partner, but you know they will take it very badly.

246. Your friends convince you to go on a blind date, but the date never shows up.

247. Your housemate tells you their significant other is moving into your already crowded tiny apartment.
248. You smile at an attractive person, and they roll their eyes.
249. You're about to go on a blind date with someone you will dislike.
250. Your significant other decides to transfer to a school on the opposite coast without discussion.
251. Your significant other has purposefully scheduled time away, and your resentment boils to the surface.
252. A stranger at a party accuses you of ogling their dance partner.
253. Your significant other threatens you physically.
254. You accidentally bump into someone at a bar, and they throw their drink in your face.
255. Your boss doesn't rehire you for the fall semester, and now you cannot afford to fly home for break.
256. A coworker rats on you for being tardy, and you get fired, while they get more hours.
257. The person interviewing you asks an unfair question, and you make a complete fool of yourself.
258. You're interviewing for a competitive internship, and you struggle to answer an inappropriate question.
259. It’s your third summer working at your aunt’s business, and she gives your friend a raise, but not you.
260. You applied to be manager, but your boss recycles the application in front of you.
261. Another business is suing your company because you have the same name as them.
262. A coworker told you everyone dresses up for Halloween, but when you arrive no one is in costume.
263. Your boss significantly reduces your pay, but there's nothing you can do about it because you're an intern.

264. The night before a deadline, you discover your group member messed up.

265. There was cheating on yesterday's exam, so the professor made a harder exam for everyone to take today.

266. Your coworker doesn't relate changed guidelines, and your boss berates you for completing the project incorrectly.

267. You ask a coworker to deliver your final project to your boss, but they misplace it.

268. A coworker doesn't do their part of an assignment and causes you to miss an important deadline.

269. You realize your friend told you the wrong due date as everyone else hands in their essay.

270. Your professor asks for take-home midterms, and you realize you left yours at home.

271. Your professor assigns extra busy work the day before your oral exams.

272. Your group project member plays hooky, and you miss the deadline to complete your final project.

273. Your internship boss is requiring you work longer hours, and they will fire you if you don't.

274. Your boss had to fire your work team, and now you have to cover all the bases.

275. Your new summer internship just rescinded their offer due to some inappropriate photos they saw on Facebook.

276. Your internship boss says you must take on more responsibilities, but they cannot pay you more.

277. Your friend insists you take the "short cut" to school to get your essay in on time, but there's traffic.

278. Your computer crashes, and you don't have a back up of your work because your friend borrowed the flashdrive.

279. The mechanic forgot to refill your car's coolant, and your engine overheats on the highway.

280. Your roommate bumps your desk, knocking your water glass over your computer, and your screen goes black.

281. Your significant other hosts a special party, but you have a take-home midterm due tomorrow morning.

282. A friend calls in a favor, and you are 2 hours late to the first day of your internship.

283. You have to stay late to meet a deadline, but your significant other's birthday dinner started an hour ago.

284. Your internship boss tells you that you need to put in several hours of overtime this week.

285. Your internship boss doesn't give you much work, but on your evaluation they rate your productivity as extremely low.

286. Your internship boss is too busy to answer questions again even though the project deadline is tomorrow.

Non-stressful Events

287. You watch a mother and child walk past you as you wait for the bus.
288. Your sibling hands over your bike after they're done riding it.
289. You're working to earn extra cash during school, and your boss asks you to hand in next week's availabilities.
290. You arrive at your summer job, and your boss says they will leave early today to catch a flight.
291. Your professor holds the door open while everyone enters class.
292. Your boss is away on a business trip and asks you to send them a weekly update email.
293. Your internship boss hands you the meeting notes for today.
294. Your internship boss puts hand sanitizers on all your workspaces as part of a new company policy.
295. You return home to find your parents decided to replace your bed pillows with other pillows.
296. Your father is in the hospital for a routine checkup and gives you a call from the waiting room.
297. Your mother buys you a magazine for the trip, and you pack it in your bag.
298. You take your parents to see your dorm room and find your roommate has left for the day.
299. Last night you and a sibling sat on the old couch and watched reruns on TV.
300. Your mother calls to ask about your plans for summer break.
301. Your roommate's significant other greets you briefly as they head out the door.

302. Your friend asks a mutual friend if they can borrow their pen for a second.

303. Your significant other says they've decided to head home for their sibling's game this weekend.

304. You walk past a group of people carrying on a conversation.

305. Your best friend tells you they invited a friend from work to watch TV tonight.

306. You tell your parents you're considering taking a class over the summer to free up your fall schedule.

307. You give your professor a doctor's note so that you won't lose points for missing class while you were sick.

308. You've been notified that there will be construction on your drive home, and you call to let your sibling know.

309. You tell your friend that both their parents are on their way over to help set up.

310. You tell your mother the times of your flights for break.

311. Your roommate tells you they got the next round of toilet paper.

312. Your roommate leaves a note for you on the counter.

313. Your mom hands you a plate from the dishwasher, and you put it up in the cupboard.

314. Your roommate gives you the cleaning supplies they bought to put under the sink in the kitchen.

315. Your TA asks you to pass your papers to the left for peer review during today's class.

316. Your professor says they received everyone's work and will hopefully have feedback by next Monday.

317. You type a memo for your boss at work in time to leave for home.

318. You meet with your professor, and they tell you to bring over a chair from the hallway.

319. Your professor requests that everyone staple their papers before handing them in.

320. You and your group member decide to stop working for the day and leave the library.

321. Your significant other tells you they've thinking about getting a new desk chair for their room.

322. You meet your group members after work to start brainstorming ideas for your upcoming mini-project.

323. You and your group partner divide up who will present what at an upcoming informal presentation.

324. You and your group member walk into the meeting room.

325. While completing an in-class exercise your professor makes a brief announcement.

326. You are meeting with a professor, and they tell you they'll be with you in just a second.

327. Your group member answers your email in the afternoon.

328. Your friend asks you to hand them a napkin while you're eating at the table.

329. Your classmate tells you the group meeting is at 1pm in the main library, which works for your schedule.

330. Your teacher gives you a rubric for an assignment that's due at the end of the semester.

331. Your friend accidentally gives the waitress their school ID card instead of their driver's license while you're ordering drinks.

332. You and your roommate decide to give away extra furniture on Craig's list just to get rid of it.

333. You and your friend walk home to your apartment after class.

334. Your friend offers to hold your things while you're giving a stranger directions.

335. Your parents forward some mail to you at school that was mailed to your home address.

336. You arrive at school to see your roommate has left you your fair share of the space.

337. Your roommate tells you they are going away this weekend as well.

338. You arrive back from class to see your roommate working quietly at their desk, as expected.

339. A classmate whispers to you in class about an upcoming assignment.

340. You're sitting at your desk doing homework, and your roommate comes in from picking up books at the library.

341. Your friend tells you about a new spice they used to make dinner last night.

342. Your roommate let a friend sleep on the couch while you were away for the weekend.

343. Your sibling helps you unload your car when you get home.

344. You see your friend before class as you lock your bike to the half-full bike rack.

345. You and your roommate run a quick errand using your car.

346. You come out of the shower and pass by your roommate and their friend making small talk.

347. Your friend asks to borrow your textbook for a second.

348. You and a friend bike past a crowd of people on your way to class.

349. You're talking to a friend on your way to a lecture, and they stop to fix their pant leg.

350. You hand the cashier money at the movie theatre for your ticket.

351. Your professor answers your question in class.

352. Your professor asks everyone to discuss the question with the person next to them before submitting answers.

353. Your group member records ideas for your next class project during your meeting in the library.

354. Your significant other gives you their drink while they run to the bathroom on the next floor.

355. You and your best friend talk about a recent event broadcast on the local news radio station.

356. Your significant other chats to you about today's headlines while you wait for the elevator to open.

357. You say hello to your teacher as you enter class and head for your normal seat.

358. Your friend just told you she's decided to move off campus this semester with her sister.

359. You hand your privacy form to the secretary at the doctor's office and wait to be called.

360. Your parents tell you they got some fresh vegetables from the local grocery store this morning.

361. Your parents ask you what major you've chosen now that you are allowed to designate a major.

362. You borrow your friend's blue pen to sign the paper while you're waiting.

363. At the beginning of class, your professor passes out handouts to help prep for the next exercise.

364. You email a PowerPoint presentation to your group partner so they have it to work on over the weekend.

365. You go to give your significant other a piece of paper, and they take it without question.

366. Your significant other asks you about your old jacket that you left on the chair back.

367. You notice your significant other missed a call from their parents, and you give them their phone.

368. You notice your significant other's eyes trail a stray dog meandering slowly across the street.

369. Your significant other tells you about their new desk at work while you eat a quick breakfast.

370. Your friend asks you about today's weather forecast, and you tell them while you get ready to go.

371. You find an old sock on the floor as you say goodnight to a friend.

372. You arrive at practice, and your coach announces today's routine practice schedule.

373. The university does random flyering in the dorms and the bulletin board outside your shared room gets picked.

374. Your friend is hosting a party, and they ask you to hold the door while they bring in the keg.

375. You bring in a bunch of extra drinks from the kitchen to give your friends at the party.

376. You're at a party, and you and your roommate decide to leave early to save your energy for tomorrow.

377. A friend asks if you'd like to go run some errands with them while you're waiting.

378. Your friend hands you a soda they just poured and decided they didn't want to drink.

379. Your friend passes you the pitcher of water while you're out eating a casual dinner.

380. Your significant other tells you they've decided to trim their hair tomorrow before their last presentation.

381. Your parent calls to ask you the exact time of your departmental graduation ceremony in may.

382. Your friend calls to tell you a mutual high school friend might come to visit them in the city.

383. You and your roommate wake up and head to class at approximately the same time each morning.

384. Your roommate decides to sleep in while you get up to grab some breakfast before class.

385. Your professor tells you they will finish today's topic next time since they didn't get through all the slides.

386. The waiter returns your credit card after he's swiped it to pay for your lunch.

387. Your teacher asks you to pass out handouts in class, and you agree without question.

388. You and one of your group members catch the bus so you can make it to your library meeting.

389. You arrive to class on time, and your professor directs everyone to their designated seats.

390. Your friend hands you your keys that you dropped on the floor on your way out.

391. Your roommate decides to stay at home to watch TV while you decide to buy your groceries for the week.

392. Your friend calls you to let you know they arrived at the airport with plenty of time to spare.

393. You overhear your significant other laughing with their friend about a new TV sitcom they found flipping through.

394. Your friend waits outside with you while you hail a quick taxi.

395. You waited at the bus station this morning so you could ride in with some other people from your complex.

396. You pass a pedestrian you think you might recognize as you drive down the street.

397. You catch another driver's eye as you turn left at a green light on the way home.

398. Your friend asks you to turn up the radio show on your drive in to school.

399. You hand your professor today's 5 min in-class exercise that won't really count for anything but attendance.

400. Your significant other asks you your mother's maiden name so they can fill out the form.

401. You mentioned an upcoming appointment to a friend while you were waiting for the bus this afternoon.

402. Your classmate asks if you've decided on a project topic while you're waiting outside of class.

403. You're TAing a class, and a student asks for clarification on a due date that hasn't been set in stone.

404. Your parents call to let you know they're sending you a package with old clothes you left at home.

405. You see someone buying a quick lunch from a vendor across the street as you walk to school.

406. Your professor is taking attendance, you say 'here' after they call your name, just like every other day.

407. Your professor returns the scrap paper you left in the classroom last week after the exam.

408. Your group member walks back with you from the library because they live in the same area.

409. You and your roommate decide to have a few people over tonight to catch up over food.

410. You see a policeman in his car pass you on the left and pull into the station.

411. You see a police officer while you are driving, and they wave you on by nonchalantly.

412. You offer to give your roommate a ride into class since it's raining and you're driving in anyway.

413. You pass a woman in a parked car as you drive calmly through a school zone.

414. You and your friend head out to the parking lot and hop in your car after class.

415. You look in your rear-view mirror and see someone you might know driving a ways behind you.

416. You're waiting outside before class and a fellow classmate asks what you thought of yesterday's assignment.

417. You return a book to the librarian while you're out running errands you've put off.

418. You are at a crowded concert with a friend, and someone gently brushes past you with apology.

419. You're tutoring a student, and they ask to reschedule tomorrow's session for a little bit later.

420. You often do homework together with one of your friends, and they ask you for clarification on question three.

421. Your parents bring in the mail and leave your pile on the counter by the door.

422. You ask a professor if you can overload into their class, and they agree.

423. You hand your mom some recycling as you answer the phone that's been ringing for a little bit.

424. A professor forwards a message about an upcoming talk to you, and you decide to attend.

425. Your professor puts everyone into groups for the in-class worksheet, and you finish it without trouble.

426. You read along and highlight important points as your professor goes through the class relatively short syllabus.

427. Your professor asks for a vote to see if everyone would like to change the due date of the assignment.

428. You hand the flight attendant your ticket so you can board your flight and find your seat.

429. Your group member sends you an email to schedule a meeting for a convenient time next week.

430. You come into class and your professor asks everyone to sit in alphabetical order.

431. Your professor makes an announcement in class about a new attendance policy that won't really affect much.

432. You pass a group of construction workers while you're riding on your bike, and say a quick hello.

433. Your professor hands out golf pencils for the questionnaire you are to complete by the end of class.

434. Your friend offers to split supplies for the party once you get to the checkout line.

435. The cashier takes your card so they can swipe it to pay for your small purchase.

436. You decide to grab a quick lunch with some classmates after class on Thursday.

437. You and your roommate move the furniture in your living room around to make more space.

438. You give the waiter your credit card to pay for the meal and wait for him to return.

439. Your parents say they will come pick you up on Friday to help cart your belongings home.

440. Your parents call to tell you they're changing the curtains in the house.

441. You ask your mom if you can borrow some extra sheets for the semester.

442. A friend from high school calls to ask about your plans for the upcoming break.

443. Your friend asks what you know about mopeds.

444. You raise your hand to ask a quick question during class, and your professor calls on you.

445. A good high school friend tells you that they have been contemplating colors to paint their bathroom.

446. You get a call that your dad is on his way home from the store.

447. Your dad tells you that he just bought new lawn furniture.

448. Your roommate offers to let your guest use their extra pillows while they stay over on your futon.

449. Your roommate offers to set their alarm for you because yours ran out of batteries.

450. You pick up vitamins from the pharmacist and they hand you a receipt.

451. Your friend stands up against the window and briefly blocks your view of the outside.

452. You go to the doctor for a routine check up.

453. Your roommate asks if they can borrow a bowl for cereal because they broke theirs yesterday.

454. The nurse asks you to roll up your sleeve so they can take your blood pressure at your routine checkup.

455. Your doctor asks you to schedule a routine follow up with the receptionist.

456. The dental hygienist gives you a bag of floss.

457. You pass a landscaper while out running in the neighborhood.

458. Your roommate decided to stay home while you went away last weekend.

459. Your rector announces that the heat will go on in the dorms over the weekend.

460. Maintenance crew members walk past your dorm room.

461. Your landlord tells you they need next month's rent, and you give it to them.

462. You're driving with your roommate, and they ask if they could make a quick stop at the grocery store.

463. You are driving with a friend, and you stop to fill up your gas tank.

464. Your roommate tells you that they cleaned the stove and kitchen sink this morning.

465. You bring your friend's birthday present to the party, and their significant other directs you to the gift table.

466. Your friend comes over to your apartment to ask for milk.

467. The store manager hands you a package of towels to take home.

468. While preparing a meal with a friend, you put the main dish in the oven.

469. Your apartment complex hires extra police during the holidays simply as a precaution.

470. You hand your neighbor mail that was accidentally put in your mailbox instead of theirs.

471. You see your neighbors drinking coffee on their front porch in the morning.

472. Your group member offers to reschedule the meeting for tomorrow.

473. You walk in your dorm room with your parents.

474. You and your roommate pay all the bills for this month.

475. You take care of your friend's dog for the weekend, and they come to pick it up Sunday afternoon.

476. You're walking with your dog, and you pass someone else walking their dog in the opposite direction.

477. You ask your friend to feed your cat while you're away, and they say they will.

478. Your sibling moves your old, discarded fish bowl into their room.

479. You hand your sibling your dog's leash so they can take it for a walk.

480. You take your dog to the vet for a routine check up at the end of the week.

481. The referee asks for captains to come to them at the end of the game.

482. You pass the ball to another player during the pick up game.

483. Your group member calls to ask you about tomorrow's mini-assignment.

484. Your classmate walks into class ahead of you.

485. You and a friend are watching a sporting event, but decide to change the channel.

486. Your mom wants to know when you're switching dorm rooms so they can help you move.

487. Your significant other comes over to your apartment to return a book they borrowed.

488. Your mom calls to ask about granola bars while you're walking home.

489. Your close friend asks if you want to take the same class as them next semester.

490. Your friend walks with you to class Tuesday morning.

491. Your significant other talks to you about the weather.

492. Your professor just passed out lecture notes in preparation for the next class.

493. Your friend says they know the way to the party, and they take the lead.

494. You just received notice that the office obtained your financial aid information and you are set.

495. Your friend gives you directions to the grocery store, and you grab a pen to write them down.

496. You drive your friend through the quiet downtown on the way to the store.

497. Your friend gives you directions to come pick them up.

498. Your uncle asks how school is going while you're both at a family party.

499. Your parents tell you there was a local news story done on French doors in your hometown.

500. Your parents call to tell you they bought a new fridge.

501. Your roommate has started doing work regularly inside your room because it's too cold to walk to the library.

502. Your roommate borrowed your textbook over the weekend while you didn't need it.

503. You're at a restaurant and the table next to you orders the same food as your table by coincidence.

504. A patron at the bar politely asks if you could move over so they can get a drink.

505. You see a man holding a grocery bag filled with household cleaning items.

506. Your professor decides to add an in-class exercise to today's class so everyone will fully understand the topic.

507. You file in line at the front of class to hand in your essay to your professor.

508. You and your group member sign up for a class meeting time at the end of class.

509. The student sitting in front of you in class leans back to give you the handouts.

510. You give a campus visitor directions to the new bookstore.

511. You talk privately with your professor about some pleasant comments they wrote on your paper.

512. Your significant other says they forgot their bag at your place, and they'll come grab it tomorrow morning.

513. Your roommate puts your bags in the back of the huge trunk of their car at the airport.

514. You drive your sibling to pick up toiletries at a nearby store.

515. You and your friend are running an errand and stop on the way for gas.

516. Your coworker asks to borrow a piece of paper to take notes during the meeting.

517. You and your group member pick days to meet for next week to discuss the upcoming project.

518. Because of a talk between you and a coworker, they decide to order a tennis racket.

519. You make an offhand remark about the color of the trees to your coworker.

520. You and your coworker grab extra chairs for this morning's meeting.

521. Before your parents drop you off, they tell you they have to stop for a few food staples.

522. You ask you sister about her newly posted "in a relationship" status on Facebook when she calls to catch up.

523. Your sister asks about your class schedule for this semester while you're out walking together.

524. You overhear your sibling talking to their significant other in the yellow room next door.

525. Your parents start to chat after your youngest sibling goes to bed early in the upstairs room.

526. Your sibling asks to borrow your water-shoes for a few minutes while they swim in a rocky area.

527. Your significant other calls to ask when you'd like to get together tomorrow after work.

528. Your friend calls your significant other to ask if you'd both like to come over to hang out.

529. Your significant other says hi to your roommate when they come home from a long class day.

530. A casual friend texts you to offer their opinion on easy to build dorm room lofts.

531. Your partner comments on the movie theatre seats as you walk into the dimly lit room.

532. Your friend asks if you'd recommend a certain restaurant to take family to when they're in town next weekend.

533. Your housemate asks if you mind if their brother sleeps on the couch while he's visiting this weekend.

534. You ask the waitress for some extra napkins while you're eating out at a local restaurant.

535. A waiter hands you a menu as you walk into the restaurant and to your booth.

536. Your significant other decides to buy some bread for tonight's potluck meal with your friends.

537. Your significant other asks you for today's paper, and you give them the section you finished reading.

538. You grab a drink from a friend while you're out at a random party.

539. Your significant other asks you to hand them their sneakers while you're in the hallway.

540. You hand a friend some money to grab you a drink while they're up at the bar.

541. You and a friend decide to shelve library books one night a week to make a little extra money.

542. You and a coworker sign up for similar hours next weekend, which should work out just fine.

543. You and a group member fill out a quick form online while your roommate talks on the phone.

544. You're in a meeting, and someone asks your boss a question about the new conference room chairs.

545. Over the summer you and a friend decide to work a couple days a week for your aunt.

546. You give your boss your time sheet for the past two weeks and grab a new one.

547. You get a call from a non-competing business to see if they can advertise in your storefront.

548. The secretary at your new job asks you to help them post a few holiday party flyers.

549. Your internship boss gives you the work schedule you expected for the next couple of weeks.

550. A month before the project is due, you and your group members equally divide up the work.

551. Your professor announces they noticed nearly everyone was in class yesterday and today.

552. You and a summer internship coworker work on a project that's not due until December 15th.

553. You asked a nearby coworker to hand you the grey stapler from their desk.

554. A coworker offers to grab a snack for you while they're on a break in the afternoon.

555. Everyone hands in their assignments at the beginning of class while the professor writes upcoming deadlines on the board.

556. Your professor asks everyone to talk amongst themselves while they take a quick phone call outside.

557. Your professor cancels a "busy work" in-class assignment at the beginning of class.

558. Your group project member asks how you'd prefer to divide up the work so you meet the deadline.

559. Your internship boss asks to discuss your work schedule with you so they can coordinate.

560. Your boss assigns you to the next work team at the start of the first quarter.

561. Your summer internship mails some paperwork for you to fill out before you come next month.

562. Your internship boss asks you to sign a very reasonable agreement about your responsibilities at work.

563. Your friend asks if you can drop them off at their building so they can hand in their assignment.

564. Your friend asks if they can borrow your flashdrive for a second so they can transfer some files.

565. You and a coworker decide to carpool to your summer internship for the next few months.

566. Your roommate comes over to your desk to look at your textbook while you're working on something else.

567. Your significant other calls to see if you'd like to hang out after you finish your take-home assignment.

568. You give your ID card to the office secretary so they can clock you in while the system is down.

569. You give the secretary a memo to distribute to everyone next week before the meeting.

570. Your internship boss tells you that they will need to move your desk over a few feet.

571. Your summer internship boss hands out extra paper clips so everyone is properly supplied for the next few weeks.

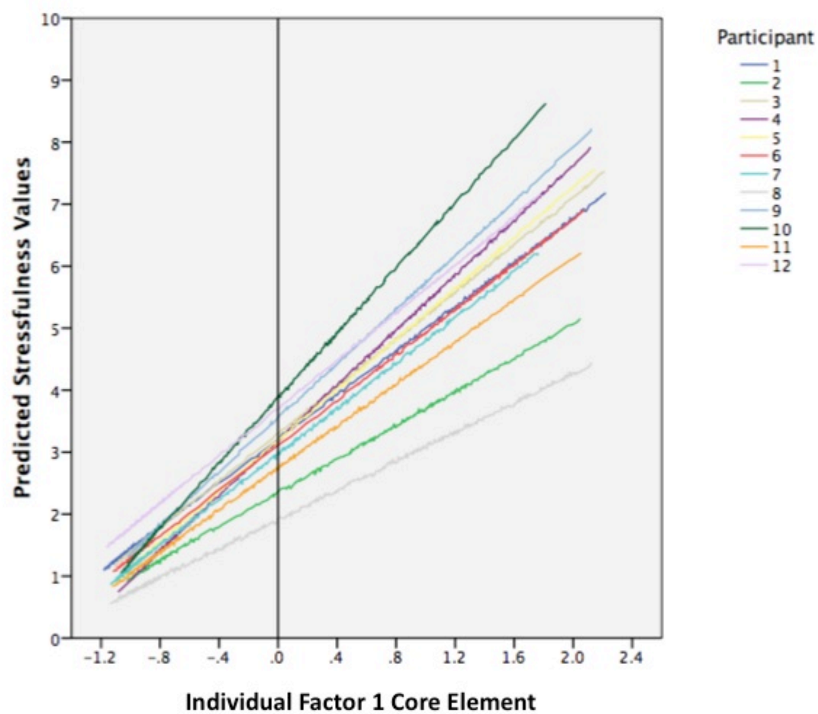
572. Your internship boss says they will answer your email about the water cooler tomorrow after the meeting.

SM Table 1. Complete correlation matrix

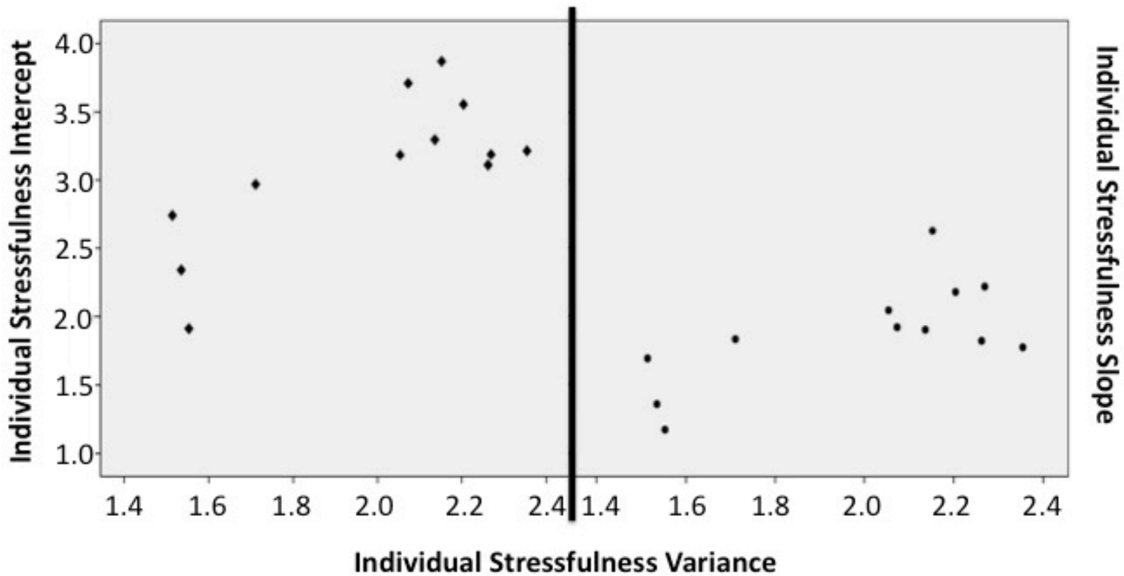
	Str	Exp	Fm	VFm	BT	Pl	ExV	STh	Eff	Prv	VsIm	BIm	AcIm	VrIm	PV	NV	Ar	SCer	CCer	OCer
Str		-.49**	-.43**	-.09**	-.06**	-.46**	.67**	.78**	-.72**	.82**	-.15**	.62**	-.05**	.01	-.46**	.85**	.63**	-.46**	-.65**	-.65**
Exp			.84**	.34**	.27**	.59**	-.43**	-.46**	.40**	-.48**	.17**	-.33**	.12**	.07**	.32**	-.48**	-.33**	.34**	.43**	.44**
Fm				.50**	.34**	.63**	-.40**	-.40**	.36**	-.43**	.18**	-.26**	.13**	.09**	.24**	-.44**	-.33**	.36**	.43**	.44**
VFm					.30**	.32**	-.18**	-.09**	.11**	-.12**	.16**	.08**	.18**	.21**	-.05**	-.11**	-.18**	.17**	.17**	.19**
BT						.54**	-.12**	-.06**	.09**	-.07**	.27**	.00	.26**	.20**	.01	-.07**	.04**	.16**	.14**	.15**
Pl							-.45**	-.44**	.41**	-.48**	.22**	-.34**	.18**	.11**	.35**	-.47**	-.31**	.37**	.42**	.44**
ExV								.75**	-.68**	.74**	-.05**	.52**	-.08**	-.02	-.44**	.74**	.55**	-.52**	-.60**	-.62**
STh									-.75**	.87**	-.03*	.63**	-.04**	.02	-.46**	.82**	.61**	-.46**	-.61**	-.62**
Eff										-.77**	.06**	-.62**	.03**	-.01	.41**	-.72**	-.48**	.44**	.60**	.59**
Prv											-.07**	.65**	-.05**	.00	-.47**	.85**	.65**	-.49**	-.65**	-.67**
VsIm												.11**	.45**	.14**	.07**	-.09**	-.02	.12**	.14**	.15**
BIm													.20**	.21**	-.42**	.65**	.46**	-.34**	-.48**	-.46**
AcIm														.29**	.06**	-.05**	.06**	.09**	.06**	.07**
VrIm															.01	.00	.03*	.02	-.02	.01
PV																-.45**	-.19**	.27**	.35**	.35**
NV																	.67**	-.51**	-.68**	-.68**
Ar																		-.35**	-.45**	-.53**
SCer																			.69**	.67**
CCer																				.83**

Note. The *N* of each cell = 6864. ** Correlation is significant at the $p < .01$ level (2-tailed). * Correlation is significant at the $p < .05$ level (2-tailed). Str is stress, Exp is experience, Fm is familiarity, VFm is vicarious familiarity, BT is being there, Pl is plausibility, ExV is expectation violation, STh is self threat, Eff is efficacy, Prv is perseveration, VsIm is visual imagery, BIm is bodily imagery, AcIm is action imagery, VrIm is verbal imagery, PV is positive valence, NV is negative valence, Ar is arousal, SCer is situation certainty, CCer is coping certainty, OCer is outcome certainty.

SM Figure 1. In the regression functions for individuals, individual intercepts for stress judgments (at X=0), and individual slopes stress as a function of F1 Core Features (across the F1 values of the 572 events).



SM Figure 2. Scatter plots of individual stress variance (*SD*), first, with individual stress rating intercepts, and second, with individual slopes for F1 Core Features.



Decentering the Self during Mindful Attention to Imagined Stressful Events

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13 June 2014

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Abstract

Part of what makes thoughts stressful is that they seem real, almost as if they were happening in the moment. One possibility is that this subjective realism results from simulating the self as being engaged in a stressful situation (immersion). If so, then the process of disengaging the self from the situation—decentering—should reduce the subjective realism associated with immersion, and therefore stressfulness. In a brief laboratory intervention, we taught participants a strategy for disengaging from events, simply viewing their thoughts as fleeting mental states (mindful attention). As participants subsequently imagined stressful and non-stressful events, their neural activity during mindful attention vs. immersion was assessed. In conjunction analyses, mindful attention appeared to rapidly down-regulate stressful events relative to baseline, whereas immersion appeared to up-regulate them more slowly. In direct contrasts between mindful attention and immersion, mindful attention showed greater activity in brain areas associated with perspective shifting and effortful attention, whereas immersion showed greater activity in areas associated with self-processing and visceral states. This overall pattern of results suggests that, through shifts of perspective, mindful attention produces decentering by rapidly disengaging embodied senses of self from stressful situations so that affect doesn't develop. These findings shed light on the mechanisms that contribute to reenacting stressful events, and that allow mindfulness to have therapeutic effects.

Because chronic stress is linked to decreased mental and physical well-being (Brosschot et al., 2006; Keller et al., 2012; Zautra, 2003), establishing the processes that both produce and disable stress is important. In this article, we focus, specifically, on an immersion process that produces stress and on a mindful attention intervention that disables it.

Subjective Realism

Continually perseverating about stressful events (rumination) elicits bodily stress responses that can affect one's health adversely, through increasing allostatic load over time (McEwen, 1998; Zautra, 2003). Of central interest here are the subjective features of thoughts that cause some of them to be perceived as stressful. We proposed that thoughts become stressful when they represent the self as engaged in a stressful situation (Lebois, Hertzog, Slavich, Barrett, & Barsalou, submitted). We will refer to such self-engagement as *immersion*. We further propose that self-engagement produces the quality of, *subjective realism* (Papies, Barsalou, & Custer, 2012), which is related to the construct of cognitive fusion in Acceptance and Commitment Therapy (Hayes, 2004). Here, subjective realism refers to mental simulations of stressful events that seem so real they trigger bodily stress responses. "Real" implies that the imagined event is experienced as if it were actually happening in the present moment, as if one had time travelled to the imagined event.

Mindfulness

One method for blocking subjective realism is mindfulness, characterized by present centered, non-evaluative awareness (Bishop et al., 2004; Kabat-Zinn, 1990). Research has documented many benefits of mindfulness across many domains of well-being, including, reduction in perceived stress, stress symptoms, rumination, negative thought avoidance, and emotional reactivity, coupled with enhanced attention and emotion regulation (for reviews see, Bishop et al., 2004; Brown, Ryan, & Creswell, 2007; Chiesa & Serretti, 2010; Gard, Hölzel, & Lazar, 2014; Keng, Smoski, & Robins, 2011; Lutz, Slagter, Dunne, & Davidson, 2008; Tang, Rothbart, & Posner, 2012). Clinical interventions have incorporated aspects of mindfulness (Acceptance Commitment Therapy, Dialectical Behavioral Therapy, Mindfulness Based Cognitive Therapy, Mindfulness Based Stress Reduction, MBSR) to improve functioning in mood, attention, and eating disorders (for reviews see, Grossman, Niemann, Schmidt, & Walach, 2004; Rubia, 2009; Hofmann, Sawyer, Witt, & Oh, 2010).

Neural mechanisms associated with mindfulness are specific to the component of mindfulness emphasized in training, but consistent patterns have emerged (Brefczynski-Lewis et al., 2007; for reviews, see Chiesa & Serretti, 2010; Tang et al., 2012; Vago, 2014,). Generally, novices and intermediate practitioners activate brain areas associated with effortful, voluntary attention (e.g., lateral prefrontal cortex, lPFC; parietal cortex), whereas, experts exhibit reductions in both these areas and the default mode network (e.g., medial prefrontal cortex; posterior cingulate cortex), while further exhibiting greater activity in dorsal anterior cingulate cortex (dACC), left insula, and striatum.

Extended practice vs. brief interventions. Most mindfulness research has focused on experts and experienced practitioners who have completed a course (e.g., 8 weeks of MBSR). Much less research addresses relevant cognitive abilities that already exist in individuals prior to undertaking mindfulness training. Is mindfulness completely learned in meditation training, or does it draw on preexisting cognitive processes?

A number of contemplative approaches, assume that individuals have natural contemplative abilities that just need to be uncovered (e.g., Dzogchen and Mahamudra in Tibetan Buddhism; Rinpoche, 1996; Rinpoche, 2004). Several researchers have also made this claim (Brown & Ryan, 2003; Brown et al., 2007; Kabat-Zinn, 2003; Taylor et al., 2011). In particular, researchers have proposed that two pre-existing cognitive abilities constitute basic mechanisms of mindfulness: attentional awareness and perspective shifting (Bishop et al., 2004). The attention mechanism maintains focus on present experience by regulating attention and inhibiting elaborative processing. The perspective shifting mechanism approaches thoughts and reactions with an air of curiosity, openness, and acceptance – observing all reactions without efforts to change their content. An important outcome of shifting perspective is an insight known as *decentering*: The realization that thoughts, feelings, and reactions are transitory patterns of mental activity that are not necessarily true representations of the self and events (Bishop et al., 2004; Brown et al., 2007; Teasdale, Segal, & Williams, 1995; see also "reperceiving," Shapiro, Carlson, Astin, & Freedman, 2006; "cognitive defusion," Hayes, 2004). From our perspective, decentering prevents subjective realism by disengaging self from simulated situations.

Consistent with the pre-existence of basic mindfulness abilities, increasing research demonstrates that very short mindfulness interventions produce immediate benefits. Some studies have addressed only attention (Arch & Craske, 2006; Delizonna, Williams, & Langer, 2009; Dickenson, Berkman, Arch, & Lieberman, 2013; Ditto, Eclache, & Goldman, 2006; Farb et al., 2007), others have addressed both attention and perspective shifting (Alberts & Thewissen, 2011; Broderick, 2005; Lutz et al., 2013;

Singer & Dobson, 2007; Zeidan et al., 2010; Zeidan, Gordon, Merchant, & Goolkasian, 2010; Zeidan, Johnson, Gordon, & Goolkasian, 2010), and a handful have emphasized decentering (Erisman & Roemer, 2010; Kross et al., 2009; Papies et al., 2012; Tincher, Lebois, & Barsalou, forthcoming). The majority of this work, however, is behavioral with little emphasis on decentering. In the study reported here, we assessed the neural mechanisms underlying immersion in stressful thoughts, together with the ability to disengage from such thoughts using the decentering process associated with mindfulness.

Experiment Overview

During a brief initial training, participants learned a mindful attention strategy for disengaging from events (decentering), and also practiced an immersion strategy. In a subsequent fMRI session, participants performed either mindful attention or immersion as they imagined experiencing mini-blocks of stressful and non-stressful events. On each trial, participants first read about an event for 6.9 sec and then performed the mindful attention or immersion strategy on it for another 6.9 sec. Of interest was the neural activity that each strategy exhibited over the course of the reading and strategy periods.

We predicted that mindful attention would engage brain areas associated with event simulation (e.g., sensorimotor), effortful attention and regulation (e.g., lPFC), and perspective shifting (AG), indicative of disengaging the self from simulations. Immersion, in contrast, should activate areas associated with self, emotion, and visceral states (e.g., ventromedial PFC, subgenual ACC, ventral attention network), producing the subjective realism of thoughts.

Method

Design and Participants

Design. The scanning session contained a completely crossed repeated-measures design with three independent variables: *period* (reading vs. strategy) X *strategy* (mindful attention vs. immersion) X *event* (stressful vs. non-stressful). As Figure 1 illustrates, four critical conditions occurred in the strategy X event sub-design (associated once with the reading period and once with the strategy period): (1) mindful attention stressful, (2) mindful attention non-stressful, (3) immersion stressful, (4) immersion non-stressful. For reasons explained next, each of these four conditions contained 30 reading period trials and 24 strategy period trials.

A mix of complete trials and catch trials allowed us to separate BOLD activations during the reading period from those during the strategy period (details provided in later sections). Catch trials constituted 20% of the total trials, enough to successfully isolate activations during the two adjacent periods (Ollinger, Corbetta, & Shulman, 2001; Ollinger, Shulman, & Corbetta, 2001). Each of the 4 critical conditions (defined above) contained 24 complete trials and 6 catch trials.

An active baseline task (visual detection) was used instead of a resting state baseline (details provided later). Because participants had to press a button to respond on the baseline task, it was analogous to the critical task that also required a button press. By subtracting the baseline from the critical conditions, we removed uninteresting activations associated with visual and motor processing that are not central to the event and strategy activations of interest. Furthermore, a resting baseline with no task typically engenders mind wandering that often involves self-related narrative processing (e.g., Mason, Norton, van Horn, Wegner, Grafton, & Macrae, 2007). Because self-related processing is central to stress (e.g., Dedovic, Aguiar, & Pruessner, 2009; Dickerson &

Kemeny, 2004), a resting baseline would have removed potentially germane activations from later analyses that establish activations in the critical conditions (e.g., cortical midline activity; Mason et al., 2007). An active baseline, therefore, was deemed more appropriate.

Participants. Thirty participants (15 female), drawn from the student populations of Emory and Georgia Tech University, were included in the complete repeated-measures design. Participants were 18-23 years old, with 50% Caucasian, 20% Asian, 17% other, 10% African American, and 3% American Indian (1 individual also identified as Hispanic or Latino). Three participants were dropped due to excessive head movement in the scanner, and one participant was dropped after disclosing that they had not followed directions (during the exit interview). These 4 participants were replaced to maintain a 30-participant sample with the aforementioned demographics. Typical imaging exclusion criteria were enforced. Any individuals who were left-handed, had metal implants, claustrophobia, were currently taking psychotropic medication, or who had any significant head injury in which they experienced a loss of consciousness, were excluded. Participants also had to be native English speakers and to have normal or corrected vision. Additionally, we excluded individuals with meditation experience, as we wanted to examine the mechanisms of mindful attention in non-meditators. Participants received $80 compensation for their time.

Materials

Scenarios. Critical events were 120 one-sentence scenarios (60 stressful, 60 non-stressful) that averaged 15 words in length. Each scenario contained second person ("you") references to promote self-engagement. Stressful scenarios all included interpersonal tensions relevant to college life, for example, "You have to tell your parents you failed a class and need to take summer school," "Your roommates had a party while you were gone, and now your landlord is threatening to evict you," and "Your professor asks for take-home midterms, and you realize you left yours at home." Non-stressful scenarios were written to match scene and character details from the stressful scenarios, but with non-threatening interpersonal interaction, for example, "You tell your parents you're considering taking a class over the summer to free up your fall schedule," "Your roommate says they decided to stay home while you went away last weekend," and "Your professor asks everyone to talk amongst themselves while taking a quick phone call outside."

To make the scenarios more ecologically valid, we drew ideas for events from a nation-wide sample of stressful events database (Almeida et al., 2002), and from undergraduate research assistants. In total, 572 stressful and non-stressful scenarios (286 each) were constructed and normed in a separate behavioral study for stressfulness, amount of self-threat, perseverative thought, expectation violation, efficacy, experience, familiarity, plausibility, valence, arousal, and certainty (Lebois, et al., submitted). The 60 most stressful scenarios with the least amount of variance in stressfulness were selected, along with their 60 matched non-stressful scenarios for use in the imaging experiment. Stressful and non-stressful scenarios did not differ in sentence length (stressful M = 15.33, SD = 3.07; non-stressful M = 15.52, SD = 2.46; $t(59) = -.39$, SE = .47, $p = .697$). On a Likert scale of 1 (low) to 7 (high), stressful scenarios were higher in perceived stressfulness (M = 5.86, SD = .37) compared to non-stressful scenarios (M = 1.34, SD = .29; $t(59) = 75.01$, SE = .06, $p < .001$). Stressful scenarios were also significantly different on core features that predict stress, including, threat, arousal, perseveration, negative valence, bodily imagery, violation of expectations, efficacy, and positive valence (Lebois et al., submitted). The SM reports details of these additional norming results.

Procedure

Each participant performed two training sessions, one scanning session, and a post-scan question period. Each session is addressed in turn (also see Figure 1).

Training session 1. Participants first completed self-report questionnaire measures of absorption, rumination, and mindfulness. The results for these measures do not bear on the current analyses and are not discussed further.

To ensure that participants fully understood and were comfortable performing mindful attention and immersion, a detailed training procedure was followed (see the SM for more complete details on this training). We adapted key concepts for this training from previous research (Lebois et al., submitted; Papies et al., 2012; Wilson-Mendenhall, Barrett, Simmons, & Barsalou, 2011). Papies et al. (2012) elicited reliable behavioral differences between mindful attention and immersion on an implicit approach task, using a similar but more concise training.

First, we introduced the concept of immersion, provided a definition, and presented examples. As described earlier, participants were asked to become completely absorbed in the experience of the scenarios, as if they were happening in the moment. They were to mentally time travel and experience the sensory details, physical sensations, feelings, emotions, and bodily states associated with the scenario vividly. Participants practiced immersing themselves in presented scenarios through a series of tasks that built up to the timing and procedure of the critical task.

Second, participants learned the distinction between complete and catch trials. As Figure 1 illustrates, complete trials contained a reading period, a strategy period, and a rating period (details later). During the reading period, participants were instructed to comprehend a presented event; during the strategy period, participants were instructed to perform either immersion (or mindful attention as described shortly) on the event; during the rating period, participants rated how well they were able to perform the strategy. As Figure 1 further illustrates, catch trials were exactly the same as the complete trials except that they only consisted of the reading period, with the strategy and rating periods excluded. Following instruction, participants practiced performing both complete and catch trials to become comfortable with each.

Third, participants received instructions on the left-right visual detection task that served as the active baseline. Participants then practiced the baseline task so that they would be comfortable performing it later in the context of complete and catch trials.

Fourth, we introduced the concept of mindful attention, provided a definition, and presented examples, following the same structure as the immersion training. As described earlier, participants were asked to remain aware of their current physical location while thinking about the scenarios. They were further asked to notice the kinds of reactions that they normally have during immersion, but rather than 'living' the event, they were instructed to simply observe their thoughts and reactions to it in the present moment. Participants were asked to perceive their thoughts about the stimuli as transitory mental states, not as parts of the scenarios, but as their psychological responses to them. Essentially, we briefly taught participants the decentering component of mindfulness, allowing them to disengage from the events being imagined.

Lastly, participants practiced one run of the experimental task, including complete trials, catch trials, and the active baseline task. All these elements had been practiced previously in training, but had not yet been implemented together. The practice run contained 1 block of 10 immersion trials interwoven with baseline trials, and 1 block of 10 mindful attention trials also interwoven with baseline trials (16 complete trials, and 4 catch trials). Within each of these blocks was a mini-block of 5 stressful scenarios and a mini-block of 5 non-stressful scenarios.

At the onset of a 10-event block, participants received a cue, “IMMERSION” or “MINDFUL,” presented in white font on a black background that lasted for 2.3 sec followed by 2.3 sec of a black screen. Cues only occurred at the beginning of a strategy block, not before each trial, nor when participants switched between stressful and non-stressful scenario mini-blocks within a strategy block.

As Figure 1 illustrates, a complete trial consisted of the following events. (1) During the *reading period*, a one-sentence scenario was presented visually in white font on a black background for 6.9 sec. During this period, the task was simply to read and understand the sentence. (2) During the *strategy period*, the sentence changed to a dark gray font, cuing participants to adopt either the mindful attention or immersion strategy for 6.9 sec, depending on the type of block. (3) During the rating period, the screen switched to “Immersion rating?” or “Mindful rating?” for 2.3 sec in a lime green font on a black background. Participants’ task was to rate their ability to immerse (or mindfully attend) on a scale of 1 (not at all) to 5 (high). On catch trials, only the reading period occurred, not followed by the strategy and rating periods. One trial in each mini-block of five trials was randomly chosen to be a catch trial.

After every complete trial or catch trial, a left-right visual detection task baseline trial occurred. For a randomly jittered interval of 4.6 to 9.2 sec, the following sentence appeared on the black screen in a dark gray font, "Find the cue and then get ready to press the direction indicated by it." This sentence was of comparable length to the critical scenarios. At a random point during the variable interval, the word "left" or "right" appeared somewhere within the sentence, occluding letters within the sentence (e.g., "Finlefte cue and then get ready to press the direction indicated by it."). A rating screen then appeared for 2.3 sec with the word "Direction?" in lime green font. Participants pressed the left most button on the response box if they saw the word "left," the right most button if they saw the word "right," and the middle button if they missed the direction word. The rating screen was followed by 2.3 sec of a blank black screen before proceeding to the next trial. A 6.9 sec black screen appeared between the immersion and mindful attention blocks, and a 16 sec black screen occurred at the end of each run.

Training session 2. Participants were not asked to practice any of the strategies outside of the lab training sessions. Training session 2 occurred 1 to 2 days after the first session. Participants reviewed the immersion and mindful attention strategies, completed one more practice run, and then proceeded immediately to the fMRI scanner.

Scanning session. In the scanner, participants completed six runs that followed the same procedure as the aforementioned practice run. To avoid repetition effects, participants viewed novel scenarios during the experimental task in the scanner not seen during practice. The scan session lasted approximately 1 hr, including one T1 anatomical scan and 54 min of critical functional scans on the experimental task.

Each of six runs, lasting about 9 min each, contained two strategy blocks, one for mindful attention and one for immersion. Each strategy block contained one mini-block of 5 stressful events and one mini-block of 5 non-stressful events, with each mini-block containing 4 complete trials and 1 catch trial randomly ordered. Within each strategy block, the assigned strategy always remained constant across the two mini-blocks (e.g., mindful attention was performed first for stressful or non-stressful events and then for the other type of event). Eight different versions of the experiment were constructed, counterbalancing run order, block order, mini-block order, and the assignment of each event to mindful attention and immersion.

Post scan session. As a manipulation check, participants rated the critical scenarios for overall stressfulness on a 1 (not at all stressful) to 7 (highly stressful) scale. Finally, participants completed an exit interview in which they described what they were doing during each strategy, and how difficult it was for them.

Scan Sequence

All scans were completed on a Siemens 3T Trio scanner with a 32-channel head coil. The scan sequences were adapted from Feinberg et al. (2010) and Moeller et al. (2010). T2* weighted functional EPI scans had a TR of 1150 ms, a TE of 24 ms, a flip angle of 45^{o}, a FOV of 220 mm x 220 mm, a matrix size of 74x74, 64 slices, and 3x3x2 voxels with whole brain coverage. The T1 anatomical scans had a TR of 2250 ms, a TE of 2.99 ms, a flip angle of 9°, a matrix size of 256 ×256, 160 sagittal slices, and 0.9375x0.9375x0.9375 voxels. The functional sequence used a multi-band acceleration factor of 8 with interleaved geometry and no PAT mode. We used a nonselective IR in which TI equaled 900ms. We also used a partial Fourier of 7/8, and a GRAPPA acceleration factor of 2, and 36 phase encode reference lines.

Image Preprocessing and Statistical Analyses

AFNI was used to perform standard preprocessing including skull stripping and slice time correction (Cox, 1996). FSL (Smith et al., 2004) was used to correct spatial intensity variations (Zhang, Brady, & Smith, 2001) and to perform spatial normalization and co-registration (Andersson, Jenkinson, & Smith, 2010; Jenkinson & Smith, 2001; Jenkinson, Bannister, Brady, & Smith, 2002). See the SM for further details on various aspects of the analyses described below.

During preprocessing, data for individual participants were resampled to 3x3x3 voxels and smoothed with a 6 mm kernel. Regression analysis was then performed on individual participants, using a canonical hemodynamic response function that modeled the reading and strategy periods as 6.9 sec blocks. The 29 regressors included 4 during the reading period for the critical conditions (mindful attention stress, mindful attention nonstress, immersion stress, immersion nonstress conditions), 4 during the strategy period for the critical conditions, 1 for cue, 6 for rest, 8 for strategy ability and baseline ratings, and 6 for motion parameters. All regressors were established with respect to the active baseline.

Each individual's beta coefficients for the 8 critical conditions in their regression analysis were entered into a random effects whole brain analysis at the group level. Group-level contrasts were computed using dependent *t* tests on each voxel. All group-level maps mentioned in the conjunction and contrast analyses to follow were thresholded at a voxel-wise level of $p < .005$ and a corrected extent threshold of .05 (26 3x3x3mm voxels), estimated using AFNI's Monte Carlo Clustsim routine.

Conjunction analyses. As Figure 2 illustrates, the eight condition maps in the period X strategy X event design (relative to the active baseline) were examined in a series of conjunction analyses. Significance in all conjunction analyses was established using the $p < .005$ level for individual voxels and the $p < .05$ level for spatial extent just described. Of primary interest was examining the neural activity in each condition relative to baseline across the reading and strategy periods. What activations did the conditions have in common? What activations were unique?

To assess these issues, we first performed two conjunction analyses for the reading period, one for the two stressful conditions (mindful attention stressful, immersion stressful), and one for the two non-stressful conditions (mindful attention non-stressful, immersion non-stressful). As Step 1 across Panels A and B of Figure 2 illustrates, these two initial conjunction analyses identified neural activity common across stressful events (S) and across non-stressful events (N) during the reading period. We then performed a third conjunction analyses of the voxels in S and N to establish the neural activity common across both stressful and non-stressful events during reading (A). Finally, in Step 2, we removed the common activity to extract the unique neural activity during reading in each of the four critical conditions: mindful attention stressful, immersion stressful, mindful attention non-stressful, and immersion non-stressful (U-MS, U-IS, U-IN, U-MN, respectively, in Figure 2).

As Figure 2 further illustrates in Panels C and D, three analogous conjunction analyses were performed for the strategy period. Again, shared voxels for stressful events (S), non-stressful events (N), and all events (A) were established, as were unique voxels for the four critical conditions (U-MS, U-IS, U-IN, U-MN).

As described in the Results section, assessing these 6 sets of shared voxels and 8 sets of unique voxels allowed us to characterize changes in brain activity relative to baseline for each condition. As we will see, mindful attention and immersion differed significantly in how neural activity changed relative to baseline across the reading and strategy periods for stressful and non-stressful events.

Finally, we examined each of the eight unique voxel sets for the extent to which they contained voxels from important neural networks. Using masks that Yeo et al. (2011) established from a large scale resting state study, we counted the number of voxels in each unique voxel set that resided in Yeo et al.'s visual, somatosensorimotor, limbic, default mode, frontoparietal control, ventral attention, and dorsal attention networks. Of interest was whether these seven networks played different roles in our eight critical conditions.

Contrast analyses. Finally, we performed linear contrasts within the reading period and the strategy period. Of interest in each period was whether neural activity differed significantly between the mindful attention vs. immersion strategies.

Results

Behavioral Results

Participants' task ratings during the scan session on the 1 to 5 scale indicated that they were able to perform the mindful attention and immersion strategies effectively (mindful attention stressful: M = 3.75, SD = .70; mindful attention non-stressful: M = 3.89, SD = .63; immersion stressful: M = 3.85, SD = .73; immersion non-stressful: M = 3.77, SD = .71). The lack of main effects for strategy type and event type indicate that both strategies were performed equally easily for both event types (strategy type: $F(1, 29) = .06$, $p = .808$, $\eta p^2 = .002$; event type: $F(1, 29) = .13$, $p = .719$, $\eta p^2 = .132$; interaction, $F(1, 29) = 2.28$, $p = .142$, $\eta p^2 = .073$).

Participants' event ratings during the post scan session on the 1 to 7 scale indicated that they found the non-stressful scenarios to be low in stressfulness ($M = 1.55$, $SD = .36$) and the stressful scenarios to be high ($M = 5.7$, $SD = .81$), with these ratings differing significantly ($t(29) = 31.90$, $SE = .13$, $p < .001$, $d_z = 4.12$).

Shared Activations in the Conjunction Analyses

As Figure 2 (Step 1) illustrates, two conjunction analyses first established the overlap in neural activity relative to the baseline, once in the two stressful conditions (voxels labeled S in Figure 2), and once in the two non-stressful conditions (voxels labeled N). In a third conjunction analysis, the shared activations for the stressful conditions and non-stressful conditions were assessed to establish neural activity shared across all four conditions (voxels labeled A). These conjunctions were completed for both the reading period (Figure 2, top panel), and the strategy period (Figure 2, bottom panel). In the Supplementary Materials, SM Tables 1 and 2 provide detailed lists of shared clusters, illustrated in SM Figures 1 and 2.

Reading period. The four conditions in the reading period shared large clusters of neural activity, especially in the temporal poles, through middle temporal gyrus (MTG), fusiform gyrus, up into angular gyrus (AG), precuneus, lingual gyrus and primary visual cortex, and down into the cerebellum. The four conditions also shared extensive lateral prefrontal cortex activity (lPFC), and orbitofrontal cortex (OFC) activity, in particular on the left. Large clusters were also shared medially, especially in the mPFC, mOFC, posterior cingulate cortex (PCC), and medial temporal lobe structures (e.g., hippocampus, amygdala, parahippocampal gyrus). These shared activations across all four conditions are likely related to language processing (e.g., Broca's area), beginning to simulate the content of the events (e.g., temporal poles, PCC, hippocampus), and establishing event self-relevance (e.g., midline cortical structures) with conscious effort (e.g., lPFC; Kross et al., 2009).

In the majority of cases, activations shared by just the two stressful conditions bordered closely on activity shared by all four conditions. Clusters in the right dmPFC, and brainstem, however, were unique to the stressful conditions. These activations were perhaps indicative of greater self-referential processing and arousal for stressful events. Activations shared by just the two non-stressful conditions bordered activity shared by all four conditions in every case.

Strategy period. The four conditions in the strategy period shared clusters similar to clusters common across the reading period. Again, large activations spanned the temporal poles, through MTG into AG and the precuneus, and also down into the cerebellum. Large activations were also shared in lPFC and sensorimotor areas. Additionally, midline cortical structures exhibited large overlaps across the four conditions, ranging from mPFC, dorsal anterior cingulate cortex (dACC) to PCC. This pattern of shared activity is likely associated with processing situation details, people, and context (e.g., parahippocampal gyrus, fusiform gyrus, temporal poles, pre and postcentral gyrus), establishing event self-relevance (midline cortical structures, insula), and actively engaging with the event (lPFC). The lPFC activation often occurs in tasks with an element of reappraisal (e.g., Kross et al., 2009), and the cerebellum is increasingly understood to be involved in emotion regulation (Schmahmann et al., 2007).

Most activations shared by just the two stressful conditions during the strategy period again bordered activity shared by all four conditions. Additionally, stressful conditions shared extensive activity in the dmPFC, paracentral lobule, and cerebellum. These additional activations may reflect more salient self-related processing in the stressful events, and also more extensive sensorimotor activity.

Activations shared by just the two non-stressful strategy period conditions bordered almost exclusively on activity shared by all four conditions, with the exception of greater parahippocampal gyrus activity (PHG). As discussed later, this activity may reflect attempts to establish situational details in these mundane scenarios that made applying immersion and mindful attention possible.

Unique Activations in the Conjunction Analyses.

As Figure 2 (Step 2) illustrates, we removed the shared clusters just described to establish the unique clusters that became active above baseline in each condition (voxels labeled U-MS, U-IS, U-MN, U-IN in Figure 2). As Figure 3 illustrates, the four conditions exhibited large differences in unique activations across the reading and strategy periods. As Figure 4 further illustrates, the four conditions exhibited large differences in the neural networks active during these periods. We address each set of results in turn. Tables 1 and 2 provide the complete lists of unique clusters that became active above baseline in each condition, for the reading and strategy periods, respectively. Figure 5 illustrates examples of these unique activations (panels A-D).

Stressful events. During mindful attention, participants exhibited much more unique neural activity above baseline during the reading period than during the strategy period (Figure 3). Although they had been instructed to only read events during the reading period (and *then* to apply mindful attention during the strategy period), they appeared to begin applying the strategy immediately while reading. Because mindful attention aims to regulate immersion in stressful events, doing so immediately while comprehending them could prevent strong affective and embodied responses from later developing. As a further consequence, less neural activity may have occurred during the strategy period, because the stressful events had already been regulated during the reading period. The brain areas active in the later network analysis support this account.

The immersion condition exhibited the opposite pattern for the stressful events, showing much more unique activity during the strategy period. Thus, the distributions of unique neural activity above baseline across the reading and strategy periods differed significantly for mindful attention vs. immersion ($\chi^2(1) = 2246.87$, $p < .001$). During immersion, participants appeared to minimize processing of the stressful events initially, waiting to begin completely simulating the situated details of these events until the strategy period. Whereas mindful attention appeared to encourage immediate regulation of the stressful events, immersion appeared to encourage later elaboration (cf. Kavanagh, Andrade, & May, 2005).

Non-stressful events. For the non-stressful events, much more processing generally occurred during the strategy period for both mindful attention and immersion (Figure 3). Because the non-stressful events were quite mundane, they may not have afforded strong affective and bodily responses initially. As a result, it may have been difficult to produce the regulatory activity associated with mindful attention during the reading period. Instead, participants may have worked harder during the strategy period at generating thoughts relevant to mindful attention. As a consequence, the distributions of unique neural activity for mindful attention across the reading and strategy periods differed for stressful vs. non-stressful events ($\chi^2(1) = 1567.59$, $p < .001$). For immersion, participants again appeared to hold off on immersing themselves in the non-stressful events until the reading period, as they had done for the stressful events.

Network Analysis of the Unique Activations

Using the seven resting state networks established in Yeo et al. (2011), we examined the unique clusters above baseline in the visual, somatosensorimotor, limbic, default mode, frontoparietal control, ventral, and dorsal attention networks. As Figure 4 illustrates, unique activations in these networks varied significantly across the four conditions.

Stressful events. For mindful attention to stressful events, the distribution of unique clusters across the seven networks differed significantly between the reading and strategy periods ($\chi^2(6) = 512.86$, $p < .001$). Initially during the reading period, large amounts of neural activity occurred in somatosensorimotor, visual, and limbic networks, with some dorsal attention network activity, suggesting that participants were simulating the scenarios and attempting to regulate them. During the strategy period, these activations decreased, suggesting that participants were no longer simulating the scenarios and emotional reactions to them as vividly, given that they had been down-regulated during the reading period (as described earlier).

Interestingly, mindful attention to stressful events produced large amounts of DMN activity during both the reading and strategy periods. Other mindfulness research only demonstrates decreases in DMN hubs (e.g., mPFC, PCC) for expert meditators (or for novices at lower thresholds; Farb et al., 2007). Because the DMN is implicated in internally goal-directed activity (e.g., Spreng et al., 2010), it may be highly engaged when first learning mindfulness practices.

For immersion in stressful events, the reading and strategy periods also exhibited large differences in the distributions of unique neural activity across networks ($\chi^2(6) = 575.35$, $p < .001$). During the strategy period, large increases occurred in the somatosensorimotor, limbic, default mode, and ventral attention networks. As suggested earlier, participants may have waited until the strategy period to immerse themselves in the stressful events, simulating both the external situations and their internal reactions to them, especially their personal salience.

Non-stressful events. For mindful attention to non-stressful events, the distribution of unique clusters differed between the reading and strategy periods ($\chi^2(6) = 896.72$, $p < .001$). During the strategy period, visual activity decreased while somatosensorimotor activity increased, suggesting that participants increasingly imagined acting in the non-stressful events. Increased activity in the DMN, the FPCN, and both attention networks during the strategy period further suggests that effortful processing increased as well. Because the non-stressful events did not readily afford emotional and bodily reactions, participants may have worked harder to produce thoughts relevant for mindful attention.

For immersion in non-stressful events, the distribution of unique clusters again differed between the reading and strategy periods ($\chi^2(6) = 318.22$, $p < .001$). Similar to mindful attention, somatosensorimotor activity increased, suggesting increased action engagement in the non-stressful situations. Also similar to mindful attention, activity in the FPCN and ventral attention networks increased, suggesting again that effortful processing increased, perhaps working harder to generate affective and bodily responses. Unlike mindful attention, DMN activity decreased, perhaps reflecting a greater focus on the physical situation for immersion than on mental states for mindful attention.

Critical comparisons between conditions. A first pair of critical comparisons demonstrates how differently mindful attention and immersion operated for stressful events across the reading and strategy periods. During the reading period, the distributions of network activity differed substantially between mindful attention and immersion for the stressful events ($\chi^2(6) = 418.45$, $p < .001$). Specifically, mindful attention exhibited much more activity in the visual, somatosensorimotor, and limbic networks than did immersion, suggesting greater simulation of the stressful events. Mindful attention also exhibited great activity in the DMN, FPCN, and both attention networks, suggesting greater processing effort and regulation during the reading period.

The distributions of network activity for mindful attention and immersion also differed substantially during the strategy period for stressful events ($\chi^2(6) = 669.76$, $p < .001$). Whereas somatosensorimotor activity was higher for immersion, DMN activity was higher for mindful attention, suggesting greater focus on the situation for immersion and greater focus on thoughts for mindful attention. Activity in both attention networks was also higher during immersion, suggesting greater attention to both personal salience and imagined external situations. Research demonstrates that there is extensive overlap for visual mental imagery and visual perception in frontal and parietal regions associated with the DAN (Ganis, Thompson, & Kosslyn, 2004), which may account for the increased processing in this network for immersion.

A second critical pair of comparisons demonstrates how differently mindful attention operated for stressful vs. non-stressful events. During the reading period, mindful attention was associated with higher activity across all seven networks for the stressful events than for the non-stressful events ($\chi^2(6) = 955.22$, $p < .001$). In particular, mindful attention especially engaged areas associated with processing stressful situations both physically (visual, somatosensorimotor) and internally (limbic, DMN), suggesting greater simulation and regulation of the stressful events. Conversely, during the strategy period, greater activity generally occurred for the non-stressful events ($\chi^2(6) = 454.36$, $p < .001$), again perhaps because greater effort was required to generate thoughts relevant for performing mindful attention.

Linear Contrast Analyses

In the conjunction analyses just presented, we focused on how neural activity increased significantly above baseline differently across conditions. As we saw, mindful attention and immersion differed considerably in how neural activity increased across the reading and strategy periods, for the stressful and non-stressful events. Next we address direct differences between mindful attention and immersion in neural activity, rather than contrasting the two strategies with respect to differences in significant neural activity above baseline. Specifically, we report the results of linear contrasts between mindful attention and immersion, first in the reading period, and then in the strategy period. In the results reported here, we collapsed across event type, given that the individual contrasts for stressful and non-stressful events were comparable but weaker (see SM Table 3 for the individual contrasts).

Reading period. The contrast between mindful attention and immersion for the reading period exhibited one small cluster with greater activity for mindful attention in the right inferior occipital gyrus (IOG, BA 18, spatial extent = 27, peak t = 3.75, center = 27, -81, -9). No other significant clusters emerged.

Notably, the relative lack of direct significant differences between mindful attention and immersion during the reading period contrasts with the large differences in significant neural activity above baseline reported earlier in Figures 3, 4, and 5 (also in Tables 1 and 2). Although mindful attention and immersion differed considerably in how neural activity increased significantly above baseline in the conjunction analyses, they didn't differ as much in their overall levels of neural activity in the linear contrasts.

From examining activation levels in different conditions, we concluded that the follow explanation underlies this pattern of results. Typically in the conjunction analyses, activation increased above baseline for *both* mindful attention and immersion in similar brain areas. Interestingly, however, these activations were often large enough to achieve significance for either mindful attention or immersion, but not for both (see SM Tables 1 and 2 for many additional activations that reached significance for *both* strategies). As a result, mindful attention sometimes activated brain areas significantly above baseline, with activity in the same areas also above baseline for immersion, but not significantly so (and vice versa). As a consequence, direct contrasts between activation levels for mindful attention and immersion often did not reach significance, because both had increased above baseline. Consistent with this conclusion, additional clusters become significant in the linear contrasts when voxel and/or extant thresholds are lowered.

Thus, our results offer two perspectives on the neural activity associated with mindful attention and immersion. On the one hand, the two strategies differ considerably in the neural activity that they produce above baseline. On the other hand, they engage similar brain areas, such that direct contrasts between them are often not significant at standard thresholds. When direct contrasts *are* significant, they indicate especially large differences between the two strategies. In our opinion, the results reported next for the strategy period illustrate such differences.

Strategy period. The contrast between mindful attention and immersion for the strategy period exhibited the differences listed in Table 3 and illustrated in Figure 5E. Brain areas more active for mindful attention than for immersion were associated with executive and attentional control (lPFC), augmented inhibitory control (mPFC, BA 8), shifting between 1st and 3rd person perspectives, specifically external agency attribution (AG), and visual activity (inferior and middle occipital gyrus). Because participants were inexperienced with mindfulness, they may have needed to exert greater effort during mindful attention than during immersion, thereby engaging executive and regulatory areas. Lack of expertise with mindful attention may have required greater shifts in perspective and agency than did the more natural and familiar process of immersion. Visual activity may be indicative of increased external attention or attention on imagined situations.

Conversely, areas more active for immersion than for mindful attention included the subgenual cingulate cortex (sgACC), ventral anterior cingulate cortex (vACC), and ventromedial prefrontal cortex (vmPFC)/orbital frontal cortex (mOFC). As established elsewhere, these areas are often involved when integrating visceral states (Vogt, 2005), monitoring and processing reward (Elliott, Dolan, and Frith, 2000), attending to feelings

(Kross et al., 2009), and labeling stimuli as self-relevant (Northoff & Bermpohl, 2004). Thus, immersion appeared to engage stronger self, bodily, and affective responses than did mindful attention, consistent with engaging oneself in events physically, becoming immersed in them, and experiencing them as subjectively real.

The activations that differed significantly between mindful attention and immersion during the strategy period suggests that mindful attention caused a shift in perspective that disengaged the self from simulated events (decentering). Specifically, activations in AG, lPFC, and mPFC may have shifted perspective such that a sense of self, as implemented in sgACC, vACC, vmPFC, mOFC, was no longer experienced as being engaged with imagined events. Instead, these events were experienced as transitory mental states in the current moment.

Discussion

As the conjunction analyses illustrated, mindful attention and immersion produced different distributions of neural activity for stressful events with respect to baseline activity. Whereas mindful attention immediately engaged brain areas associated with simulation, regulation, and perspective shifting while reading about stressful events, immersion waited to up-regulate neural activity until the strategy period. By operating quickly, mindful attention may serve to down-regulate potentially stressful affective and bodily responses before they have a chance to develop. Besides reflecting a greater willingness to engage immediately with unpleasant states, rapid decentering may reduce emotional reactivity (Bränström et al., 2010; Brown, Ryan, & Creswell, 2007; Keng, Smoski, & Robins, 2011; see also desensitization, Baer, 2003). Indeed engaging with negative experience has the potential to reduce experiential avoidance, a key goal in DBT and ACT (Hayes, Luoma, Bond, Masuda, & Lillis, 2006; Keng, Smoski, & Robins, 2011).

Interestingly, mindful attention exhibited different distributions of neural activity for stressful vs. non-stressful events. During the reading period, more neural activity occurred above baseline for stressful events, suggesting that they afford salient affective and bodily responses that mindful attention can regulate. Conversely, non-stressful events produced greater neural activity during the strategy period, suggesting that greater effort was required to generate appropriate thoughts relevant for applying mindful attention.

Finally, direct contrasts between mindful attention and immersion found, first, that both strategies activate many similar areas, and second, that a small subset of areas were significantly more active for one strategy vs. the other. Whereas mindful attention was more active in areas associated with regulation, attention and perspective shifting, immersion was associated with more processing of self and bodily states. Putting the contrast results together with those from the conjunction analyses, mindful attention appeared to produce decentering by rapidly disengaging embodied senses of self from stressful situations so that affect did not develop.

Relations to Previous Neuroimaging Findings

Relative to immersion, mindful attention exhibited significantly less neural activity in ventral medial frontal cortex (sgACC and vmPFC/mOFC cluster). As much previous research has found, these areas are associated with integrating visceral, autonomic, and affective states, representing the reward value of stimuli, and labeling it as self-relevant (e.g., Ressler & Mayberg, 2007; Kross et al., 2009; Greicius, et al., 2007;

Northoff & Bermpohl, 2004), suggesting that these areas could contribute to the experience of subjective realism. Several recent studies have similarly found that mindfulness is associated with low activity in these areas (e.g., Farb et al., 2007; Kross et al., 2009; Westbrook et al., 2013). Thus, our finding suggests that mindful attention down-regulates these areas as well as being consistent with our proposal that decentering results from disengaging self from imagined situations.

Conversely, mindful attention produced higher activations in brain areas associated executive processing (lPFC) and inhibitory control (mPFC, BA 8). Activity in these regions is increasingly recognized to be a hallmark of mindfulness in inexperienced meditators, requiring more effort in novices than experts (e.g., Creswell et al., 2007; Farb et al., 2007; 2010; Tang, Rothbart, & Posner, 2012). Likewise, several activations for mindful attention overlapped with the frontoparietal control network, FPCN (e.g., lPFC, superior mPFC, AG) and the dorsal attention network, DAN (e.g., SFG/FEF, MTG). Whereas the FPCN facilitates goal-directed cognition through executive control, the DAN controls externally directed attention (Spreng et al., 2013). Our occipital cortex activity is close to the SOG hub in the DAN, and may also be indicative of greater externally-oriented attention. Other research similarly reports increased mPFC (BA 8) activity in novice meditators related to down-regulating emotional reactions (Taylor et al., 2011), and similar occipital cortex activation (e.g., Brefczynski-Lewis et al, 2007; Goldin & Gross, 2010; Taylor et al., 2011).

Greater activity occurred in parietal cortex, in particular left AG and IPL for mindful attention. Similar activations are associated with high trait mindfulness (Dickenson et al., 2013), and with increased gray matter in this area following MBSR

(Hölzel et al, 2011). AG activity is associated with transferring attention to a relevant target (Gottlieb, 2007; Seghier, 2013), and with shifting between first and third person perspectives of the body (Blanke et al., 2005). Interestingly, our AG coordinates are closest to those for activity associated with external agency attribution (Seghier, 2013; Sperduti, Delaveau, Fossati, & Nadel, 2011), again suggesting that decentering may block ascribing simulated events to the self.

Additionally, activity for mindful attention occurred in the brainstem and cerebellum. Hölzel et al. (2011) reported increased gray matter in both these regions following MBSR. Whereas the brainstem contributes to arousal level and mood (Singleton et al., 2014), the cerebellum contributes to emotion regulation (Schmahmann et al., 2007)**.** Thus, activity in these areas may reflect participants attempting to down-regulate affect.

The contrast analyses did not demonstrate differential activity for internally-oriented self-referential processing in the DMN (e.g., mPFC, PCC; Buckner & Carroll, 2007). Consistent with previous literature, reduced DMN activity primarily occurs for expert meditators, or for novices at lower thresholds (e.g., Farb et al, 2007; Taylor et al., 2011; Brefczynski-Lewis et al., 2007). Many novice studies actually report higher activation in mPFC regions relative to experts, perhaps reflecting greater regulation of thought (Brefczynski-Lewis et al, 2007; Hölzel et al, 2007; Taylor et al., 2011) and emotion (Modinos et al, 2010; Ochsner et al., 2002; Ochsner and Gross, 2005).

Implications for Extended Practice and Intervention

We found that brief mindful attention training produced immediate changes in how people process stressful events. Such rapid acquisition of a meta-cognitive strategy suggests that all individuals possess the basic decentering mechanism associated with mindfulness. Much additional research demonstrates that novices can also draw immediately on attentional mechanisms (e.g., Arch & Craske, 2006), further demonstrated in the engagement of multiple attention and control networks here. As such findings indicate, the benefits of being more mindful can begin right away.

We hasten to add, however, that the non-meditator mindfulness skills demonstrated here lie on the earliest part of the learning curve. As much research shows, time spent in meditation practice is correlated with a wide variety of behavioral and neural changes, and with well-being (Carmody & Baer, 2008; Chiesa & Serretti, 2010; Hölzel et al., 2011). Thus, there is clearly much more to mindfulness practice than our results demonstrate. An important goal for future work is to better understand how these initial skills develop in extended practice.

Nevertheless, it appears that a wide variety of mindfulness interventions can capitalize on these initial skills. Clinicians can assume that most people have the basic cognitive abilities to begin performing mindfulness, and that clients are likely to immediately begin showing benefits. Again, however, these skills and benefits are likely to increase considerably with regular practice. Much, too, remains to be learned about the underlying mechanisms that increasingly produce benefits of mindfulness over the course of a clinical intervention.

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Author Contributions. LAML, LWB, EKP, LFB, KG, and KQ developed the initial study concept and design. LAML played the primary role in implementing, running, and analyzing the experiment in the Barsalou Lab at Emory University. LWB played central roles in implementing the experiment, analyzing the results, and managing the project. KG and RC also played central roles in implementing the procedure. KG played a leading role in developing and implementing the analyses. VK assisted with programming related to a preliminary imaging analysis. KQ and RC played central roles in analysis and interpretation of peripheral physiological data not reported in this manuscript. LAML, LWB, EKP, LFB, and KG contributed to the interpretation of the results. LAML, and LWB drafted the manuscript, and all authors will contribute to revising it. LWB and LFB are joint senior authors. All authors will approve the final version for submission.

Acknowledgments. We are grateful to David Almeida for sharing his stressor database, Taryn Colton, Hailey Friedman, and Bridget Warren for assistance with sampling the stressful life events, Michael Larche for assistance with MRI set up, Wendy Hasenkamp for assistance with an earlier design of this experiment, and Robyn Fivush, Jim Rilling, Kim Wallen, and Christine Wilson-Mendenhall for comments on an earlier version of this manuscript.

Declaration of Conflicting Interests. The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Funding. Work on this article was supported by NIH NRSA award 1 F31 AT007130-01 and 5 F31 AT007130-02 to Lauren McDonough Lebois at Emory University, and by an NIH Director's Pioneer Award DPI OD003312 to Lisa Feldman Barrett at Northeastern University, with a sub-contract to Lawrence Barsalou at Emory University.

Table 1. Uniquely active clusters for mindful attention and immersion to stress events during the reading and strategy periods (from two conjunction analyses, one for each period).

Cluster	Brain Region	Brodmann Area	Spatial Extent	Peak *t*	Center x	Center y	Center z
Reading Period: Mindful Attention (Stress Events)							
1	R MTG	21	633	7.07	48	3	-21
	R STS						
	R STG	22, 39					
	R ITG	20					
	R Temporal Pole	38					
	R Fusiform Gyrus	20					
	R PHG	36, 35					
	R lOFC	47					
	R Amygdala						
	R Culmen						
	R Tuber						
	R Cerebellar Tonsil						
	R Inf Semi-Lunar Lobule						
	R Pyramis						
	R Uvula						
2	L ITG	20	570	7.43	-42	-9	-30
	L Temporal Pole	38					
	L STS						
	L MTG	21					
	L Fusiform Gyrus	36, 37					
	L IOG	18					
	L Lingual Gyrus	19					

	L Uncus	20, 36					
	L PHG	35, 28					
	L Hippocampus						
	L Thalamus						
	B PCC	31					
	B Precuneus	7					
	L Culmen						
	L Declive						
3	R SFG	9	134	6.57	-3	54	-18
	R dmPFC	9					
	B vmPFC	10					
	B mOFC	11					
	B vACC	32					
4	B Cerebellar Tonsil		92	5.05	12	-42	-42
5	R Precentral Gyrus	4	67	4.51	36	-24	45
6	R IOG	18	65	4.39	30	-93	0
	R Lingual Gyrus	18, 17					
7	R SFG/FEF	8	65	4.77	12	36	54
	R SMA	6					
8	R MFG	46	57	4.64	-51	24	24
	R dlPFC/MFG	9					
9	L Pyramis		50	4.68	-24	-75	-33
	L Inf Semi-Lunar Lobule						
10	L Lingual Gyrus	18, 17	49	4.67	-12	-96	-12
11	B Brainstem		48	4.61	-9	-21	-30
12	L MFG	6	47	4.73	-36	15	45

13	L STG	22	42	4.76	-54	-45	15
14	B SMA L dACC	6 32	42	4.29	-12	0	60
15	R STG R Posterior Insula	41 13	34	5.68	42	-21	12
16	B SMA	6	27	3.59	-6	-21	57
17	L Frontopolar Cortex	10	26	3.97	-18	45	39
Reading Period: Immersion (Stress Events)							
1	B Culmen B Brainstem		98	4.79	-15	-33	-9
2	B vACC B sgACC B mOFC	32 25 11	39	5.56	-3	24	-6
3	B dmPFC	9	28	4.43	0	45	30
Strategy Period: Mindful Attention (Stress Events)							
1	L vlPFC L mOFC	10 11	281	5.59	-3	54	-15
2	L STG L AG L IPL L Precuneus	39 39 40 19	188	6.17	-51	-60	39

3	L Precentral Gyrus	4	164	5.32	-15	-18	63
	L SMA	6					
	B Paracentral Lobule						
4	L ITG	20	148	5.12	-63	-42	-9
	L MTG	21					
5	L vlPFC	44, 45	88	4.46	-36	18	6
	L Anterior Insula	13					
6	R lOFC	47	77	4.77	42	24	-12
	R Temporal Pole	38					
7	B Brainstem		62	4.16	15	-36	-36
	R Cerebellar Tonsil						
8	R Pyramis		60	5.82	33	-78	-33
9	B dmPFC	9	59	5.15	-3	48	42
	B MFG/FEF	8					
10	L PHG		54	5.65	-15	-36	6
	L Thalamus						
11	R Precentral Gyrus	4	42	3.76	39	-24	48
	R Postcentral Gyrus	3, 40					
12	L Brainstem		41	4.43	-18	-36	-33
	L Cerebellar Tonsil						
13	L Lentiform Nucleus		40	4.20	-21	3	12
	L Lateral Globus Pallidus						
	L Thalamus						
14	R Inf Semi-Lunar Lobule		32	4.15	24	-69	-42

Strategy Period: Immersion (Stress Events)							
1	L mOFC	11	796	6.55	-12	-24	39
	B vmPFC	10					
	B dACC	32					
	B MCC	24					
	B SMA	6					
	B Paracentral Lobule						
	R dmPFC	9					
2	L Fusiform Gyrus	20, 37	376	8.01	-39	-30	-12
	L PHG	36, 34					
	L Uncus						
	L Amygdala						
	L Culmen						
3	R STG	22	278	6.11	57	-66	9
	R MTG	21					
4	L Postcentral Gyrus	2	221	5.34	-36	-18	45
	L Precentral Gyrus	4					
	L SMA	6					
5	L Putamen		178	7.32	-12	15	9
	L Caudate						
	L Lateral Globus Pallidus						
	L vACC/vmPFC	32, 10					
	L mOFC	11					
6	B RSC	29, 30	166	5.78	-12	-51	12
	B Precuneus	31, 7					
	B dPCC	31					
	R PCC	23					

7	R Putamen		140	5.69	18	12	9
	R Caudate						
8	R PHG		111	4.85	21	-12	-18
	R Mid Insula	13					
	R Claustrum						
9	R MTG	21	80	5.02	42	21	-24
	R Temporal Pole	38					
10	L Uvula		59	5.18	-24	-75	-30
	L Pyramis						
	L Inf Semi-Lunar Lobule						
11	L MFG/vlPFC	10	57	5.16	-30	42	27
	L SFG/dlPFC	9					
12	L MTG	37, 19	56	4.32	-42	-78	27
	L SOG	19					
13	R Cerebellar Tonsil		46	4.90	45	-45	-42
14	L Cerebellar Tonsil		34	5.04	-42	-60	-33
15	R v Anterior Premotor Cortex	44	31	5.33	60	9	12
16	R Fusiform Gyrus	20	30	4.77	42	-24	-3
	R STG	22					
	R PHG	36					
17	L Temporal Pole	38	29	4.83	-48	9	-6
	L Anterior Insula	13					
18	L Temporal Pole	38	26	3.89	-36	18	-27
	L lOFC	47					

Note. Clusters were thresholded at a voxel-wise level of $p < .005$ and a corrected extent threshold of .05 with 26 3x3x3mm voxels. L = left, R = right, B = bilateral, ACC = anterior cingulated cortex, AG = angular gyrus, d = dorsal, FEF = frontal eye fields, Inf = inferior, IOG = inferior occipital gyrus, IPL = inferior parietal lobule, ITG = inferior temporal gyrus, l = lateral, m = medial, MCC = middle cingulated gyrus, MFG = middle frontal gyrus, Mid = middle, MTG = middle temporal gyrus, OFC = orbitofrontal, PCC = posterior cingulated cortex, PFC = prefrontal cortex, PHG = parahippocampal gyrus, RSC = retrosplenial cortex, SFG = superior frontal gyrus, SFG = superior frontal gyrus, sg = subgenual, SMA = supplemental motor area, SOG = superior occipital gyrus, STG = superior temporal gyrus, STS = superior temporal sulcus, v = ventral.

Table 2. Uniquely active clusters for mindful attention and immersion to non-stress events during the reading and strategy periods(from two conjunction analyses, one for each period).

Cluster	Brain Region	Brodmann Area	Spatial Extent	Peak *t*	Center x	y	z
Reading Period: Mindful Attention (Non-stress Events)							
1	R Temporal Pole	38	237	6.40	33	12	-30
	R MTG	21					
	R ITG	20					
	R PHG	35, 28					
	R Uncus						
	R Amygdala						
	R Culmen						
2	L MTG	21	138	6.17	-45	6	-27
	L ITG	20					
	L Uncus	20					
	L PHG						
	L Hippocampus						
	L Amygdala						
	L Culmen						
3	L IOG	18	90	4.42	-36	-75	-18
	L Fusiform Gyrus	18					
	L Lingual Gyrus	18, 17					
	L Declive						
4	R IOG	18	73	4.64	27	-87	0
	R Lingual Gyrus	18, 17					
	R Declive						

5	B Cerebellar Tonsil		54	4.17	3	-51	-42
6	R Pyramis R Inf Semi-Lunar Lobule		50	5.65	24	-72	-39
7	L MFG/dlPFC	46, 8	38	4.39	-42	15	24
8	L PHG L Culmen	36	31	4.10	-9	-30	-6
Reading Period: Immersion (Non-stress Events)							
1	B vmPFC L dmPFC	10 9	150	4.68	-9	66	9
2	L SFG/FEF L Premotor Cortex	8 6	99	5.68	-36	15	51
3	R MTG R STG	39 22, 39	92	4.85	51	-66	21
4	R Fusiform Gyrus R PHG R Uncus	20, 37 36 20	67	6.63	36	-30	-18
5	L PHG L Culmen	36, 28	59	5.86	-12	-33	-18
6	L lOFC L Temporal Pole	47 38	51	5.47	-27	18	-27
7	R Tuber R Cerebellar Tonsil		49	4.95	24	-63	-30
8	R Postcentral Gyrus R Precentral Gyrus	3 4	44	4.98	39	-21	45

9	R ITG R STS	21	42	5.05	66	-6	-12
10	B mOFC	11	42	5.30	0	30	-21
11	L Culmen		33	4.30	-15	-42	-6
12	L AG L Precuneus L SOG	39 19 19	32	5.02	-30	-78	39
13	R Temporal Pole	38	31	5.74	48	3	-39
14	L Culmen L Tuber		30	5.20	-42	-36	-27
Strategy Period: Mindful Attention (Non-stress Events)							
1	L ITG L MTG L STS L STG L Fusiform Gyrus L Temporal Pole B PHG L Uncus L Hippocampus L Amygdala L Supramarginal Gyrus L AG L IPL L Precuneus L MFG/vlPFC L Anterior Insula L lOFC	20 21 22, 39 20 38 35 40 39 39, 40 19 46 13 11, 47	1140	7.57	-48	6	-24

	B Brainstem						
	B Culmen						
	L Cerebellar Tonsil						
	L Fastigium						
2	L Premotor Cortex	6	750	5.67	-18	15	48
	L Precentral Gyrus	4					
	B SFG/MFG	6					
	L Postcentral Gyrus	3					
	L dmPFC	9					
	B dACC	32					
	L MCC	24					
	B Paracentral Lobule						
	B SMA	6					
3	R Cerebellar Tonsil		301	8.89	18	-78	-33
	R Inf Semi-Lunar Lobule						
	R Pyramis						
	R Uvula						
4	L MFG/vlPFC	46, 10	175	5.93	-18	57	3
	L vmPFC	10					
5	L Inf Semi-Lunar Lobule		80	4.93	-18	-78	-36
6	R STS		78	5.32	57	-21	-3
	R MTG	21					
	R Fusiform Gyrus	20					
	R PHG	36					
7	L MFG/FEF	8	55	5.01	-36	18	39
8	L Mid Insula	13	32	3.74	-33	-6	9
	L Claustrum						
	L Putamen						

9	R Postcentral Gyrus	2, 3, 40	30	3.48	33	-24	45
10	R Cerebellar Tonsil		29	4.87	9	-45	-39
11	L mOFC	11	27	4.19	-3	45	-18
12	L Putamen		27	4.13	-15	9	-6
	L Caudate						
13	R IFG/vlPFC	45	27	4.00	57	21	6
Strategy Period:	**Immersion (Non-stress Events)**						
1	L Paracentral Lobule		175	5.19	-6	-18	39
	L MCC	24					
2	B vmPFC	10	156	5.42	-6	27	-12
	B mOFC	11					
	B sgACC						
3	R MTG	37, 39	101	4.93	57	-60	6
	R MOG	37					
4	R Temporal Pole	38	77	4.80	42	6	-39
5	L PHG	20, 36, 37	71	5.16	-30	-39	-12
	L Culmen						
6	L Thalamus		63	5.10	-15	-30	3
	L PHG	30					
	L Lingual Gyrus	18, 19					
	L RSC	30, 29					
7	L lOFC	47	58	4.47	-18	3	12
	L Anterior Insula	13					

	L Claustrum L Putamen						
8	R MTG R STS	21	55	5.32	57	-6	-9
9	R RSC R dPCC	29, 30 31	55	4.73	6	-51	9
10	R Fusiform Gyrus R PHG R Hippocampus	20 36	53	5.24	27	-12	-18
11	R Precentral Gyrus R Postcentral Gyrus	4 3	46	4.36	36	-18	54
12	R lOFC R Anterior Insula	47 13	44	4.44	42	27	-12
13	R SFG R dmPFC	9 9	44	4.13	9	63	24
14	R dACC	33, 24	33	3.97	12	15	39
15	L Posterior Insula L Claustrum	13	30	3.95	-33	-30	12
16	R Caudate R Putamen R Lateral Globus Pallidus		27	4.43	18	6	6
17	R STG	22	27	4.19	57	-42	15
18	L Uncus L PHG		26	5.92	-21	-6	-24

Note. Clusters were thresholded at a voxel-wise level of $p < .005$ and a corrected extent threshold of .05 with 26 3x3x3mm voxels. L = left, R = right, B = bilateral, ACC = Anterior Cingulate Cortex, AG = Angular Gyrus, d = dorsal, FEF = Frontal Eye Field, IFG = Inferior Frontal Gyrus, Inf = Inferior, IOG = Inferior Occipital Gyrus, IPL = Inferior Parietal Lobule, ITG = Inferior Temporal Gyrus, l = lateral, m = medial, MCC = Middle Cingulate Cortex, MFG = Middle Frontal Gyrus, Mid = Middle, MOG = Middle Occipital Gyrus, MTG = Middle Temporal Gyrus, OFC = Orbitofrontal Gyrus, PCC = Posterior Cingulate Cortex, PFC = Prefrontal Gyrus, PHG = Parahippocampal Gyrus, RSC = Retrosplenial Cortex, SFG = Superior Frontal Gyrus, sg = Subgenual SMA = Supplemental Motor Area, SOG = Superior Occipital Gyrus, STG = Superior Temporal Gyrus, STS = Superior Temporal Sulcus, v = ventral.

Table 3. During the strategy period, clusters significantly active in a linear contrast between mindful attention vs. immersion (collapsed across stress and non-stress events).

Cluster	Brain Region	Brodmann Area	Spatial Extent	Peak *t*	Center x	Center y	Center z
Mindful Attention > Immersion (Strategy Period)							
1	B IOG	18, 17	261	3.95	-3	-90	-12
	L MOG	18					
	B Lingual Gyrus	18, 17					
2	L vlPFC	10	144	4.69	-42	45	-12
3	L vlPFC	45	93	4.84	-54	30	3
	L v Anterior Premotor Cortex	44					
4	L IPL	40, 39	82	4.14	-48	-57	39
	L AG	39					
5	B Cerebellar Tonsil		80	4.61	9	-39	-36
	B Brainstem (Pons)						
6	L MTG	21	72	3.89	-60	-45	-6
7	L SFG/FEF	8	40	3.80	-15	9	57
	L mPFC	8					
8	R vlPFC	10	29	4.65	36	54	-3
Immersion > Mindful Attention (Strategy Period)							
1	B mOFC/vmPFC	11	75	-5.33	0	24	-12
	B vACC	24, 32					
	B sgACC	25					

Note. Clusters were thresholded at a voxel-wise level of $p < .005$ and a corrected extent threshold of .05 with 26 3x3x3mm voxels. L = left, R = right, B = bilateral, ACC = Anterior Cingulate Cortex, AG = Angular Gyrus, FEF = Frontal Eye Field, IOG = Inferior Occipital Gyrus, IPL= Inferior Parietal Lobule, l = lateral, m = medial, MOG = Middle Occipital Gyrus, MTG = Middle Temporal Gyrus, OFC = Orbitofrontal Gyrus, PFC = Prefrontal Gyrus, SFG = Superior Frontal Gyrus, sg = Subgenual, v = ventral.

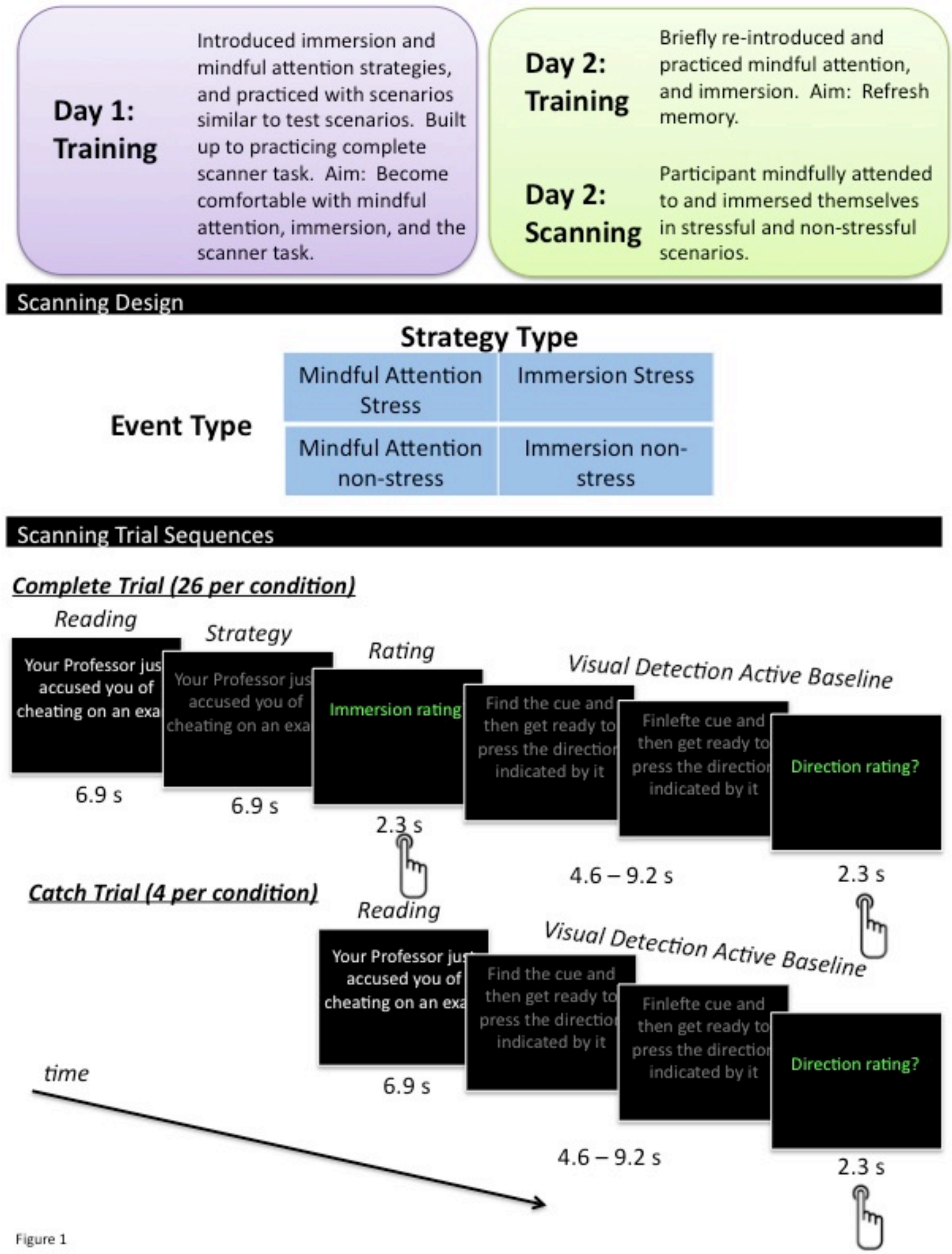

Figure 1. The experimental design. The top panel is a broad overview of the training procedure. The middle design panel presents the four event types. These conditions occur both in the reading period and the strategy period. The bottom panel describes the trial sequence using the immersion stress condition as an example. Mindful attention trials, and non-stressful trials follow the same procedure. The first trial sequence is a complete trial. The second sequence is a catch trial.

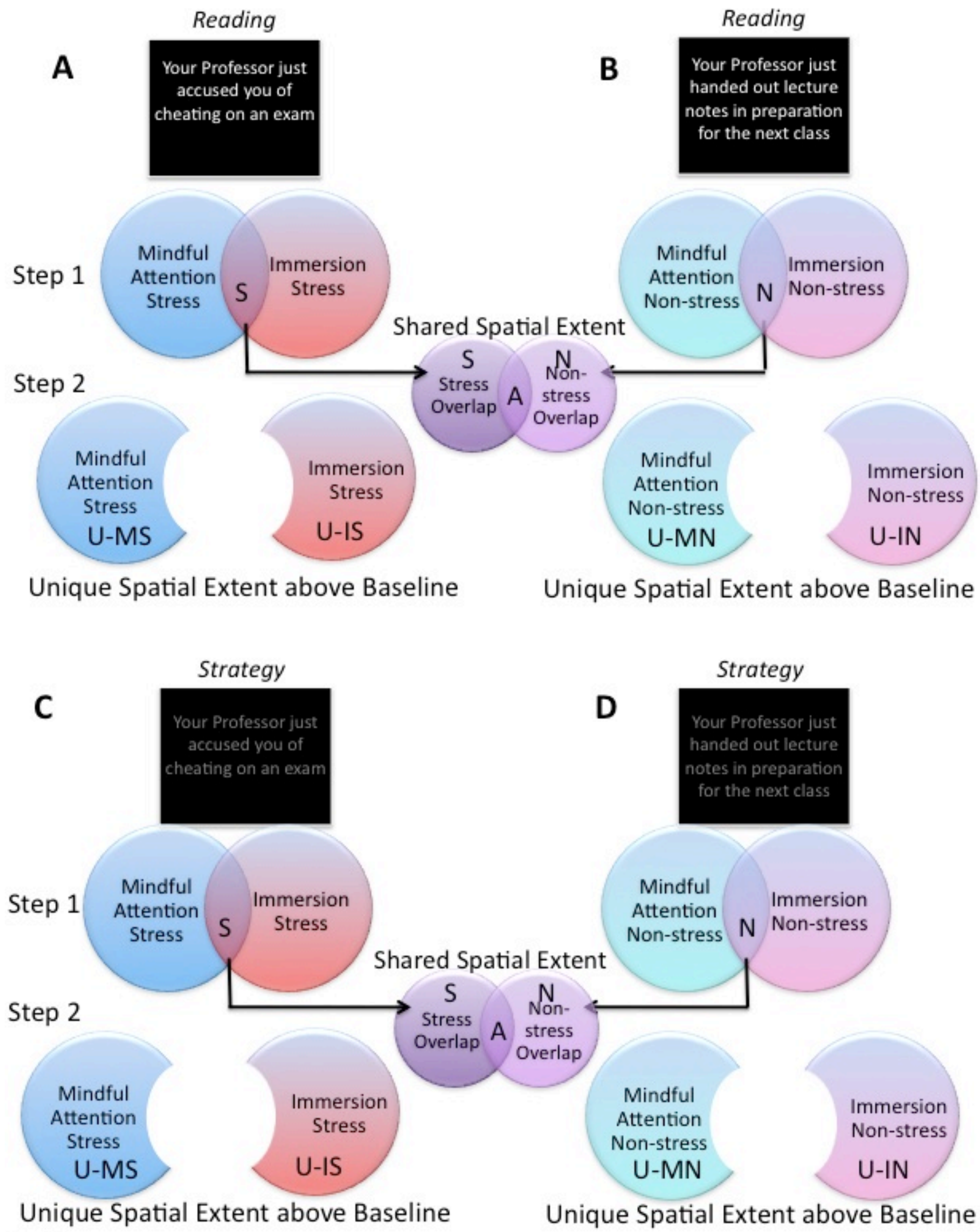

Figure 2. The conjunction analysis procedure. Step 1 across Panels A and B illustrates the two initial conjunction analyses, identifing neural activity common across stressful (S) and non-stressful events (N) during the reading period. The arrows point to a third conjunction analysis of the voxels in S and N to establish the neural activity common across both stressful and non-stressful events during reading (A). In Step 2, we removed the common activity to extract the unique neural activity during reading in each of the four conditions: mindful attention stressful (U-MS), immersion stressful (U-IS), mindful attention non-stressful (U-MN), and immersion non-stressful (U-IN). Panel C and D specify the same procedures for the strategy periods.

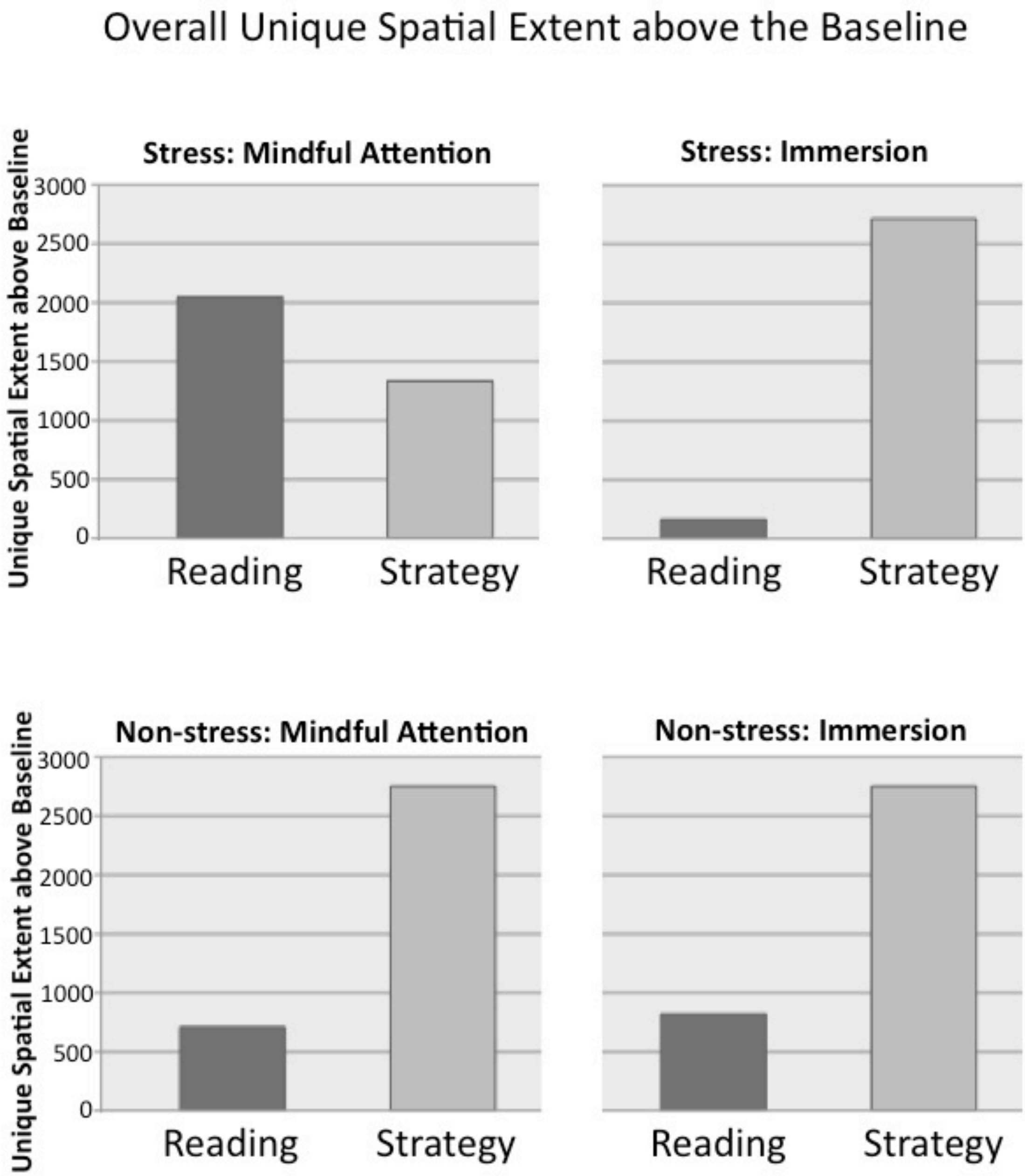

Figure 3. The total unique spatial extent, relative to the active baseline, in a conjunction of the two strategies, mindful attention and immersion, for each event type (stress and non-stress) once in the reading and once in strategy period. All the shared activity has been removed from these graphs.

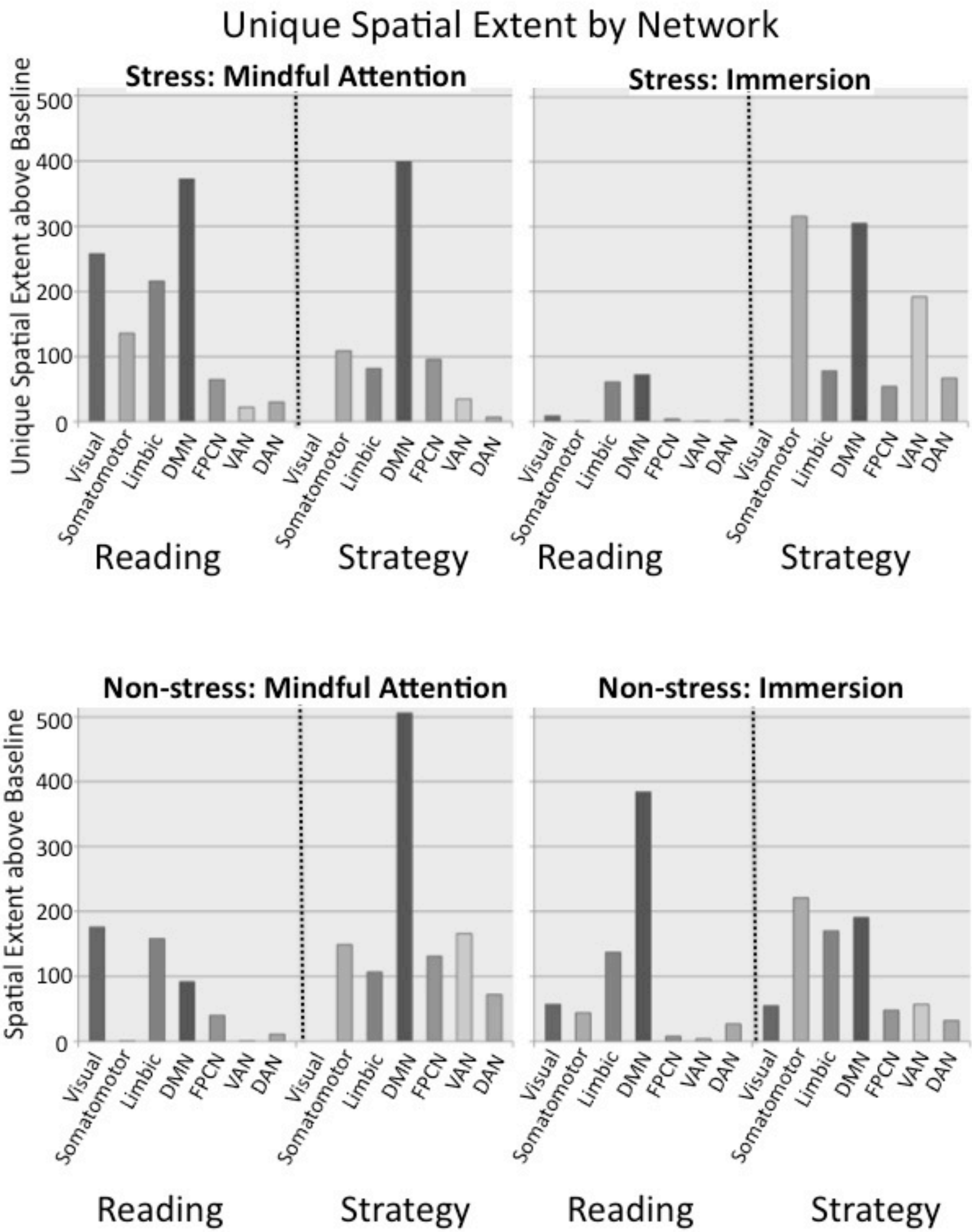

Figure 4. The total unique spatial extent, relative to the active baseline, in a conjunction of the two strategies, mindful attention and immersion, for each event type (stress and non-stress) once in the reading and once in strategy period. The spatial extent is separated out by 7 Yeo et al. (2011) resting state networks. All the shared activity has been removed from these counts. Visual = visual network, Somatomotor = somatosensorimotor network, limbic = limbic network, DMN = default mode network, FPCN = frontoparietal control network, VAN = ventral attention network, DAN = dorsal attention network.

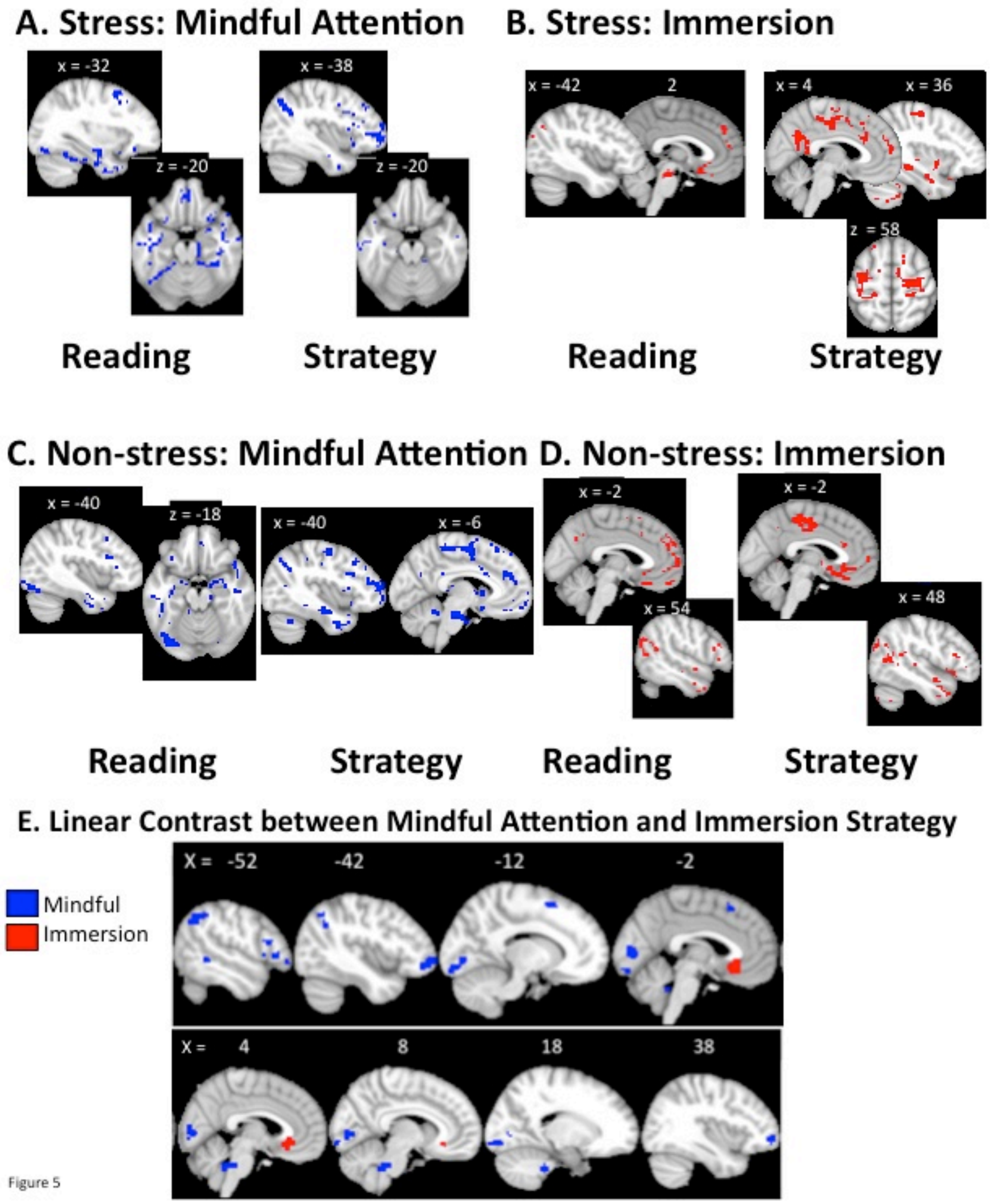

Figure 5. Unique activation for the various conditions with the common activity removed for panels A, B, C, and D. A. Unique activation above baseline for the mindful attention stress condition. These results resulted form the mindful attention stress and immersion stress conjunction once in the reading period and once in the strategy period. B Unique activation above baseline for the immersion stress condition. These results resulted form the mindful attention stress and immersion stress conjunction once in the reading period and once in the

strategy period. C Unique activation above baseline for the mindful attention non-stress condition. These results resulted form the mindful attention non-stress and immersion non-stress conjunction once in the reading period and once in the strategy period. D Unique activation above baseline for the immersion non-stress condition. These results resulted form the mindful attention non-stress and immersion non-stress conjunction once in the reading period and once in the strategy period. E The linear contrast results for mindful attention (minus the active baseline) > immersion (minus the active baseline) collapsed across stressful and non-stressful events.

Supplemental Materials

Decentering the Self During Mindful Attention to Imagined Stressful Events

Lebois, Papies, Gopinath, Cabanban, Quigley, Krishnamurthy, Barrett, & Barsalou

Materials

Critical events were 120 one-sentence scenarios (60 stressful, 60 non-stressful). These 120 scenarios were drawn from a larger sample of 572 stressful and non-stressful scenarios (286 each) normed in a separate behavioral study for stressfulness, amount of self-threat, perseverative thought, expectation violation, efficacy, experience, familiarity, plausibility, valence, arousal, and certainty (Lebois, Hertzog, Slavich, Barrett, & Barsalou, submitted).

Stressful and non-stressful scenarios were different on key features shown to predict the amount of perceived stress (Lebois et al., submitted). Stressful scenarios were higher in threat (M = 5.38, SD = .73), arousal (M = 5.67, SD = .50), perseveration (M = 6.04, SD = .51), negative valence (M = 5.82, SD = .53), bodily imagery (M = 5.24, SD = .47), and violation of expectations (M = 4.36, SD = 1.37), and lower in efficacy (M = 4.21, SD = .59), and positive valence (M = 1.05, SD = .08) compared to non-stressful scenarios (threat: M = 1.17, SD = .26; arousal: M = 2.99, SD = .53; perseveration: M = 1.10, SD = .16; negative valence: M = 1.40, SD = .27; bodily imagery: M = 1.96, SD = .47; expectation violation: M = 1.07, SD = .17; efficacy: M = 6.94, SD = .11; positive valence: M = 2.50, SD = .78; p values all less than .001).

Training

In training session 1, we first introduced the concept of immersion, provided a definition, and presented examples. To reiterate, during immersion instruction, participants were asked to become completely absorbed in the experience of the scenarios almost as if they were actually happening in the moment. They were to mentally time travel and live the experience of sensory details, physical sensations, feelings, emotions, and bodily states associated with the scenario in vivid detail.

Second, we had participants generate an example of a time when they were completely immersed in a thought from their past experience. They again tried to become immersed in this thought, and described it briefly to the experimenter.

Third, participants read two example sentences for the kinds of events to be used later in the experiment (none of the events seen during practice occurred during the critical scan session). After participants read each sentence, the experimenter verbally guided them through the mental simulation of immersing themselves in the scenario (e.g., telling them to imagine particular sounds, visualize certain aspects of the scene, and how their body felt).

Fourth, participants completed two self-guided immersions with example sentences. Participants read each sentence, immersed themselves in the situation, and then verbally told the experimenter what they experienced, for example, how their body felt, the sounds they heard, what the scene looked like, and feelings that came up.

Fifth, participants read another two example sentences, and immersed themselves without verbally reporting their experience to the experimenter.

After completing the previous 6 practice sentences, the participant read another 10 example sentences (5 stressful, 5 non-stressful). Participants were told the difference between complete and catch trials, and that the catch trials would occur randomly in the upcoming practice. This practice mimicked the timing of the scanner task described in the main text.

Next participants learned how to complete the left-right visual detection task that served as the active baseline, and completed 10 trials of just this task. Again this practice had the same timing as the scanner task. Finally, to complete this section of the training, participants practiced 10 trials of immersion interwoven with 10 trials of the left-right visual detection baseline task, including both complete and catch trials.

After immersion training, we introduced the concept of mindful attention, provided a definition, and presented examples. During mindful attention instruction, participants were asked to remain aware of their current physical location. They were told to notice that, in reaction to the scenarios, they were probably thinking about many of the kinds of details that they experienced when immersing themselves in an event, but rather than 'living' the event, they were instructed to simply observe their thoughts and reactions to it *in the present moment*. Participants viewed their thoughts about the stimuli as transitory mental states, not as actual parts of the scenarios, but something psychologically constructed in response to them.

After this initial introduction, we had participants think back to the example event they generated from their own experience for the immersion training. This time they practiced mindfully attending to the example. The rest of the mindful attention training procedure and practice was the same as the aforementioned immersion training, except that participants did not practice the left-right detection task separately, but interwoven with the mindful attention task.

Following mindful attention instruction, participants practiced one run of the experimental scanner task as described in the main text. This concluded day 1 of training.

Training session 2 occurred 1-2 days later. It served as a refresher for the immersion and mindful attention strategies, and for the scanner task to come later. First we reintroduced the concepts of immersion and mindful attention, provided definitions, and presented examples, just like the ones used in training session 1. Second, participants read two example sentences. After they read each sentence, the experimenter verbally guided them through the mental simulation of immersing themselves in one of the scenarios and mindfully attending to the other.

Third, participants completed two self-guided examples, one for immersion and one for mindful attention. They read a sentence, immersed themselves in the scenario, and then verbally told the experimenter what they experienced. Then for the other sentence, they mindfully attend to the scenario and verbally told the experimenter what they noticed in their thoughts and reactions.

Fourth, participants read another two example sentences, and immersed themselves in one, and mindfully attended to the other, without verbally reporting their experience to the experimenter.

After this refresher, participants practiced one block of 10 immersion trials, one block of 10 mindful attention trials, and one block of 10 left-right visual detection task trials, with the blocks of immersion and mindful attention trials including both complete and catch trials. Each type of trial was practiced separately in this section of the training to remind participants of the tasks, and their timing. All trials had the same timing as the scanner task. Participants were also reminded that the immersion and mindful attention trials would include a few catch trials. To conclude the pre-scan training, participants performed one complete run of the scanner task, using events not received later. Finally, participants entered the scanner for the critical experimental session.

Further Details about Preprocessing and Analysis

AFNI was used to perform standard preprocessing (Cox, 1996). In addition, FSL was used to correct spatial intensity variations, and to perform spatial normalization and co-registration (Smith et al., 2004). First, the T1 anatomical volume was corrected for spatial intensity variations and skull-stripped. Next the T1 was transformed into MNI space using the MNI152 template brain in both a linear (FLIRT) and nonlinear (FNIRT) transformation.

The functional volumes were slice-time corrected, and then each volume was registered to a middle volume within its own run. Registering each run to its own middle volume minimized the amount of warping done to the functional data. It also minimized the extent of motion-related censoring during later regression analyses, because most motion occurred between runs. Each registered volume was then co-registered to the transformed anatomical volume. This procedure minimized the overall amount of warping required for aligning the anatomical and functional volumes. All data were then resampled into 3x3x3 voxel space, and transformed to Talairach coordinates.

The functional data were then smoothed using an isotropic 6 mm FWHM Gaussian kernel. Next the BOLD signal was normalized and used to compute the percent signal change in each run (signal intensity in each voxel in a given volume was divided by the average signal intensity for that voxel in the run and multiplied by 100). This calculation was done only on voxels within the brain. Finally, voxels outside the brain, and noisy voxels (high variability, low intensity) were identified and removed from further analysis. All subsequent analyses used this final voxel set.

Time points associated with the mindful attention stress, mindful attention non-stress, immersion stress, and immersion non-stress conditions for both the reading and strategy period were extracted from each participant's data set. Time points for each of these eight conditions were convolved with a canonical block hemodynamic response function of 6.9 sec in duration. As discussed in the main manuscript methods section, our catch trial design made separate regression for the reading and strategy periods possible without the use of jitter. Time points for cue (1), rest (6), strategy ability and baseline ratings (8), and motion (6) were also extracted and convolved (21 total), thereby removing them from the active baseline. Because these regressors were not of interest to our hypotheses, they are not discussed further. Volumes associated with motion greater than 3mm or outlier signal intensity were censored from the regression analysis.

References

Cox, R. W. (1996). AFNI: software for analysis and visualization of functional magnetic resonance neuroimages. *Computers and Biomedical research*, *29*(3), 162-173.

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Smith, S. M., Jenkinson, M., Woolrich, M. W., Beckmann, C. F., Behrens, T. E., Johansen-Berg, H., et al., & Matthews, P. M. (2004). Advances in functional and structural MR image analysis and implementation as FSL. *Neuroimage*, *23*, S208-S219.

SM Table 1. During the reading period, shared clusters across all four conditions (mindful attention/stress, immersion/stress, mindful attention/non-stress, immersion/non-stress), across just the two stress conditions, and across just the two non-stress conditions (from three conjunction analyses).

Cluster	Brain Region	Brodmann Area	Spatial Extent
All Four Conditions (Reading Period)			
1	L MTG	21, 37, 39, 19	2150
	L Temporal Pole	38	
	L STG	22, 39	
	L STS		
	L AG	39	
	L SOG	19	
	L Precuneus	19	
	L IFG/dlPFC	9	
	L IFG/vlPFC	45, 10	
	L v Anterior Premotor Cortex	44	
	L lOFC	47	
2	L MFG/FEF	8	767
	L Premotor Cortex	6	
	L SFG	8, 9, 10	
	L vmPFC	10	
	L dmPFC	9	
	L SMA	6	
3	L Fusiform Gyrus	20, 36	528
	L PHG	36, 28	
	L Uncus		
	L Hippocampus		

	L Amygdala		
	L Culmen		
4	B Lingual Gyrus	19	517
	B dPCC	31	
	B RSC	23, 29, 30	
	B Precuneus	7	
5	B vmPFC	10	340
	B mOFC	11	
6	R MTG	21	339
	R STS		
	R Temporal Pole	38	
7	R Fusiform Gyrus	20	284
	R PHG	36, 28	
	R Uncus		
	R Hippocampus		
	R Amygdala		
	R Culmen		
8	R Pyramis		135
	R Uvula		
	R Inf Semi-Lunar Lobule		
9	R STG	22, 39	119
10	R MTG	21	100
	R STS		
11	R MOG	18	91
	R Lingual Gyrus	17	
	R IOG	17	

12	R IFG/vlPFC	45	89
	R lOFC	47	
13	L MOG	18	57
	L Lingual Gyrus	17	

Stress Events (Reading Period)

1	R SFG	9, 10	427
	B vmPFC	10	
	B dmPFC	9	
	L SMA	6	
2	R MTG	21	241
	R Fusiform Gyrus	20	
	R Temporal Pole	38	
3	L STG	39	68
	L AG	39	
	L Precuneus	39	
4	L ITG	20	67
	L MTG	21	
	L Temporal Pole	38	
5	L MFG/FEF	8	62
6	L Temporal Pole	38	61
	L lOFC	47	
7	L PHG	35, 34, 28	52
	L Hippocampus		
	L Amygdala		
	L Brainstem (Pons)		

8	R Pyramis R Inf Semi-Lunar Lobule		40
9	R IFG/vlPFC R lOFC	45 47	38
10	R STG	22, 39	34
11	R PHG R Hippocampus R Amygdala	35	32
12	B Cerebellar Tonsil		31
Non-stress Events (Reading Period)			
1	L ITG L Fusiform Gyrus L PHG L Culmen L Uncus	37, 20 20, 36 36	192
2	R Fusiform Gyrus R PHG R Culmen R Uncus	20 20	136
3	B Lingual Gyrus B RSC	19 30	101
4	L MFG/vlPFC L IFG L MFG/dlPFC	46 45 9	62

5	L Lingual Gyrus	17	53
	L MOG	18	
6	L MFG/FEF	8	44
	L dACC/MCC	32	
7	L MTG	19	41
	L SOG	19	
8	B sgACC	25	32
	R mOFC	11	

Note. Clusters were thresholded at a voxel-wise level of $p < .005$ and a corrected extent threshold of .05 with 26 3x3x3mm voxels. L = left, R = right, B = bilateral, ACC = Anterior Cingulate Cortex, AG = Angular Gyrus, d = dorsal, FEF = Frontal Eye Fields, IFG = Inferior Frontal Gyrus, Inf = Inferior, IOG = Inferior Occipital Gyrus, ITG = Inferior Temporal Gyrus, l = lateral, m = medial, MCC = Middle Cingulate Cortex, MFG = Middle Frontal Gyrus, MOG = Middle Occipital Gyrus, MTG = Middle Temporal Gyrus, OFC = Orbital Frontal Cortex, PCC = Posterior Cingulate Cortex, PFC = Prefrontal Cortex, PHG = Parahippocampal Gyrus, RSC = Retrosplenial Cortex, SFG = Superior Frontal Gyrus, sg = subgenual , SMA = Supplementary Motor Area, SOG = Superior Occipital Gyrus, STG = Superior Temporal Gyrus, STS = Superior Temporal Sulcus, v = ventral.

SM Table 2. During the strategy period, shared clusters across all four conditions (mindful attention/stress, immersion/stress, mindful attention/non-stress, immersion/non-stress), across just the two stress conditions, and across just the two non-stress conditions (from three conjunction analyses).

Cluster	Brain Region	Brodmann Area	Spatial Extent
All Four Conditions (Strategy Period)			
1	L MTG	21, 37	4010
	L Temporal Pole	38	
	L STS		
	L IFG/vlPFC	45, 46	
	L lOFC	47	
	L MFG	46	
	L MFG/dlPFC	9	
	L Premotor Cortex	6	
	L MFG/FEF	8	
	L Anterior Insula	13	
	L SFG	10, 9, 8	
	L mOFC	11	
	L vmPFC	10	
	L dmPFC	9	
	B SMA	6	
	B dACC	32	
2	L STG	22, 39	485
	L MTG	39, 19	
	L AG	39	
	L Precuneus	19	

3	R Pyramis			424
	R Cerebellar Tonsil			
	R Tuber			
	R Inf Semi-Lunar Lobule			
4	R MTG	21		387
	R STS			
	R Temporal Pole	38		
5	L PHG	19		332
	L Lingual Gyrus	19		
	L Precuneus	31, 7		
	L dPCC	31		
	L RSC	30, 29		
6	L Postcentral Gyrus	2, 3		186
	L Precentral Gyrus	4		
7	R IFG/vlPFC	45		161
	R lOFC	47		
8	L PHG	28		102
	L Hippocampus			
	L Culmen			
	L Cerebellar Tonsil			
9	R dmPFC	9	51	

Stress Events (Strategy Period)

1	B SFG/Premotor Cortex	6	548
	L SFG/vlPFC	10	
	L dACC	32	
	B vmPFC	10	
	B dmPFC	9	

	B SMA	6	
	L MCC	24	
	R Precentral Gyrus	4	
2	R Cerebellar Tonsil		188
	R Pyramis		
	R Inf Semi-Lunar Lobule		
	R Uvula		
3	R MTG	21	61
	R STS		
4	L MTG	21	57
	L ITG	20	
	L Fusiform Gyrus	20	
	L Temporal Pole	38	
5	R MTG	21	43
	R ITG	20	
6	L Inf Semi-Lunar Lobule		36
7	L Cerebellar Tonsil		35
8	L MFG/FEF	8	31
9	L MTG	21	26
	L STS		
Non-stress Events (Strategy Period)			
1	L MTG	21, 37, 39	636
	L ITG	20	
	L STS		

	L MOG	19	
	L STG	22	
	L AG	39	
	L SOG	19	
	L Precuneus	19	
	L SPL	7	
	L PHG	36, 35, 28, 34	
	L Fusiform Gyrus	20, 37	
	L Uncus		
	L Culmen		
2	L IFG/vlPFC	44, 45, 9, 46	471
	L MFG/dlPFC	9	
	L MFG/vlPFC	10	
	L lOFC	47	
	L Anterior Insula	13	
	L Temporal Pole	38	
	L Putamen		
	L Caudate		
3	R STG	22, 39	312
	R MTG	21	
	R MOG	37	
4	B dPCC	31	137
	L RSC	30	
	B Precuneus	7	
	R PCC	23	
5	B dACC	24	106
	L SMA	6	
	R dACC	32	
6	R MTG	21	96
	R ITG	20	

	R Fusiform	20	
	R PHG	35, 34	
7	L Frontopolar Cortex	10	96
	L vmPFC	10	
	B mOFC	11	
8	L Premotor Cortex	6	94
9	R IFG	45, 44	73
	R lOFC	47	
	R Anterior Insula	13	
10	L Postcentral Gyrus	2, 3	70
	L IPL	40	
	L Precentral Gyrus	4	
11	L Thalamus		37
12	L Frontopolar Cortex	10	30
13	L MCC/dPCC	31	30
	B Paracentral Lobule	5	

Note. Clusters were thresholded at a voxel-wise level of $p < .005$ and a corrected extent threshold of .05 with 26 3x3x3mm voxels. L = left, R = right, B = bilateral, ACC = Anterior Cingulate Cortex, AG = Angular Gyrus, d = dorsal, FEF = Frontal Eye Fields, IFG = Inferior Frontal Gyrus, Inf = Inferior, IPL = Inferior Parietal Lobule, ITG = Inferior Temporal Gyrus, l = lateral, m = medial, MCC = Middle Cingulate Cortex, MFG = Middle Frontal Gyrus, MOG = Middle Occipital Gyrus, MTG = Middle Temporal Gyrus, OFC = Orbitofrontal Cortex, PCC = Posterior Cingulate Cortex, PFC = Prefrontal Cortex, PHG = Parahippocampal Gyrus, RSC = Retrosplenial Cortex, SFG = Superior Frontal Gyrus, SMA = Supplemental Motor Area, SOG = Superior Occipital Gyrus, SPL = Superior Parietal Lobule, STG = Superior Temporal Gyrus, STS = Superior Temporal Sulcus, v = ventral.

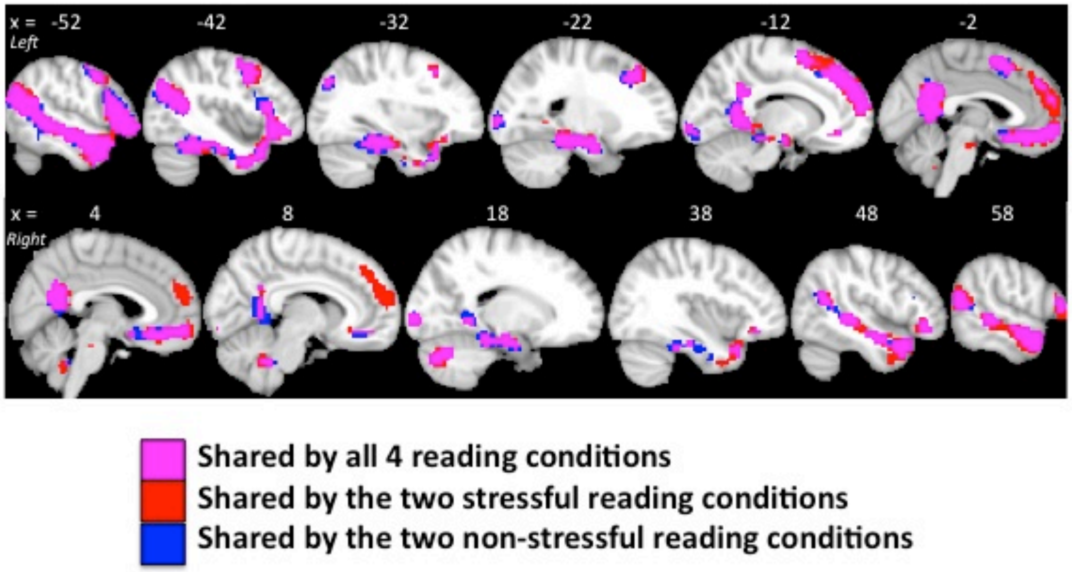
SM Table 3. During the strategy period, clusters significantly more active for mindful attention vs. immersion from two linear contrasts for stress and non-stress events.

Cluster	Brain Region	Brodmann Area	Spatial Extent	Peak t	Center x	Center y	Center z
Stress Events: Mindful Attention > Immersion							
1	L IPL L AG	40, 39 39	55	4.94	-48	-57	42
2	L IFG/vlPFC	10	18	3.74	-36	48	0
3	L MFG/dlPFC	9	17	4.43	-48	30	30
Stress Events: Immersion > Mindful Attention							
1	L dPCC	31	20	-4.37	-12	-24	36
2	B sgACC	25	12	-3.95	0	24	-12
3	R IPL	40	12	-3.38	60	-24	30
4	R Premotor Cortex	6	10	-4.21	48	-6	33
Non-stress Events: Mindful Attention > Immersion							
1	L IOG L MOG L Lingual Gyrus	19 18 18, 17	244	4.23	-6	-87	-15

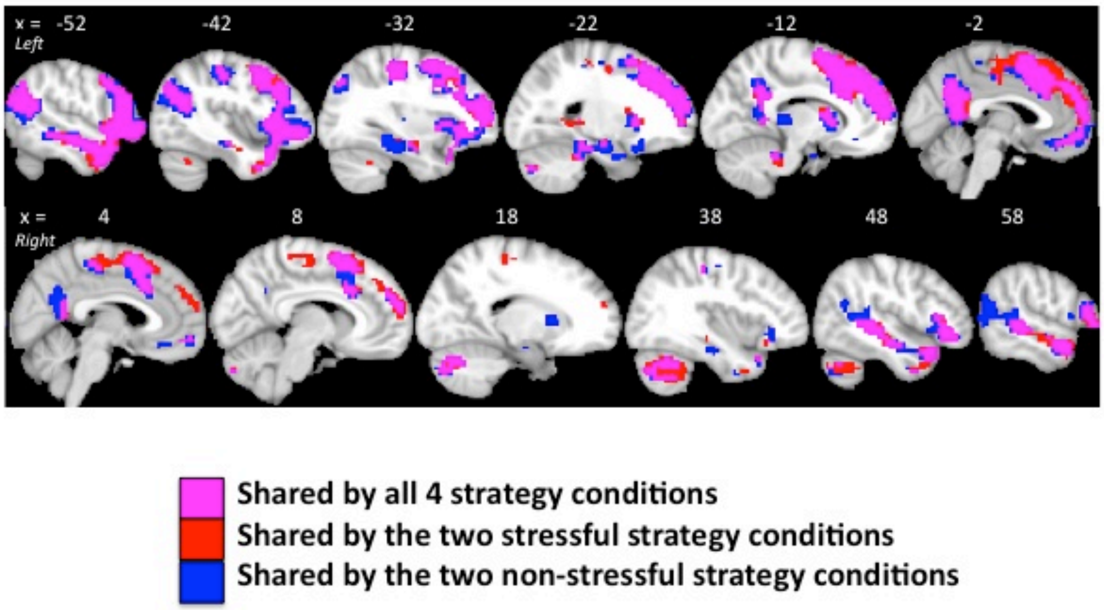
	L Declive L Uvula						
2	L Premotor Cortex L SMA	6 6	110	4.48	-15	12	60
3	L vlPFC L v Anterior Premotor Cortex	45, 44 44	93	4.99	-57	21	12
4	L MTG	21	62	3.84	-54	-54	0
5	L vlPFC	10	58	4.07	-30	57	0
6	B Brainstem (Pons) R Cerebellar Tonsil		49	4.11	3	-36	-39
7	R Pyramis R Uvula		30	3.80	21	-72	-33
8	R IOG	18	28	3.72	42	-84	-6
9	R Lingual Gyrus	18	26	3.39	9	-75	0
10	R Cuneus	19	24	3.44	21	-90	24
11	L Temporal Pole	38	20	3.43	-54	15	-12
12	R IOG	17	20	3.35	21	-96	-15
13	L Brainstem		19	4.41	-6	-21	-21
14	R Cerebellar Tonsil		15	3.70	21	-42	-39
15	L MOG	19	11	3.54	-27	-90	21
16	R MFG/vlPFC	10	10	4.12	33	63	9

Non-stress Events: Immersion > Mindful Attention							
1	L vACC	32	21	-4.55	-3	27	-9

Note. Clusters were thresholded at a voxel-wise level of $p < .005$ and an uncorrected extent threshold of .05 with 10 3x3x3mm voxels. L = left, R = right, B = bilateral, ACC = Anterior Cingulate Cortex, AG = Angular Gyrus, d= dorsal, IFG = Inferior Frontal Gyrus, IOG = Inferior Occipital Gyrus, IPL = Inferior Parietal Lobule, l = lateral, MFG = Middle Frontal Gyrus, MOG = Middle Occipital Gyrus, MTG = Middle Temporal Gyrus, PCC = Posterior Cingulate Cortex, PFC = Prefrontal Cortex, SMA = Supplemental Motor Area, sg = subgenual, v = ventral.



SM Figure 1. The overlapping clusters across all four conditions in the reading period. Additionally, the overlap just across the two stressful conditions, and just the two non-stressful conditions.



SM Figure 2. The overlapping clusters across all four conditions in the strategy period. Additionally, the overlap just across the two stressful conditions, and just the two non-stressful conditions.

General Discussion

In article 1, we built on the existing stress and appraisal literatures to introduce a new account of stress cognition, the Grounded Theory of Stress Cognition, with an initial test of this theory. According to this theory, individuals store situated conceptualizations of their stressful experience in memory, gradually forming categories for specific types of stressful events. When aspects of these experiences are encountered at another time, they reactivate (simulate) associated situated conceptualizations in a pattern completion process. These simulations then reactivate patterns of cognitive, perceptual, and bodily states, potentiating similar stress and coping responses associated with these previous stressful events.

The theory further postulates that certain features may be consistently active across situated conceptualizations of stress. Drawing from the existing stress literature and from situated cognition, we identified a number of features that might be reliably present in individual stress categories, thereby consequently predicting the perception of events as stressful. These features were related to expectancy violation, threat, efficacy, peripheral physiology, emotion, rumination, coping, and metacognition. All of these features were highly related to perceived stress, and a subset of hypothesized key features (threat, perseveration, efficacy, bodily imagery, expectation violation, valence, and arousal) accounted for almost all of the variance in perceived stress. These results support our hypothesis that these features are integral to the situated conceptualizations that people establish for their categories of stressful experiences.

As article 2 illustrated, mindful attention and immersion produced different patterns of activity in relation to the active baseline, and also in direct contrast to each other. Whereas mindful attention engaged stressful events immediately, producing decentering by rapidly by disengaging embodied senses of self from stressful situations (also indicative of reduced experiential avoidance), immersion waited to fully develop simulations of the stressful events.

When participants were mindfully attending to events, they engaged areas related to simulation, attentional control, and perspective shifting. Participants appeared to be actively decentering, that is, viewing their thoughts as passing mental states instead of becoming immersed in them, potentially reducing subjective realism. In contrast, immersion activated areas related to integrating visceral states and to labeling them as self-relevant, perhaps especially in terms of their relation to personal goals (Amodio & Frith, 2006; Northoff & Bermpohl, 2004; Van Overwalle, 2009), implying that the integration of visceral states and self-relevance may be key to what makes thoughts feel subjectively real. It is still debated as to why mindfulness reduces stress (e.g., Jha, Krompinger, Baime, 2007). Our results suggest that decentering plays a central role, disengaging the self from simulations of stressful situations through a shift in perspective.

Clarification of Additional Results

In article 1, the Grounded Theory of Stress Cognition hypothesized that categories for stressful experience are built through situated conceptualizations based on an individual's unique life experiences. In our multilevel regression model, however, we found that the Experience factor did not predict a significant amount of variance in perceived stressfulness. While these results may seem contradictory to those predicted by the theory, they actually are not. The seeming contradiction arises because the theory and results are referring to different types of "experience." Experience in the Grounded

Theory of Stress Cognition describes an individual's process of building situated categories of stress. Experience in the factor analysis and multilevel regression model refers to whether someone has previously encountered a similar situation to the experimentally presented event. As the multilevel regression model illustrates, it does not follow that previous experience with an event would predict how stressful individuals found the situation. For example, previous experience with a stressful event could result in knowledge of how to cope with this type of situation. This would make a later encounter with a similar event less stressful because the individual knows how to meet the demands of the situation. Conversely, if successful coping did not occur previously with this event, experiencing a similar one later on might simply reactivate stressful cognitive, perceptual, and bodily states. Thus, experience in the regression model and in the process of building situated conceptualizations related to stressors through experience are not the same construct.

To test the Grounded Theory of Stress Cognition hypothesis that categories for stressful experience are built through situated conceptualizations based on an individual's unique life experiences an experience-sampling study would be efficacious. Experience sampling methods provide access to both the contents of an individual's current awareness and the context (Barrett & Barrett, 2001), which would offer the opportunity to assess variation in stressful experience while measuring the existence of features predictive of stress. Previous work has assessed daily stressors in a more retrospective manner (e.g., Almeida, 2005), which is subject to various biases associated with reconstructing memories after the fact (Barrett & Barrett, 2001).

In article 2, SM Table 3 presents the active clusters for mindful attention vs. immersion broken out by the stressful and non-stressful events. The clusters that met a voxel-wise threshold of $p < .005$ and a corrected extent threshold of .05 with 26 3x3x3mm spatial extent occurred largely only in the mindful attention to non-stressful events condition. That is, differences between mindful attention and immersion were evident most robustly when participants were engaging with non-stressful events. With an uncorrected threshold of 10 voxels, more differences between mindful attention and immersion events were evident for stressful events (i.e., more similar to the pattern exhibited in the main article, Table 3, Figure 5 E). This may simply be a power issue. As article 2 illustrated, when directly compared, mindful attention and immersion in non-meditators share a lot of processing in common, and the differences between them, though significant, are on the smaller side. By aggregating across stressful and non-stressful events, we established enough power to detect the pattern of differential activation reported. A similar pattern emerges when events are not aggregated in this way, but it is weaker. Further research is necessary to replicate and better understand this pattern of results.

Integrating Results Across Articles

Together, these two articles provide a significant contribution to our understanding of stress cognition and a viable intervention, mindfulness. People evaluate the stressfulness of an event or thought based on their individual experience and population of situated conceptualizations. These situated conceptualizations are simulated in the context of a current stressful experience, and reactivate cognitive, perceptual, and bodily states associated with that individual's stress category. In article 1, we see that these conceptualizations consistently include threat, perseveration, efficacy, bodily imagery, expectation violation, valence, and arousal. The conjunction results associated with article 2 are consistent with these findings. Specifically, unique activity in the immersion stress condition during the strategy period occurred in the somatosensorimotor, limbic, default mode, and ventral attention networks. This distributed pattern suggests that participants were simulating both the external situations and their internal reactions to them, especially their personal salience.

Article 2's linear contrast results also support article 1's identification of features consistently active in stress cognition, illustrating that immersion is related to more activity in sgACC, vACC, and mOFC/vmPFC. These regions are associated with integrating self-relevance and visceral states (Elliott, Dolan, and Frith, 2000; Kross et al., 2009; Vogt, 2005), supporting involvement of valence, arousal, and bodily imagery in stress cognition. Resting state connectivity analyses reveal sgACC activity is positively correlated with activity in posterior cingulate cortex (Margulies, et al., 2007), an area involved in self-referential (Whitfield-Gabrieli, et al., 2011) and emotion processing (Kober et al., 2008), both for past and future mentalizing (Andrews-Hanna et al., 2010). This suggests that sgACC is part of a broader network that may support self-referential perseverative thought, a key feature identified in the Grounded Theory of Stress Cognition article.

Arguably this type of processing may be central to what makes a thought feel so real. Our results provide evidence that, in novice mindful processing, decentering is achieved through effortful perspective and attentional shifting. This shifting appears to reduce activity involved in integrating self-relevance with visceral states, arguably making the thought feel less subjectively real, and ultimately less stressful. This pattern of activity is also supported by evidence that sgACC activity is negatively correlated with regions in parietal cortex associated with attentional control and perspective shifting (Margulies, et al., 2007). Of further interest here is assessing whether these areas are functionally related in our data set.

Self and Stress

Further support for these claims comes from a similarity between the neural correlates of stressful and self-referential cognition. As much previous work has found, cortical midline structures (e.g. medial frontal cortex, anterior and posterior cingulate cortex extending to the precuneus, the orbitofrontal/ventromedial prefrontal cortex), the temporoparietal junction, and the temporal poles are traditionally implicated in self-referential processing (Amodio & Frith, 2006; Northoff & Bermpohl, 2004). Interestingly, the medial frontal cortex, anterior cingulate, orbitofrontal cortex, and insula appear to also be consistently involved in stressful cognition (as reviewed in the general introduction section; for reviews, see Barrett, Mesquita, Ochsner, & Gross, 2007; Ganzel, Morris, & Wethington, 2010; Pruessner et al., 2008). It appears a major part of stressful cognition is an assessment of self-relevance and threat (Dickerson & Kemeny, 2004; also see article 1). Thus, one central reason why stressful thoughts in particular feel so real is because they engage the self system intensely.

Social self-preservation theory. Social Self-Preservation Theory further motivates why this overlap between areas involved in self-referential processing and stressful cognition exists (Dickerson & Kemeny, 2004). According to this theory, humans are evolutionarily motivated to preserve both our physical and social selves for survival. Successful negotiations of social situations such as finding a mate, gaining acceptance, and obtaining power improve one's survival rate and reproductive fitness (Kaschak & Maner, 2009). To optimize these social goals, we become experts at detecting threats to our social self and status, where these threats often involve situations where our identity or an important self-related goal could be rejected or evaluated negatively by peers (Dickerson & Kemeny, 2004). Thus, threats to self are inherently very stressful because they have critical consequences for one's survival and well-being.

Limitations

There are several limitations in our articles, the most prominent being the dependence on self-report data. In the first article, the test of the Grounded Theory of Stress Cognition relied solely on self-report ratings of the scenarios for the hypothesized features of stressful cognition. Additionally, although 20 different ratings were made on nearly 600 scenarios, we had a small sample of 12 participants providing data, which limited our ability to explore patterns of individual differences in evaluations of stress. A larger sample, perhaps rating fewer scenarios, would complement, and build on this initial study. Finally, the characters and settings in the scenarios were not manipulated systematically. Many scenarios included multiple contexts (e.g., work and school related scene), and multiple interpersonal relationships (e.g., boss and family member). Although this variance was intended to mimic the complex situations and relationships encountered in real life, it would be interesting to separate out specific contexts and relationships to see if different features (e.g., threat, efficacy, imagery) or collections of features are more predictive of stressfulness in certain contexts.

The second article also relied on participant's self-report ratings of ability to mindfully attend and immerse. No implicit behavioral assessment of whether participants could successfully immerse and mindfully attend was made. Neural activity, however, demonstrated differential processing in mindful attention and immersion. Furthermore, this neural activity was similar to previous mindfulness research, suggesting that participants were able to adopt both perspectives while experiencing their thoughts and reactions, switching between them as instructed.

The active baseline in this article may also have been problematic. As described earlier, this baseline was designed so as not to engage default mode network activity associated with a rest baseline. As a consequence, however, our baseline involved constant monitoring for a visual cue. This constant vigilance may have engaged executive and attentional control, processes also implicated for mindfulness in inexperienced meditators. Thus, we may have been subtracting out potentially germane activity from our analyses by using this type of baseline. Our results, nevertheless, still found greater attention-related activity in the mindful attention conditions compared to the immersion conditions during the strategy period. This suggests that attention-related processing in mindful attention was robust enough to rise above baseline activity, but that a different baseline may have revealed even greater attention processing differences between mindful attention and immersion.

Finally, in the exit interview, some participants revealed they occasionally had trouble remembering the cued strategy type on a given trial, especially as fatigue set in toward the end of the scan session. Although we were still able to find differences in neural activity between mindful attention and immersion, they may have been muted by instances in which participants were immersing when they were supposed to be mindfully attending (and vice versa). Future studies could address this issue by providing cues for immersion and mindful attention on every trial, not just at the beginning of a 10-trial block.

Future Directions and Conclusions

Much more can be done with the current data sets in both article 1 and article 2. We plan to complete additional analyses with the Grounded Theory of Stress Cognition data using MPlus to conduct factor analyses for individuals, as opposed to only at the group level. Such analyses are likely to provide an even more nuanced level of prediction in perceived stress. Additionally, they may identify subsets of individuals who emphasize different core features in perceived stress. In future work, identifying such sub-groups may assist in assessing stress ailments, and in ascribing effective treatments on an individual basis. A follow up study more systematically varying the content of the scenarios would also be fruitful for identifying patterns of perceived stressfulness based on situational context, and relevant interpersonal relationships.

We also plan to continue analyzing the imaging data, beginning with two key individual difference analyses. First, it would be beneficial to examine patterns of neural activity associated with individual differences on the self-report measures of mindfulness, absorption, and rumination, across the different conditions. No fMRI research that we know of examines these individual differences in the context of a brief mindfulness training that emphasizes decentering. Second, a principle component analysis (PCA) would also shed light on the sub-groups in our dataset. Specifically, PCA may identify sub-groups of individuals who have similar patterns of neural activity across conditions based on component weights. We could then see if these weights are correlated with individual difference measures, and whether the identified sub-groups demonstrate even more robust differences between mindful attention and immersion than in the whole-group analyses.

Finally, we also collected measurements of skin conductance, cardiovascular activity, and respiratory activity while participants were in the scanner. All of these could be used as an additional assessment of whether mindful attention and immersion had measurable differences in this physiology. We predict that there would be, for example, increases in these measures when participants are fully immersed in simulations of the stressful scenarios compared to when they are attending to them mindfully. Investigations such as these would be instrumental in understanding the impact of decentering on autonomic arousal.

As mentioned in the limitations section, our current study serves as an initial test of the Grounded Theory of Stress Cognition, but follow up experiments involving experimental manipulations in the lab, peripheral physiological measurement, and experience sampling in the real world would offer more rigorous and insightful tests of this theory.

Currently, assessments of mindfulness state, trait, and training efficacy are overwhelmingly based on questionnaire and self-report measures. It would be beneficial to develop implicit measures of participants' abilities in mindfulness and decentering that could be administered pre- and post-training. These implicitly assessed individual differences in ability could be entered as covariates in analyses, and could also allow researchers and clinicians to titrate interventions based on an individual's baseline level of mindfulness. Someone who enters therapy, for example, with a very low level of mindfulness could be targeted to receive more training compared to an individual who enters with more developed abilities.

Our conjunction analyses illustrated a different time course of engagement with stressful events for mindful attention vs. immersion. Specifically, while applying mindful attention to stressful events, participants appeared to regulate their experiences of the events right away (less experiential avoidance), whereas while applying immersion, participants appeared to wait before fully engaging with the events. Given these different time courses, it would also be efficacious to complete a sliding window connectivity analysis on these two processes, as well as assessing them with EEG and ERP.

Although our research concentrated on a non-clinical sample, future studies could incorporate clinical populations into these paradigms (e.g. Depression, Generalized Anxiety Disorder, PTSD) to identify how immersion and mindful processing enter into and remediate these disorders. Some of the most effective treatments for trauma are variants of exposure therapy (Powers, Halpern, Ferenschak, Gillihan, & Foa, 2010), which involve immersion in a stressful memory or situation until the stress abates (Ponniah & Hollon, 2008). Intriguingly, exposure to trauma-related memories is typically done while explicitly grounded in the current situation, which implies that the memory is a thought, analogous to viewing stressful thought as passing mental states in mindfulness (Vujanovic, Niles, Pietrefesa, Schmertz, & Potter, 2011). Future studies could directly compare components of exposure therapy and mindfulness to examine shared vs. distinctive underlying mechanisms.

In two articles, we provide a Grounded Theory of Stress Cognition, an initial test of this theory, and an assessment of decentering in the context of stressful thought. Decentering, previously underemphasized in brief mindfulness interventions, appears to be a key aspect of blocking subjective realism. Together these two articles increase our understanding of how participants categorize events as stressful, why stressful thoughts feel so real, and how adopting a mindful perspective disengages the experience of self from them.

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