Emotional Reactivity, Negative Affect, and Executive Functioning: Does Physiology Matter?

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Emotional reactivity reflects the activation, intensity, and duration of an emotional event. Although it is well-established that emotional reactivity has negative implications on psychological functioning, studies have demonstrated that high emotional reactivity enhances executive functioning performance when in negative mood states. The underlying mechanisms that elicit these benefits remain less understood. The current study investigated the relationship between negative affect and executive functioning by examining the role of emotional reactivity through self-report questionnaires and objective physiological skin conductance measures. Participants completed a task of working memory embedded with emotional images, while electrodermal activity was recorded. Based on previous research, we predicted that individuals with high emotional reactivity would perform better on the working memory task when in a negative mood state compared to low-reactive individuals. At the physiological level, we hypothesized that high-reactive individuals would demonstrate higher phasic peaks to emotionally-laden content compared to low-reactive individuals. We also predicted that the underlying mechanism that would lead high-reactive individuals to experience better behavioural performance on the task would be a more rapid physiological habituation to the negative condition, as they would shift attention from the negative images back to the working memory task more quickly. Results indicated that high-reactive individuals actually performed worse in the negative condition compared to low-reactive individuals. Moreover, emotional reactivity did not predict skin conductance magnitudes. Finally, individuals with high emotional reactivity habituated to the negative condition more quickly than individuals with low-reactivity; however, more rapid habituation did not improve behavioural performance on the working memory task. We outline the implications of this work and provide suggestions for future research.

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Introduction

Executive Functions

Executive function is an umbrella term for higher order cognitive skills that facilitate goal-directed behaviour (Goldstein et al., 2014). Executive functions include a wide variety of skills and processes that are used to self-regulate an individual's thoughts and behaviours in pursuit of specific goals. According to Miyake and colleagues' (2000) unity and diversity framework, executive skills are conceptualized as separable yet interrelated constructs, and they are critical for navigating the changing milieu of day-to-day life. These foundational or 'core' skills include the ability to keep goal-relevant information in mind (e.g., working memory), refrain from actions that are pre-potent yet inappropriate in a given goal-context (e.g., response inhibition), and flexibly switch between different mental sets and/or behaviours (e.g., shifting) in the service of goal attainment (Miyake et al., 2000). Historically, investigations of executive functions were tied to neuropsychological studies that identified functional deficits in patients who had frontal lobe damage. These individuals experienced severe challenges in behavioural control and regulation, as well as in their ability to function properly in their daily lives (Miyake et al., 2000).

Working Memory

Contrasting Miyake and colleagues' (2000) view of executive functions as separate but connected constructs, Baddeley and Hitch's (1974) conceptualization of working memory suggests a more unitary view of executive functioning. This model postulates that goal-related thoughts and behaviours are ultimately controlled by a limited-capacity central executive, which is linked to functioning in the frontal lobe. These central structures and processes work together to maintain, store, and manipulate "active" task-relevant information for a temporary period of time in order to support processes related to thinking and behaving. Additionally, working memory also interacts with long-term memory, which is responsible for "passive" stores of information for longer durations of time. This process enables individuals to upload and download information from long-term memory systems (Atkinson & Shiffrin, 1968).

Engle and colleagues further developed Baddeley and Hitch's (1974) central executive concept by proposing a dual-component model of working memory capacity (Kane et al., 2007; Kane & Engle, 2002; Unsworth & Engle, 2007a; Unsworth & Engle, 2007b). This dual-component model suggests that working memory capacity consists of two controlled functions of the central executive. The first function is executive attention, referring to an individual's ability to focus attention within the domain of primary memory on pertinent information in highly activated states while distracting information is present. The second function refers to a calculated search of secondary memory, demonstrating the ability to retrieve appropriate information from long-term storage, in the presence of competitive information that is irrelevant to the task at hand (Kane & Engle, 2002).

Particular executive functioning performance tasks (e.g., complex span tasks) reflect these two functions of working memory capacity. For example, within the Symmetry Span Task, the memory component of the task includes sets of items that the individual must remember (e.g., positions of squares in sequential order within a 16-square grid). However, between presentations of these square items, participants must engage in irrelevant processing components of the task (e.g., identifying whether an image is symmetrical or not). As such, working memory capacity (e.g., the ability to correctly identify positions and sequences of the squares) is measured during states of interference from the second processing component of the task. Individual differences in working memory are common and influence performance on these tasks (Conway et al., 2005). Differences in performance result from significant variability in individuals' capacity to apply their working memory and other executive skills – particularly in situations that are affective in nature (Gyurak et al., 2012).

Affect

Core affect has previously been defined as a "neurophysiological state consciously accessible as the simplest raw (nonreflective) feelings evident in moods and emotions" (Russell, 2003, p. 148). There are a variety of conceptualizations regarding what makes up the construct of affect. Russell's (1980) original four-factor circumplex model of affect demonstrated the interplay of combined arousal and pleasure aspects, as it included factors of pleasure, excitement, arousal, and contentment. As such, this model suggested that both positive and negative affect vary with regards to levels of physiological arousal and satisfaction. Updated work by Russell (2003) suggested that core affect is made up of a single bivalent dimension of pleasure and displeasure, as well as a dimension of activation and deactivation. Watson and Tellegen (1985) proposed a more rudimentary model of affect. They postulated that affect includes two distinct orthogonal dimensions; a positive dimension and negative dimension to affect, each of which ranges from high to low. This particular model does not include an arousal factor, although subsequent work by Watson and colleagues (1999) incorporated factors associated with arousal and contentment.

Affect Inductions

Over the past several decades, research has investigated the influence of emotions on various aspects of functioning by employing a variety of mood induction techniques to induce affective states. These techniques include the use of images (Lang et al., 2008), films (Gross & Levenson, 1995), self-generated imagery (e.g., recounting autobiographical recollections or reliving past events from previous memories; Zhang et al., 2014), music (Sutherland et al., 1982), a combination of self-generated imagery and music (the Music and Contemplation in Idiographic context technique; Eich et al., 2007), facial muscle movements (Ekman et al., 1983), hypnosis (Bower, 1983), interactions with trained confederates (Ax, 1953) and even drugs or sleep deprivation (both of which pose ethical concerns and are less frequently used in contemporary research; Martin, 1990; Hagemann et al., 1999).

One of the most widely used affect inductions that requires no deception and is easily standardized among participants involves the presentation of visual affective stimuli (e.g., images) to elicit positive, negative, and neutral affective responses (Zhang et al., 2014). The International Affective Picture System (IAPS; Lang et al., 2008) is an internationally known method of disseminating a large set of emotionally-laden photographs that span a variety of content categories (e.g., people, animals, objects, etc.). The images available vary in three different dimensions; valence (ranging from pleasant to unpleasant), arousal (ranging from calm to excited), and dominance (ranging from experiencing feelings of low control to high control when looking at the image; Lang et al., 2008). Duration of image presentations typically range from subliminal applications of 2.5 seconds (Chiew & Braver, 2011) up to durations of 8 seconds (Amrhein et al., 2004) in order to elicit emotional responses. IAPS images are considered to be an effective mood induction technique and have been incorporated into studies examining the influence of affect on executive skills like working memory (Wingert et al., 2018), as well as attention (Bradley & Lang, 2007), pain tolerance (Meagher et al., 2001), personality (Tok et al., 2010), and physiology (Smith et al., 2005).

Affective Influences on Executive Functions

Varying affective states influence individuals' ability to implement their executive skills. Recent studies have demonstrated that emotional content may capture attention, ultimately resulting in diminished capacity for ongoing cognitive processing (Mather, 2007). Wingert and colleagues (2018) conducted a study that examined the ways in which valence and arousal influence attentional processes during working memory encoding on the Symmetry Span Task.

This cognitive test was modified to include negative and neutral images from the IAPS, which were embedded into the encoding phases of each trial. Across three experiments, they found that negative high arousing images impaired working memory encoding more strongly when compared with neutral images, as evidenced by diminished partial span scores on the cognitive task. Within study 2, they further determined that the presence of neutral images also led to impaired working memory performance compared to the traditional administration of the Symmetry Span Task without the inclusion of images. As such, the presentation of any image had a distracting effect on attention, which resulted in poorer working memory performance. Study 3 included negative and neutral images that were both of high and low levels of arousal. Negative and high arousing images captured attention and were processed despite their lack of congruence with task goals, and this increased recollections of the images in a subsequent recognition task (Wingert et al., 2018).

Theoretical Frameworks for how Affect Influences Executive Functioning

Mitchell and Phillips (2007) were interested in assessing whether certain theoretical frameworks are able to explain the influence of affect on executive functioning. As such, they conducted a review of various papers and developed a number of theoretical models to examine the relationship between these two constructs.

Cognitive Load Theory

The cognitive load theory postulates that both positive and negative affective states will result in greater activation of working memory through a widespread network of thoughts that are emotion-focused, and ultimately loads up cognitive resources. They suggest that individuals ruminate about mood-relevant information instead of task-relevant information, which diminishes the capacity to utilize executive skills to achieve external goals (Mitchell & Phillips, 2007).

Mood-as-Information Theory

The mood-as-information theory considers the influence of positive and negative affect on executive skills distinctly. It suggests that positive moods signify the absence of a threat and reduces motivation to alter current circumstances. As such, it results in a heuristic processing style that leads to shortcuts and non-rigorous ways of working through tasks, which ultimately impairs executive functioning performance. Contrastingly, negative moods reflect the presence of a threat and motivates an individual to carry out careful, systematic, and detailed problem-solving to work through the threat. For that reason, negative mood promotes an analytic processing style, which is expected to improve executive performance (Mitchell & Phillips, 2007).

The review article by Mitchell and Phillips (2007) found, with regards to working memory performance, that positive mood states influenced executive skills in a negative manner, while no consistent patterns of results were determined for the effect of negative mood states on working memory. For shifting abilities, the review suggested that positive mood negatively influenced switching task performance in cases where participants were required to switch to previously attended to stimuli in the environment. However, when novel information was being processed, positive mood enhanced switching abilities. The researchers noted that there is a dearth in the literature regarding the influence on positive and negative mood for response inhibition. Evidently, the findings of this review suggest that positive mood states impair executive skills (thus supporting the cognitive load theory and mood-as-information theory), while negative moods do not appear to influence executive functions (which does not support either theory). The results of this review were inconclusive and did not clearly support one particular theoretical perspective for the influence of affect on executive functioning. These findings suggest that the associations between affect and executive functioning may be moderated by factors that have not yet been explored in the literature. One aspect that was not given much attention in the articles reviewed in this paper was arousal, which is a key factor in the affect models. As such, the present study is interested in examining arousal, in the form of emotional reactivity, to determine whether emotional reactivity moderates how affect influences executive functioning performance.

Emotional Reactivity

Emotional reactivity reflects how readily individuals experience emotional arousal to an event, at what intensity, and for what duration of time (Davidson, 1998; Nock et al., 2008). There are a variety of factors that culminate in the experience of emotional reactivity. At the onset of an emotional stimulus, there is a particular duration of time, termed the emotional response time, for which it takes the emotional response to be activated. Following activation, the intensity of emotional response to that stimulus rises until it reaches its peak amplitude. The intensity will ultimately decrease and will return back to its baseline level (see Figure 1; Becerra & Campitelli, 2013). Studies suggest that individuals who experience high levels of emotional reactivity typically react to stressful circumstances with increased levels of negative affect and have maladaptive evaluations of these events. For that reason, individuals high in emotional reactivity typically experience predominantly negative emotional reactivity (Shapero et al., 2016).

Individual Differences in Emotional Reactivity

Variability in emotional reactivity can arise in a number of different ways, including (a) the threshold for how strong a stimulus is required to be in order to elicit an emotional response or how quickly the level of arousal reaches its peak altitude (b) the level of intensity of the emotional response (e.g., the peak amplitude of the arousal) (c) the duration for which it takes the level of arousal to return to its baseline (Davidson, 1998). Together, these terms are typically conceptualized as activation, intensity, and duration, which make up the construct of emotional reactivity (Becerra & Campitelli, 2013). Differences in emotional reactivity levels have been discerned as early as in the first year of life, such that infants will exhibit varied responses to the same emotional stimuli based on how emotionally reactive they are, and these reactivity levels persist into later years (Ursache et al., 2013; Diener et al., 1985; Skinner & Zimmer-Gembeck 2007).

Emotional Reactivity and Temperament

Emotional reactivity and temperament are two distinct but related constructs (Nock et al., 2008). Emotional reactivity has previously been conceptualized as a dimension of temperament. Temperament is posited as a much larger construct that encompasses emotional reactivity, as well as other factors associated with behaviour (e.g., self-regulation). According to Rothbart and Ahadi (1994), temperament refers to an intrinsic tendency toward both positive and negative emotional arousal. It further encompasses regulation of arousal through both voluntary processes such as attention, as well as automatic processes including avoidance or self-soothing (Derryberry & Rothbart, 1997; Rothbart & Ahadi, 1994). Kagan and colleagues (1998) found that when exposed to novelty, high levels of temperamental negative emotionality in infancy is moderately stable throughout the first 5 years of life (Kagan et al., 1998). However, 13% of infants in this study who were classified as high in reactivity at 4 months demonstrated inhibited temperament in subsequent assessments, indicating that changes in negative emotionality may be linked to the development of strategies to regulate emotional reactivity (Kagan et al., 1998).

Emotional Reactivity and Emotion Regulation

Emotional reactivity has also been conceptualized as a component of the well-researched construct of emotion regulation. Emotional regulation incorporates both intrinsic and extrinsic processes related to monitoring, assessing, and adapting emotional reactions in order to obtain goals (Becerra & Campitelli, 2013). These processes vary along a continuum and include voluntary reactions (e.g., having an awareness and understanding of emotions, strategies to regulate emotions, and impulse control), as well as involuntary reactions related to emotional responses (e.g., emotional reactivity). The family environment plays an important role in children's abilities to develop emotional regulation strategies. Beginning in infancy, self-regulation strategies mature through direct observation of parents' behaviours and emotional responses. A study by Bernier and colleagues (2010) reviewed how external influences affect self-regulation in infants. They demonstrated that parent-infant interactions between the ages of 12 to 15 months had subsequent influences on executive functioning skills related to impulse control and working memory, and that maternal autonomy support (e.g., mothers' behaviours that aim to support their child's goals, decisions, and sense of volition) was the strongest predictor of these skills. Development of emotional regulation strategies is also affected by particular parenting styles and the emotional climate within the family (Morris et al., 2007). Although automatic and volitional categories of emotional regulation are shown to be distinct constructs, it is presumed that they function in a hierarchical manner. Emotional reactivity, which is considered to be involuntary arousal in the form of automatic regulation, is suggested to lead to the emergence of voluntary control processes like attention and executive functions, which support self-regulation (Ursache et al., 2013). Thus, emotional reactivity can lead to a predisposition of difficulties with emotion regulation (Nock et al., 2008).

Negative Consequences of Emotional Reactivity

High emotional reactivity is considered an important risk factor for the development and maintenance of psychopathology. Numerous studies suggest a link between mood disorders and emotional reactivity (Bylsma et al., 2008; Shapero et al., 2016; Gruber et al., 2011). Emotionally reactive responses were found to weaken with clinical levels of depression (Bylsma et al., 2008); however, subthreshold depression was related to greater negative emotional responses (e.g., Shapero et al., 2016). Similarly, Shapero and colleagues (2019) indicated that high emotional reactivity was directly linked with increased depressive symptoms. They also noted that factors may influence the relationship between emotional reactivity and depression. For example, maltreatment may enhance the connection between emotional reactivity, depression, and suicidal thoughts and behaviours, while resiliency factors associated with coping abilities of stress may buffer the effects of emotional reactivity (Shapero et al., 2019). Emotional reactivity has also been investigated in individuals with bipolar disorder. Gruber and colleagues (2011) demonstrated that individuals with inter-episode bipolar disorder who were exposed to emotionally arousing films (happy, neutral, and sad) experienced increased self-reported positive emotional reactivity across all films compared to healthy controls; however, these individuals did not experience emotional recovery.

Emotional reactivity has also been linked with clinical levels of anxiety. Macatee and Cougle (2013) demonstrated that heightened levels of emotional reactivity came out as a salient feature of generalized anxiety symptoms. Furthermore, Goldin and colleagues (2009) reported that individuals with social anxiety disorder experienced emotional hyperactivity, and they demonstrated that these individuals experienced greater negative emotion than controls during social and physical threat. Within child populations, Carthy and colleagues (2010) established that children with anxiety experienced greater intensity and frequency of negative emotional reactions, deficiencies in utilizing reappraisal in negative emotional situations and self-efficacy, and an increased dependency on negative emotion regulation strategies. This, in turn, exacerbated risk of impaired functioning, intense negative emotion, and deficiencies in self-efficacy related to emotion regulation (Carthy et al., 2010).

Studies have also demonstrated the association between emotional reactivity and substance use disorders. For example, a study by Kornreich and colleagues (1998) suggests that newly detoxified alcoholics who were shown affective film excerpts demonstrated greater within-group emotional variability compared to controls. Personality disorders, such as borderline personality disorder (BPD), are also distinguished by a susceptibility for hyperarousal with regards to emotions (Linehan, 1993). Similar to Davidson's (1998) description of the three factors that make up emotional reactivity, Linehan (1993) postulates that individuals with BPD experience negative emotional responses that are readily activated, intense in magnitude, and persistent in duration.

Disruption in the development and implementation of emotional regulation skills is also suggested to increase emotional reactivity and subsequent psychopathology (Aldao et al., 2010). For example, one study found that adolescents who experienced greater emotion dysregulation, which was evidenced by heightened expressions of emotional states (e.g., emotional reactivity), were likely to endure greater depressive symptoms when confronted with stressors (McLaughlin et al., 2009). Silk and colleagues (2003) further suggested that individuals who experienced more intense and labile emotions and had a limited ability to self-regulate reported experiencing increased rates of depressive symptoms and greater externalizing behavioural problems.

Positive Consequences of Emotional Reactivity

Although high emotional reactivity has been associated with increased risk for a variety of psychological disorders, previous research has also demonstrated some benefits associated with increased emotional reactivity. For example, Gabel and McAuley (2018, in press) conducted a study examining the moderating effect of emotional reactivity on executive functioning and mood. In one study, participants' natural variations in mood were assessed, such that individuals participated in the study with whatever mood state they entered the lab in. The researchers found that negative affect was associated with variable performance on executive functioning tasks (e.g., response inhibition and working memory); however, the nature of this relationship depended on levels of emotional reactivity. Individuals high in emotional reactivity performed better on the executive skills tasks when they experienced negative affect, while individuals low in emotional reactivity performed worse in these tasks (Gabel & McAuley, 2018). A second study was conducted with negative and positive mood inductions (e.g., written tasks with mood congruent music) and similar patterns of findings emerged. High emotionally reactive individuals in the negative mood induction condition performed quicker on a response inhibition task compared to individuals with low emotional reactivity. Interestingly, individuals in the positive mood induction condition did not vary significantly based on reactivity levels (Gabel & McAuley, in press).

The results of these studies may provide evidence in support of an integration of theoretical perspectives of the cognitive load theory and the mood-as-information theory. The studies demonstrate that negative mood states may either bias individuals towards more analytic processing styles, which improves cognitive performance, or they may place demand on cognitive resources, thereby impeding performance. It appears that executive functioning performance in these mood states is moderated by whether an individual is high or low in emotional reactivity. Interestingly, Gabel and McAuley (2018) suggested that high emotionally reactive individuals may demonstrate improved performance on executive functioning tasks as a consequence of how typical it is for them to experience negative affective states in their daily lives while simultaneously utilizing their executive skills. As a result, they are more ‘practiced’ at using these skills under negative emotionally arousing circumstances. Presently, a paucity in the literature exists regarding what mechanisms may facilitate these processes. As such, the current study seeks to determine whether physiological habituation acts as a mechanism that allows for individuals high in emotional reactivity to ultimately benefit from the experience of a bad mood when they employ their executive skills.

Habituation

"Habituation is an evolutionarily ancient mechanism of neuronal plasticity and non-associative learning whereby behavioral and physiological responses during initial exposure to a stimulus diminishes with repeated presentations of that stimulus" (Pace-Schott et al., 2011, p. 2). As individuals with high emotional reactivity more regularly experience negative moods, we are interested in assessing whether these individuals demonstrate something akin to habituation in relation to these negative affective states more rapidly than individuals who are not used to consistently being in these states. As habituation is expected to be quicker in high-emotionally reactive individuals, they may be able to divert their attention back to the task and use their executive skills more effectively than those who are less experienced at integrating these skills in negative mood states.

A variety of theories have been proposed to outline the mechanisms by which habituation occurs. These include the stimulus-model comparator theory, gnostic unit theory, and the dual-process theory. Evgeny Sokolov (1960, 1963) developed the stimulus-model comparator theory of habituation by examining arousal of the orienting response as the foundation of his studies. He expressed that the orienting response, which is established via EEG activity, results in heightened sensitivity through the amplifying system when one is exposed to a novel stimulus or a change in a previously experienced stimulus. When an orienting response occurs, the individual, or organism will experience observable behaviours and physiological responses, but will then experience habituation upon repeated presentation of that stimulus. It is suggested that the mechanism by which this occurs stems from the development of a stimulus model, which is formed within the cerebral cortex. As the same stimulus is presented repeatedly, this stimulus model continuously develops, and greater inhibition on the amplifying system results in habitation. When new or altered stimuli are experienced that do not match the stimulus model, the orienting response is no longer inhibited.

The Wagner-Konorski gnostic unity theory elaborates on Sokolov's theory by focusing on the role of short-term memory and associative networks. Within this model, a stimulus object is processed through afferent networks towards a memory system, the gnostic assembly, and to the arousal system. Following the repeated presentation of the stimulus, the gnostic unity is formed, whereby a neuronal model or memory of that stimulus becomes progressively more accurate. As this develops, there is activation of an inhibitory system that hinders the arousal system. This model includes a reverberating circuit of transient memory (short-term memory) as well as influences of pre-existing associative networks. Additionally, particular contextual cues may be engaged through the associative network, which excite the representations of that stimulus within memory (the gnostic assembly) and can result in context-specific long-term habituation.

Grove & Thompson's (1970, 1973) dual process theory suggests that any stimulus will prompt two separate processes in the central nervous system that interact with one another in order to elicit habituation. These processes include habituation (decremental) and sensitization (incremental). When a stimulus is presented, both habituation and sensitization are activated. The behaviour that will be elicited is correlated with the process that is more dominant. For example, if habituation is greater than sensitization, there will be a diminished response; if sensitization is greater than habituation, an increased response will occur. Two neural pathways are involved; a "stimulus-response" (S-R) pathway, which is involved when a stimulus-evoked response is being habituated, and a "state-system" pathway, which is involved in the development of sensitization. The state-system pathway acts on the S-R pathway to elicit the final behavioural outcome. This conceptualization of habituation is most typically accepted in contemporary research.

While habituation is typically examined by presenting a singular exemplar that individuals are exposed to repeatedly, the present study investigates habituation to a specific category of stimuli with different exemplars. In daily life, it is quite common to face a host of negative affective stimuli rather than exposure to the same stimulus repeatedly. Thus, using novel images may be more representative of how negative affect is experienced in typical daily life. Individuals high in emotional reactivity may be better at coping with this category of negative information due to practice.

Electrodermal Activity

In an effort to understand the process of habituation, measurements of physiological habituation have been used to examine how individuals experience autonomic reactions to events that elicit emotional responses. Emotions have previously been measured through autonomic arousal in the autonomic nervous system (ANS), which is a physiological system responsible for regulating peripheral functions (Mauss & Robinson, 2009). The ANS consists of the sympathetic and parasympathetic nervous system, which are associated with activation of the fight-flight-freeze response (e.g., increased heart rate, blood pressure, and sweating) and slow changing processes associated with resting and digestion, respectively. The physiological arousal component of emotion reflects the activation of the sympathetic nervous system and the deactivation of the parasympathetic nervous system (Mauss & Robinson, 2009).

One of the most commonly assessed indices of ANS activation is skin conductance, also commonly referred to as electrodermal activity or galvanic skin response. Skin conductance is a non-invasive measure of changes in electrical conductivity of the skin. It is considered to be one of the most sensitive measures of emotional arousal and is solely modulated by autonomic sympathetic activity that drives bodily processes at the subconscious level. As skin conductance cannot be consciously controlled, it is the ideal marker for emotional arousal by providing pure insight into the physiological processes of a person based on their psychological operations (iMotion Guide, 2016).

History of Skin Conductance Measures

The study of psychological influences on electrical changes in skin spans over 100 years (Dawson et al., 2017). Fere (1888) and Tarchanoff (1890) were two influential figures in setting the foundation for current measurement techniques in electrodermal activities. Fere (1888) demonstrated that momentary decreases in skin resistance in response to various forms of stimuli (e.g., ranging from visual, auditory, gustatory, olfactory, etc.) could be detected by passing a small electrical current across two electrodes that are positioned on the skin's surface. This discovery was crucial to the study of electrodermal activity, as it established that the skin momentarily becomes a better conductor of electricity when an individual is exposed to stimuli external to the body (Dawson et al., 2017). Tarchanoff (1890) elaborated on this idea and suggested that one can measure changes in electrical potentials between two electrodes on the skin in the absence of an external current. As a result of these discoveries, contemporary research in skin conductance focuses on one of two methods: the exosomatic method addresses the skin resistance response (or its reciprocal, the skin conductance response), which depends on movement of an external current across the skin, and the endosomatic method, which suggests that recordings of the skin potential response do not require external currents. The present study focuses on the exosomatic method of recording the phasic skin conductance response (SCR), as this is the method widely utilized in contemporary electrodermal activity research (Dawson et al., 2017).

Anatomical and Physiological Aspects of Electrodermal Activity

The skin is the largest organ in the human body and serves many functions, such as preventing external substances from entering the body and thermoregulation. The skin further receives signals from the brain, and electrodermal activity is the measurement of the electrical changes that result from these signals (Edelberg, 1972).

The secretion theory relates electrodermal activity to sweat gland activity (Dawson et al., 2017). Darrow (1927) found that sweat secretion and electrodermal activity were closely associated with one another. However, Darrow determined that the SCR, the phasic response that is sensitive to emotionally arousing stimuli, begins approximately 1 second prior to moisture appearing on the surface of the skin. As such, it was determined that a critical component underlying electrodermal activity is the activation of the sweat glands themselves, not the identification of sweat on the skin.

The human body contains approximately 3 million sweat glands, and the density of sweat glands varies across different areas of the body (iMotion Guide, 2016). The eccrine glands, which are primarily associated with thermoregulation, contain a coiled compact body which is considered to be the secretory aspect of the gland, as well as the sweat duct, which is a long tube that serves as the excretory component of the gland that opens at the surface of the skin as a pore (Edelberg, 1972). Electrodermal activities, such as electrical changes in the SCL and SCR amplitudes, are based entirely in the sweat glands (Edelberg, 1993).

Recording Electrodermal Activity

Electrodermal activity is measured through the passage of a small current through a pair of electrodes that are strategically placed on surfaces of the skin that have significant eccrine glands (e.g., typically including the volar surfaces on medial phalanges, volar surfaces of distal phalanges, and thenar and hypothenar eminences of palms; Dawson et al., 2017). Measurement of skin resistance or conductance follows Ohm's law, which indicates that skin resistance (R) is equivalent to the voltage (V) applied between two electrodes placed on the skin surface, divided by the current (I) being passed through the skin (i.e., $R = V/I$). Skin conductance is considered to be the reciprocal of skin resistance. Skin conductance research utilizes equipment that applies a constant voltage to the skin through electrodes, which is undetectable to the participant. As such, the current flow can be measured, allowing for the measurement of skin conductance.

Skin conductance is characterized by SCL and SCR. The SCL is considered to be the tonic level, which varies slowly and only exhibits slight changes that change in occurrence from tens of seconds to minutes (iMotion guide, 2016). SCL is the baseline level of skin conductance that rises and declines consistently in the absence of particular environmental events, but is affected by individual differences in hydration, skin dryness, and autonomic regulation. As such, it is not considered to be a highly informative measure on its own. The SCR is the phasic component, which typically exhibits much quicker changes in the form of SCR peaks. SCR is particularly sensitive to emotionally arousing stimuli, and peaks are typically seen between 1-5 seconds after the onset of an emotional stimulus. Skin conductance amplitude is expressed in units called mircroSiemens (µS), while latency and rise time are expressed in seconds. The amplitude measures the difference between the tonic SCL at the time the response was evoked and the peak of the SCR. Additionally, the latency period is the time between the stimulus and the onset of the event-related SCR (ranging from 1-3 seconds). Rise time focuses on the time between the onset of the event-related SCR and the peak of the response (ranging from 1-3 seconds as well) and measures of recovery to baseline can be used to determine habituation.

Habituation and Skin Conductance

An important strength of measuring SCR is the ability to assess diminishing effects and its eventual disappearance, following repeated presentation of the stimulus or categories of stimuli (SCR habituation). Habitation has previously been assessed through skin conductance measures. The trials-to-habituation method involves counting the number of stimulus repetitions that are required to reach a predetermined level of physiological habituation. Typical guidelines suggest that habituation occurs after two or three trials, as no meaningful SCR magnitudes (≥

.05) are evident at this point (Dawson et al., 2017). Habituation has also been assessed by utilizing analysis of variance to evaluate a "trials" main effect or interaction through the use of rates of decline of SCR magnitude across trials. Finally, the regression approach evaluates SCR magnitude on the log of the trial number and provides a slope and intercept score which are typically highly correlated (Dawson et al., 2017).

Researchers have utilized habitation of skin conductance response to investigate factors associated with emotional reactivity and its relationship with mental health disorders. For example, one study assessed skin conductance habituation to tones in patients with panic disorder (Roth et al., 1990). The results suggest that individuals with panic disorder experienced slower rates of habituation compared to healthy participants, as assessed via trials-to-habituation, total number of responses, and slope of decline of skin conductance (Roth et al., 1990). Walker and colleagues (2019) suggest an association between SCR habituation to a repeated acoustic startle stimulus and resilience-related psychometric constructs. Utilizing the slope measures of habituation, they found that steep negative slopes which reflect quicker rates of habituation corresponded with lower depression/anxiety and higher resilience, while slower or no habituation depict individuals who are less resilient (Walker et al., 2019).

Purpose and Hypotheses

The primary aim of the current study is to rigorously investigate the influence of emotional reactivity on negative affect and executive functioning performance by integrating behavioural and physiological measures in an experimental research design. As noted, previous research investigating the theoretical frameworks of affect on executive functioning (e.g., the cognitive-load theory and mood-as-information theory) has been inconclusive. Negative mood may bias individuals towards a more analytic processing style and may also place demands on cognitive resources; however, the cognitive demand may vary for high- and low-reactive individuals. As such, the current study suggests that the integration of these theoretical perspectives (i.e., mood-as-information theory and cognitive load theory) may be warranted and seeks to determine what underlying mechanisms may lead individuals high in emotional reactivity to benefit from negative mood states.

Behaviourally, we are interested in investigating whether individual differences in self-reported emotional reactivity will influence how negative affect (as induced by negative emotional stimuli) will impact performance on a working memory task. We hypothesize that affect will predict working memory performance, such that individuals high in self-reported emotional reactivity will perform better on working memory compared to their low-emotionally reactive counterparts within the negative condition. We do not expect significantly different performance within the neutral condition.

Physiologically, we seek to examine whether differences in self-reported emotional reactivity will be evident in underlying physiological responses during executive functioning performance. We hypothesize that individuals high in self-reported emotional reactivity will evidence high phasic peaks at the onset of negative emotional stimuli within the task but will have fewer trials-to-habituation to the emotional stimuli compared to low emotionally reactive individuals. We suspect this may occur as high emotionally reactive individuals are more practiced at utilizing their executive skills within negative affective states, as negative moods are generally more common for these individuals. As a result, habituation of the physiological response enables shifting of attention from the negative emotional stimuli to the task at hand.

Two analytic designs are proposed. The first design involves multilevel models, which will assess whether emotional reactivity (high vs. low) and image condition (negative and neutral) influence performance on working memory (proportion correct per trial) and physiological responses (SCR). The second design includes general linear models (repeated measures ANOVA), which will assess whether differences in trials-to-habituation scores would be observed based on image condition (negative and neutral), emotional reactivity (high vs. low) and their interaction. Table 1 outlines the research questions, hypotheses, analytic approach, and expected findings of the present study.

Methods

Participants

Ninety-one undergraduate students were recruited to participate in the study in exchange for partial course credit. Previous studies have demonstrated that the influence of emotional reactivity on executive functioning is different depending on whether one is high-reactive (+1 SD from the mean) and low-reactive (-1 SD from the mean), with little effect on individuals who are average (Gable & McAuley, 2018; Gable & McAuley, in press). As such, only those determined via a prior mass-testing survey to have high (> 50; $n = 51$) or low (< 15; $n = 36$) total scores on the Emotion Reactivity Scale (ERS) were eligible. The only other eligibility requirement was operating a computer mouse using their right hand, as skin conductance electrodes were applied to left hands. Additionally, after study completion, we excluded two participants with an accuracy score of < .85 on the Symmetry Span Task to ensure that participants were paying attention to the irrelevant processing components of the task (see Conway et al., 2005), as well as two other participants with technological glitches. For the physiological analyses, an additional participant was removed as over 90% of this individual's data was invalid. In sum, we had 87 participants in our behavioural models, and 86 in our models involving physiological data.

For multilevel models that nested trials within participants, a total of 24 trials were removed from analyses (1.65%) as a result of having invalid physiological data (i.e., ceiling artifacts in which the circuit is overloaded and floor artifacts in which electrodes lose contact with the skin). The sample of 87 participants included in the behavioural analyses of the study consisted of 71 females (81.6%), 15 males (17.2%), and 1 participant who identified as other (1.2%). Participants ranged between the ages of 18-40 years ($M = 19.6$, $Mdn = 19$, $SD = 2.7$). Forty percent of participants identified as Caucasian, 11.5% identified as Chinese, 4.6% identified as East Indian, and the rest reported having multiple or other ethnicities.

Procedure

Post-consent, non-invasive skin conductance measures were applied to participants' fingers (described further below). Following this set up, participants' resting physiological measures were recorded while watching a relaxing fireplace movie for 20 minutes and they then completed the computerized task of working memory (e.g., Modified Shortened Symmetry Span Task) that had emotional images embedded throughout. Emotional images were meant to impact physiological arousal by eliciting peaks in SCR. Following the task, participants had a resting period of 5 minutes where they watched a shortened version of the fireplace video to return to baseline levels of physiological arousal. Participants were then asked to complete the Self-Assessment Manikin, Emotion Reactivity Scale, and a demographic questionnaire. The skin conductance electrodes were removed, and participants were provided with feedback about the study. After completing the study, participants received 1.5 course credits. The current study's protocol was reviewed and approved by the University of Waterloo Research Ethics Committee.

Apparatus

Video Recording

Two computers were utilized in the study session. Participants used one to complete the study tasks, and the other recorded and displayed the skin conductance data to the researcher. Participants' computer screen was recorded with a Logitech c270 webcam that was positioned on the table in front of the participant so that the screen (and not the participant's face) was visible in the video.

Skin Conductance

SCR was recorded using non-gelled passive electrodes attached to participants' index and ring finger on their left hand. The skin conductance electrodes were connected to an ADinstruments PowerLab (model 8/30) with a Galvanic Skin Response amplifier. A 1000 Hz sampling rate was used and LabChart 7.0 analysis software was utilized in order to analyze SCRs based on the precise time of image presentation for each trial. Based on frequency distributions of response latencies to stimuli, common practice in research utilizing SCR is to have a 1-3 second or 1-4 second latency period (Dawson et al., 2017). Given the short duration of stimulus presentation in the current study, 1 second was used as the latency period, and a 3 second window was used to calculate the SCR. This variable was computed by subtracting the value of skin conductance at the 1 second mark of image exposure from the maximum value of skin conductance (i.e., SCR peak) within the 3 second window. Physiological habituation was assessed using the trials-to-habituation method for each participant (Dawson et al., 2017). SCR magnitudes were reviewed in the order of stimulus repetitions for each category of stimulus (i.e., negative and neutral). As such, two trials-to-habituation scores were acquired per participant; habituation to the negative condition and habituation to the neutral condition. Habituation to each condition was defined as two consecutive SCR magnitudes ≤ .05 to stimulus presentations within that category.

Resting Baseline Video

Participants watched a fireplace video, which has previously been used in skin conductance research (Branje et al., 2014), for 20 minutes immediately following electrode application. Skin conductance measurements during this time were used as a baseline. The same video was presented immediately following the working memory task for 5 minutes to allow participants' skin conductance values to return to baseline.

Measures

Modified Shortened Symmetry Span Task

The Shortened Symmetry Span Task (Foster et al., 2015) is a measurement of working memory, which requires memory of squares' spatial locations on a 4x4 grid with distraction tasks involving symmetry judgments of abstract designs on an 8x8 grid interleaved throughout. The modified task was shortened to one block, and included affective images from the IAPS (i.e., negative and neutral images) that were displayed for 5 seconds at the beginning of each trial. The images were presented in an intermixed and randomized order, and condition was not blocked to ensure that participants would not anticipate a continuous set of negative images. We attempted to reduce risk that participants would disengage from a block of negative images to avoid unpleasantness, thereby impacting physiological responses. A 5-second image presentation was chosen as SCRs can be activated in this timeframe (Dawson et al., 2017), while not disrupting the flow of the Symmetry Span Task. Each trial included a sequence that ranged from 2-5 sets of memory-judgment (e.g., encoding phases) and symmetry-judgement items. At the end of each trial, the sequence of spatial locations was to be recalled in the same order of presentation (see Figure 2). Following practice, participants completed a total of 16 trials (i.e., 8 negative trials and 8 neutral trials). Working memory was indexed by the symmetry span partial score, which reflects the total number of spatial locations correctly recalled across trials. The internal consistency of partial span scores across conditions was .77.

Emotion Reactivity Scale (ERS)

The ERS (Nock et al., 2008) is a 21-item self-report scale on experiences of emotions when reacting to affective events, using a 5-point Likert scale ranging from *not at all like me* (0) to *completely like me* (4). This scale assesses 3 facets of emotional reactivity, including a subscale for emotional sensitivity (e.g., "my feelings get hurt easily;" 8 items), emotional persistence (e.g., “when something happens that upsets me, it’s all I can think about for a long time;” 3 items), and emotional arousal/intensity (e.g., “when I experience emotions I feel them very strongly/intensely;” 10 items). Responses are summed to create a total score ranging from 0-84. The ERS demonstrates strong internal consistency with an overall alpha of .94 (Nock et al., 2008). In the present study, we observed an internal consistency with an overall alpha at .98. Participants completed this scale as part of mass testing, which determined eligibility and was used in analyses, as well as at the end of the in-lab study procedures, results of which are not discussed herein as variability in scores existed between the two time points.

The Self-Assessment Manikin (SAM)

The SAM (Bradley & Lang, 1994) is a measure used as a non-verbal, subjective rating of one’s appraisals of images viewed in the study. Participants were presented with the same 16 images they observed during the Symmetry Span Task and were asked to rate their emotions in relation to valence (ranging from pleasant to unpleasant), arousal (ranging from excited to calm), and dominance (ranging from experiencing feelings of low control to high control when looking at the picture; Figure 3; Bradley & Lang, 1994), all on 5-point scales.

Demographic Questionnaire

Participants were asked questions regarding age, gender, ethnicity, and education.

Results

Analytic Approach

Table 1 describes the analytic approach and expected findings based on the study research questions and hypotheses. The vast majority of analyses were conducted using multilevel models. Multilevel models nested the 16 trials within participants. Within these models, predictors that were obtained for each of the 16 trials (e.g., proportion correct, SCR, image condition, SAM ratings, and set size) were entered as level-1 predictors, and pre-screen emotional reactivity was entered as a level-2 predictor. Cross-level interactions were also examined. For data not assessed using multilevel models (data at the participant level), general linear models were used. Across all models, image condition (-1 = negative, +1 = neutral) was an effect coded predictor. Although we pre-screened participants based on high (> 50) and low (< 15) values of the ERS, standardized continuous scores from this measure were used in the analyses. In-lab ERS scores were not assessed, as a number of participants who were eligible based on pre-ERS scores fell into the 15-50 score range for the in-lab measure, likely as an artifact of it being administered following the study tasks. Although pre-screen ERS and in-lab ERS were highly correlated (see Bivariate Correlations section below), pre-screen ERS was used in the subsequent analyses. Performance on the working memory task was assessed by calculating proportion correct for each trial by dividing mean partial span scores for that trial by the trial set sizes. This computation determined the proportion of correctly recalled squares for that specific trial (e.g., 1 square correctly recalled in a set size of 2 resulted in a proportion correct score of .50 for that trial). SCR magnitudes were generated for each of the negative and neutral trials, as were subjective ratings of valence, arousal, and dominance from the SAM for each of the 16 images preceding the trials. Trials-to-habitation scores were not assessed at each trial; rather, they were calculated for each condition (negative and neutral) at the participant level. Thus, analyses assessing trials-to-habituation scores were examined using a repeated measures ANOVA instead of multilevel models. Simple effects were probed by pooling error across the omnibus term. All analyses were completed on IBM SPSS 24 Statistics.

Prior to analyses, descriptive statistics were completed, and assumptions of normality were assessed. Values of three standard deviations above or below the mean were flagged as outliers. The skewness and kurtosis of the outcome measure (proportion correct) fell within the normality assumptions per Kline (1998); |skewness| < 3 and |kurtosis| < 10. Univariate outliers were assessed using z scores in order to determine whether any scores exceeded three standard deviations above or below the mean, and no cases were identified. Descriptive statistics of all major variables in the study are presented in Table 2.

Validation of Images

The Appendix includes the list of IAPS images utilized in the study. Using IAPS guideline ratings (Lang et al., 2008), negative and neutral images were selected to vary in valence whilst having comparably high levels of arousal. The latter was done to ensure that arousal would not be a confound when comparing results for the negative and neutral conditions. Using the IAPS validation sample, the valence of negative images ($M = 2.50$, $SD = 0.43$) and neutral images ($M = 5.07$, $SD = 0.65$) were significantly different, $t(14) = 9.30$, $p < .001$, whereas arousal ratings for negative ($M = 5.76$, $SD = 0.14$) and neutral ($M = 5.76$, $SD = 0.20$) images were statistically similar, $t(14) = -0.03$, $p = .977$. In our sample, the valence of negative images and neutral images was also significantly different, $t(86) = -21.90$, $p < .001$, with negative images rated as more unpleasant than neutral images. However, participants rated negative images as being more arousing than neutral images, $t(86) = -6.83$, $p < .001$. Likewise, dominance was also significantly different for neutral and negative images, $t(86) = -6.29$, $p < .001$. Participants rated negative images as resulting in feelings of less control of the situation in the image than neutral images. Table 2 includes descriptive statistics of SAM valence, arousal, and dominance ratings at the participant level.

Bivariate Correlations of Study Variables at the Participant Level

Although there was variability between emotional reactivity scores on the ERS during mass testing and within the lab, bivariate correlations indicated that emotional reactivity pre-study and within-study were significantly correlated with one another at the participant level, r = .89, $p < .001$. Further, bivariate correlations between major study variables by condition were examined at the participant level. Emotional reactivity was not significantly associated with partial span scores, SAM ratings of valence, arousal, and dominance, SCR, and trials-to habituation (all within both the negative and neutral conditions); however there was a was trending level significant association between emotional reactivity and trials to habituation in the negative condition, r = -.21, p = .050. All other bivariate correlations are presented in Table 3.

Base Model of Image Condition on Proportion Correct

When used as a lone predictor of proportion correct, image condition did not significantly predict proportion correct, b = 0.01, t(1261.73) = 1.42, p = .156 (see Table 4). Further, as set size accounted for a significant proportion of the variance associated with proportion correct, b = -0.13, t(1238.27) = 20.43, $p < .001$, when tested with image condition, it was included as a covariate in all future models. With this added covariate, image condition still did not significantly predict proportion correct, b = 0.01, t(1235.41) = 1.48, p = .140 (see Table 4).

Emotional Reactivity, Image Condition, and Proportion Correct

Further analyses were conducted to examine whether emotional reactivity moderated the effect of image condition on proportion correct, while covarying for set size (see Table 4). Set size remained a significant covariate, b = -0.13, t(1235.23) = 20.47, $p < .001$, and the main effect of image condition was again non-significant, b = 0.01, t(1232.13) = 1.47, p = .141. Emotional reactivity prior to study enrollment also did not produce a significant main effect, $b = 0.00$, $t(375.77) = 0.51$, $p = .611$. However, a significant interaction indicated that emotional reactivity moderated the effect of image condition on proportion correct, $b = 0.02$, $t(1210.85) = 2.13$, $p = .033$.

Simple Effects of Emotional Reactivity Within Image Condition

Within the negative image condition, there was a trending level effect of emotional reactivity, $b = -0.02$, $t(789.24) = 1.71$, $p = .087$, such that individuals higher in emotional reactivity performed worse on the working memory task than those low in emotional reactivity. Conversely, within the neutral image condition, emotional reactivity had no impact on proportion correct, $b = 0.01$, $t(787.27) = 0.91$, $p = .362$ (see Table 4). In sum, contrary to our hypotheses, individuals high in emotional reactivity had worse performance on proportion correct within the negative condition compared to their lower-emotionally reactive counterparts. See Figure 4 for further details.

Moderation of Emotional Reactivity, Image Condition, and SAM Ratings on Proportion Correct

Moderation analyses were conducted to assess the influence of emotional reactivity, image condition, and the three SAM ratings scales (valence, arousal, and dominance) on proportion correct while covarying for set size. In all three models, set size was a significant covariate, however, no simple effects or interactions were statistically significant (see Table 5).

SCR and Emotional Reactivity

We assessed the extent to which subjective ratings of emotional reactivity predicted measures of skin conductance. Interestingly, emotional reactivity did not significantly predict measures of SCR, $b = -0.02$, $t(293.63) = 0.62$, $p = .539$. Similar results were observed when examining the interaction between emotional reactivity and condition on SCR, while including set size as a covariate (see Table 6).

SCR and Proportion Correct

We tested the extent to which SCR and image condition predicted proportion correct, while covarying for set size (see Table 4). Set size was a significant covariate, $b = -0.13$, $t(1209.30) = 20.37$, $p < .001$, and the main effect of image condition significantly predicted proportion correct, $b = 0.02$, $t(1237.31) = 2.15$, $p = .031$. Thus, participants scored higher on proportion correct within the neutral condition. Additionally, the main effect of SCR per trial significantly predicted proportion correct, $b = -0.02$, $t(1358.78) = 2.77$, $p = .006$, such that individuals with higher SCRs performed worse on proportion correct than those with lower SCRs (see Figure 5). Image condition and SCR per trial did not significantly interact, $b = -0.01$, $t(1240.40) = 1.09$, $p = .277$.

Trials-to-Habituation by Image Condition and Emotional Reactivity

Omnibus Analysis

A repeated measures ANOVA was conducted to test differences in trials-to-habituation scores by image condition (negative and neutral), emotional reactivity, and the interaction of image condition and emotional reactivity. The main effect of image condition, $F(1, 84) = 1.27$, $MSE = 4.14$, $p = .264$, $\eta^2_p = .02$, and emotional reactivity, $F(1, 84) = 1.67$, $MSE = 13.73$, $p = .200$, $\eta^2_p = .02$, were not statistically significant. Furthermore, the interaction between image condition and emotional reactivity was not statistically significant, $F(1, 84) = 2.97$, $MSE = 4.14$, $p = .089$, $\eta^2_p = .03$, although this reached trending level significance. Given our hypothesis that individuals with higher emotional reactivity would habituate to the negative conditions faster than their low-emotionally reactive counterparts, further analyses were conducted to assess the impact of emotional reactivity on trials-to-habituation scores in both conditions.

Simple Effects of Emotional Reactivity on Trials-to-Habituation Scores

A test of the simple effects indicated that there was a trending level significant effect of emotional reactivity on negative trials-to-habituation scores, $F(1, 84) = 3.94$, $MSE = 8.71$, $p = .050$, $\eta^2_p = .05$, such that individuals higher in emotional reactivity had lower trials-to-habituation scores, and thus habituated to the negative image condition more quickly (see Figure 6). There was no significant effect of emotional reactivity on neutral trials-to-habituation scores, $F(1, 84) = 0.09$, $MSE = 9.16$, $p = .765$, $\eta^2_p < .01$.

General Discussion

To further elucidate underlying mechanisms that may explain why emotional reactivity moderates the relationship between negative affect and some aspects of executive functioning, this project utilized both subjective self-reports of emotional reactivity as well as more objective physiological indicators through skin conductance responses. Previous work in our lab has shown that high levels of negative mood are detrimental to the executive functioning task performance of low-reactive individuals, whereas the opposite pattern is observed in their high-reactive counterparts (Gabel & McAuley, 2018; Gabel & McAuley, in press). The current study examined whether self-report and physiological markers of emotional reactivity influenced performance on a working memory task with embedded affective stimuli (i.e., neutral and negative images). Specific questions included (1) will individual differences in self-reported emotional reactivity influence how negative affective stimuli impact performance on a working memory task, and (2) will differences in self-reported emotional reactivity be evident in the underlying physiological response during working memory performance. To address these questions, participants completed self-report questionnaires measuring emotional reactivity as well as a task of working memory, while physiological measures of skin conductance were recorded.

With regards to our first research question, we hypothesized that individuals high in self-reported emotional reactivity would perform better in the negative condition of a working memory task compared to their low-emotionally reactive counterparts. This hypothesis was based on suggestions by prior work (Gabel & McAuley, 2018; Gabel & McAuley, in press) that emotional reactivity influences whether negative moods engender a more analytic thinking style that is beneficial to some kinds of cognitive task performance (i.e., in more reactive individuals) or engenders cognitive load that is detrimental to cognitive task performance (i.e., in less reactive individuals). We did not expect to observe significant differences between high- and low-reactive individuals within the neutral condition. Contrary to our hypothesis, we found that individuals with high emotional reactivity performed worse on the working memory task in the negative condition compared to individuals with low emotional reactivity. In line with our prediction, however, high and low-emotionally reactive participants performed comparably in the neutral condition. Our diverging findings from those reported by Gabel and McAuley (2018, in press) may have been influenced by methodological differences associated with the type, length, and operationalization of mood inductions used. Gabel and McAuley (2018, in press) examined natural variations in participants' mood states and also induced mood states with a well-validated induction procedure (written task with mood congruent music) prior to administration of executive functioning tasks. Contrastingly, participants in the present study were exposed to negative and neutral images for 5 seconds within the Shortened Symmetry Span Task, which allowed us to examine physiological responses and working memory performance simultaneously.

The use of images may have negatively impacted performance on the working memory task for a number of reasons. Recent work has demonstrated that task-irrelevant images shown during a test of working memory disrupted performance to a greater extent when negative images were shown compared to neutral images (Dolcos & McCarthy, 2006; Anticevic et al., 2010). Wingert and colleagues (2018) further found that content that is emotional in nature impeded working memory encoding processes, particularly when the stimuli were negatively valanced and highly arousing. Pessoa (2009) proposed a dual competition model, suggesting that cognitive performance is impaired by emotional content as resources need to be distributed between both the task itself and the task-irrelevant emotional stimuli. The findings from the present study suggest that individuals high in emotional reactivity might be particularly susceptible to distraction associated with negative images, even though this does not seem to be reflected in their skin conductance response or SAM ratings. The intermittent images presented may have led high-reactive individuals to allocate greater resources to the negative images than those low in emotional reactivity, disrupting their cognitive processing in the negative condition, and ultimately worsening performance.

Although IAPS images have been widely used as effective mood inductions in research, it is possible that their use in this study elicited emotional responses rather than shifts in mood states. Distinctions in moods and emotions have been previously noted in the literature. Mood has been characterized as a controllable, persistent, and primarily cognitive experience resulting from a non-defined cause (Beedie et al., 2005). Moods are also typically mild and do not have distinct physiological patterns. Conversely, emotions are largely uncontrollable, short-lived, and result in behavioural or expressive actions. Emotions are caused by a particular object or event, felt more intensely than moods, and are evidenced by specific physiological patterns. As the negative and neutral conditions were interleaved and image presentation was very brief, it is possible that participants in our study experienced distinct emotional responses as opposed to enduring shifts in mood. Further, Bradley and Lang (2007) suggest that unpleasant images that portray human threat, animal threat, and mutilated bodies result in heightened SCRs across males and females. The images used in the present study did include some of these themes (see the Appendix), however, images were chosen based on comparable arousal for the two conditions, so we were limited in the categories of images that we could incorporate. As such, some of these themes (e.g., animal mutilation) were not included due to the restricted selection of images, which may have further contributed to the experience of emotional responses instead of shifts in mood states. Thus, while research suggests that negative moods may enhance executive skills in high emotionally reactive individuals by allowing them to engage in analytic thinking styles (mood-as-information theory), brief emotional reactions may diminish use of such skills by adding cognitive load (cognitive load theory). This distinction should be examined in future studies by investigating whether unpleasant images with these three distinct themes and blocked trials of consistent negative and neutral images would more effectively shift mood, yielding results in line with Gabel and McAuley's (2018, in press) findings.

Our second research question focused on differences in physiological responses. We hypothesized that self-reported emotional reactivity would predict skin conductance measures, such that individuals with higher emotional reactivity would experience higher peaks following exposure to emotional stimuli. Contrary to our predictions, self-reported emotional reactivity did not predict SCR magnitudes. Similarly, when assessing SCR by image condition and emotional reactivity, there was no significant effect. A number of confounding factors may have contributed to these findings. Both emotional reactivity and electrodermal activity are influenced by individual differences in personality traits in the context of emotional stimuli (Berenbaum & Williams, 1995; Steenhaut et al., 2018; Mardaga et al., 2006). For example, neuroticism has been shown to increase emotional reactivity to sad film clips amongst both younger and older adults (Steenhaut et al., 2018). Additionally, high novelty seeking was associated with larger SCRs when positive or negative stimuli were displayed subliminally and high harm avoidance was associated with larger SCRs for positive, neutral, and negative images (Cloninger et al., 1993). Electrodermal activity has also been shown to be influenced by factors such as trait anxiety. For instance, Wilken and colleagues (2000) found that individuals with low trait anxiety experienced greater arousal (SCL, spontaneous SCR, and SCR) to stress than individuals high in trait anxiety. They postulated that high-trait anxiety individuals entered the study with greater arousal than individuals with low trait anxiety, and the induced stress from the task resulted in a peak of the inverted U-arousal curve, and an ultimate reduction in arousal. Factors such as these were not controlled for in our study and may have confounded the results by influencing the relationship between emotional reactivity and skin conductance measures. Thus, future studies investigating the impact of emotional reactivity on physiological responses should control for possible confounding variables like personality traits.

Furthermore, the present study found that higher magnitudes of SCR resulted in poorer performance on proportion correct within the working memory task in both conditions. This finding is supported in the literature. Choi and colleagues (2013), for example, investigated the impact of three different levels of emotional arousal on performance during the 3-back working memory task while measuring physiological responses. They found that performance was better in the neutral (lower) arousal state compared to the tense (higher) emotionally arousing conditions, which they attributed to the activation of the sympathetic nervous system (Choi et al., 2013). This is because shifts in electrodermal activity in response to emotionally-arousing content demonstrate the activation of the fight, flight, or freeze response in the sympathetic nervous system. As humans instinctually focus attention towards emotional stimuli that signifies threat, greater physiological changes negatively influence information processing of succeeding input. Thus, in Choi and colleagues' (2013) study, performance in the higher arousal condition diminished, as attention was diverted to the high arousing images, and participants' cognitive processing of the subsequent task was impaired. Developmental studies investigating electrodermal activity have demonstrated similar results by exhibiting that parasympathetic nervous system activation resulted in reduced arousal and better cognitive performance (Frick & Richards, 2001; Richards & Gibson, 1997). Within the present study, we posit that the high-arousing images used throughout may have captured participants' attention, resulting in intermittent moments of emotional responses activated by the sympathetic nervous system (as evidenced by high SCR peaks). As activation of the sympathetic nervous system increased, cognitive processing of the subsequent memory-judgment components from the working memory task diminished, resulting in worse performance.

We were also interested in understanding the underlying mechanism by which emotional reactivity may influence performance on executive functioning tasks when in negative mood states. We hypothesized that high-reactive individuals would physiologically habituate to negative images more quickly, allowing them to shift attention back to the task and perform better than low-reactive individuals. In line with our prediction, high emotionally reactive participants had fewer trials-to-habituation in the negative conditions, indicating that they habituated to the negative images more quickly than low-emotionally reactive participants. Individuals both high and low in emotional reactivity habituated equally in the neutral condition. Gabel and McAuley (2018) suggested that individuals with high emotional reactivity experience negative mood states more frequently and may thus be more practiced at functioning while in these affective states through rapid habituation. Results from this study indicate that it is possible to habituate to a category of negative stimuli, instead of just repeated presentations of the same stimuli. However, while there was a more rapid habituation to emotional stimuli, this process may not necessarily improve functioning of executive skills. As such, physiological habituation may not be sufficient to shift participants' attention back to the task at hand. It should be noted that this finding may have been impacted by the use of novel images presented for each trial instead of repeated images. Thus, although physiological habituation was observed for the condition itself, novel images that were simultaneously presented during a cognitive task may have demanded more attentional resources for individuals high in emotional reactivity, thereby impeding subsequent performance on the task. An interesting next step to further unpack this finding would be to compare whether the last few trials where participants have presumably habituated is the time in which we see improvements in working memory performance for those high in emotional reactivity, compared to low-reactive individuals. Additionally, future studies could investigate how habituation to repeated stimuli, instead of habituation to general negative and neutral conditions, may impact results.

Unsurprisingly, study participants' ratings of valence indicated that they found negative images to be more unpleasant than neutral images. However, although negative and neutral images were chosen on the basis of being comparable on arousal, participants in the present study rated negative images as more arousing than neutral images. This difference in ratings may be linked to the explosion of electronic mass media in the past decade. As young adults are continuously flooded with distressing content at the touch of a button through electronic devices, neutral images that were considered as highly arousing over a decade ago may not have the same impact on arousal in young adults today. Huesmann (2007) suggests that a process termed desensitization may be at play. Desensitization occurs when negative emotions that are automatically elicited in response to emotionally arousing content reduces in intensity, as the individual habituates to the emotional response, and physiological reactivity diminishes (Huesmann, 2007). As such, neutral images that were highly arousing in the past may no longer be perceived as equivalently arousing as the negatively valanced images when they are compared to the typical images seen in the media.

Another notable finding in the study was that set size within the working memory task accounted for a significant proportion of variance on proportion correct, as higher set sizes resulted in poorer performance on the working memory task. Other studies investigating working memory performance have likewise found a list-length effect on performance. For example, Kline and Fiss' (1999) study indicated that the recall accuracy on the Turner and Engle operation span (1989) decreased as operation set size increased due to greater working memory load. Further, Wingert and colleagues (2018) found that list length disproportionately impacted individuals with low working memory capacity on the Symmetry Span Task compared to those with high working memory capacity and that the impact of emotion and list length affected performance during specific set sizes (e.g., set size of 3 and 5). Unsworth and Engle's (2007) investigation of the reliability of complex and simple span tasks proposed that list-length impacts proportion correct as a result of competing items that share the same cues on these span tasks. Evidently, our findings support the well-established notion that greater set-sizes negatively affect working memory performance.

Although there is vast literature indicating that emotional reactivity is implicated in psychological dysfunction, the present study sought to investigate the potential benefits of negative affective experiences for those high in emotional reactivity. While the results from our study did not find that negative emotional stimuli improved performance, as seen in Gabel and McAuley (2018, in press), the findings suggest that there may be a particular threshold of negative affect that needs to be elicited in order to shift distracting emotional responses (cognitive load theory) to stable negative moods that promote detail-oriented analytic thinking styles (mood-as-information theory) and subsequent cognitive performance. Although high reactive individuals physiologically habituated more quickly to different negative images, performance still diminished, suggesting that habitation may not be enough to account for shifts in individuals' attention back to the task at hand. Further research is required to determine what it is about stable negative mood states that allow highly reactive individuals to utilize their executive skills more masterfully than when they experience negative emotional responses in the absence of a mood shift.

Several limitations should be considered when interpreting the conclusions of the present study. Firstly, study testing was halted prematurely due to the COVID-19 pandemic, and as a result, we had fewer participants enrolled than expected. Although multilevel modeling was used to help mitigate this effect through the use of a within-subjects study design, the findings still may have been impacted by having a smaller sample size than originally intended. Secondly, emotional reactivity was assessed through the ERS scale prior to and during the study. Although pre-study ERS scores and in-lab ERS scores were highly correlated, ratings between the two time points showed variability within participants, likely as a function of the in-lab ERS scale being administered after the study tasks. Thus, the data is reflective of pre-study ratings of emotional reactivity, and not in-lab ratings. Moreover, the study relied on physiological measures to assess shifts in emotional responses and moods. Incorporating self-report questionnaires to assess moods prior to and after the presentation of images would have been useful in clarifying the effectiveness or limitations of the mood induction used. Finally, according to Dawson and colleagues (2017), although trials-to-habituation scores are useful, they may be subject to distortions by the occurrence of one response. For example, whether a meaningful isolated SCR occurs at trial 2 or not considerably impacts the score (resulting in either a score of 0 or 2), and thus needs to be interpreted with caution. As such, future studies should include repeated presentations of the same images so that they are able to get a more accurate assessment of physiological habituation by extracting slopes rather than trials-to-habitation scores.

In conclusion, the current study extends our understanding of the relationship between negative affect and executive functioning by investigating behavioural and physiological indices of emotional reactivity. The results indicate that although physiological responses impact performance on a working memory task, highly reactive individuals who habituate more quickly to emotional responses don't perform better on working memory tasks. The findings suggest that the benefits of negative affect on executive skills performance may only be reached at a particular threshold of being in a negative mood state, not otherwise achieved by experiencing an emotional response. If this threshold is not reached, emotional responses merely disrupt cognitive processes by increasing cognitive load.

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Figures

Figure 1

Activation of the Emotional Reactivity Response

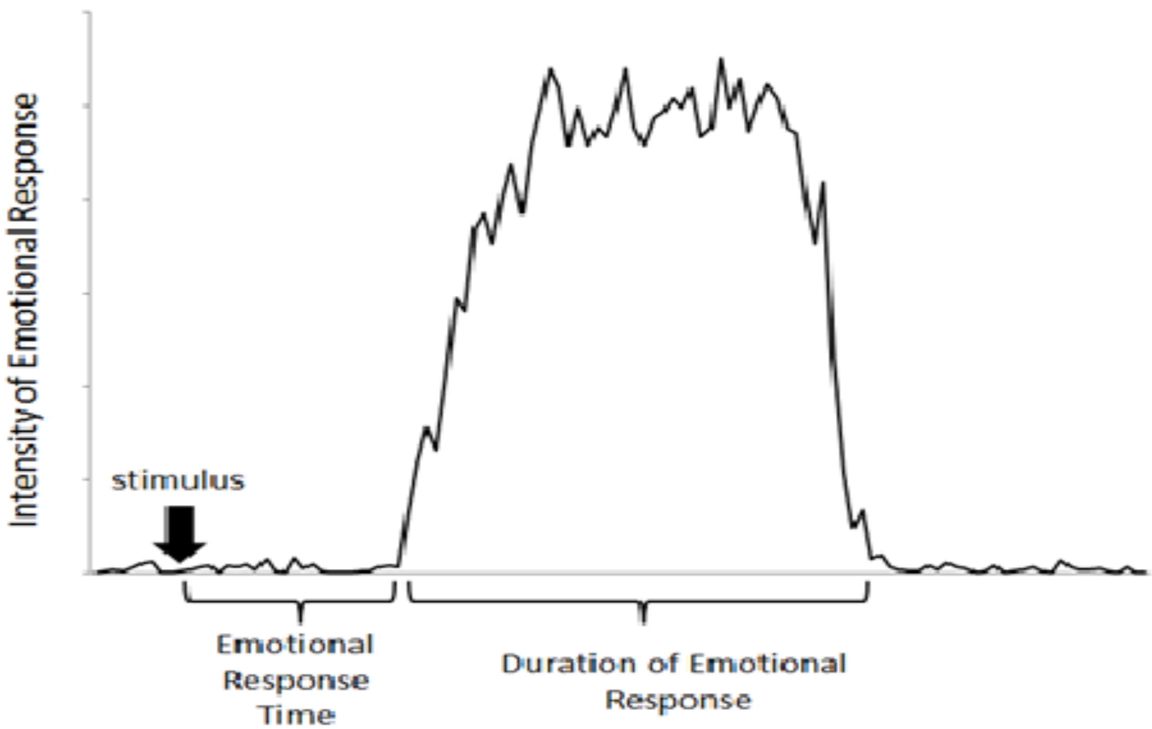
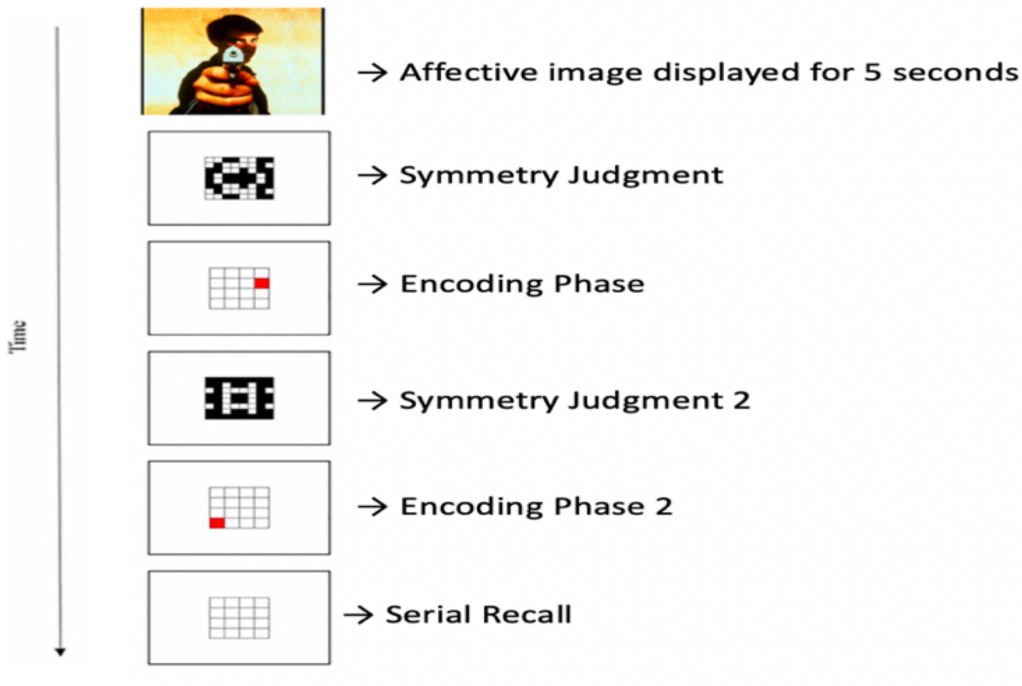


Figure 2

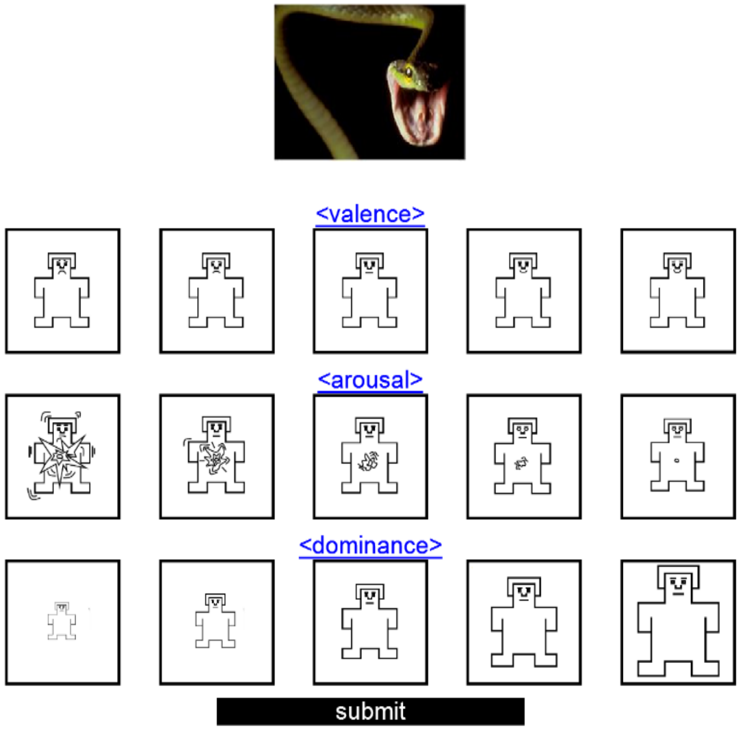
Modified Shortened Symmetry Span Task



Note. The Modified Shortened Symmetry Span Task of working memory includes affective IAPS images at the beginning of each trial. Images are presented for 5 seconds and are followed by sets including a symmetry-judgment task (i.e., irrelevant processing task) and a memory-judgment task (i.e., encoding phase), as well as a serial recall grid at the end of the trial. Presented in this figure is a trial with 2 sets of symmetry- and memory-judgment tasks. Sets can range from 2-5.

Figure 3

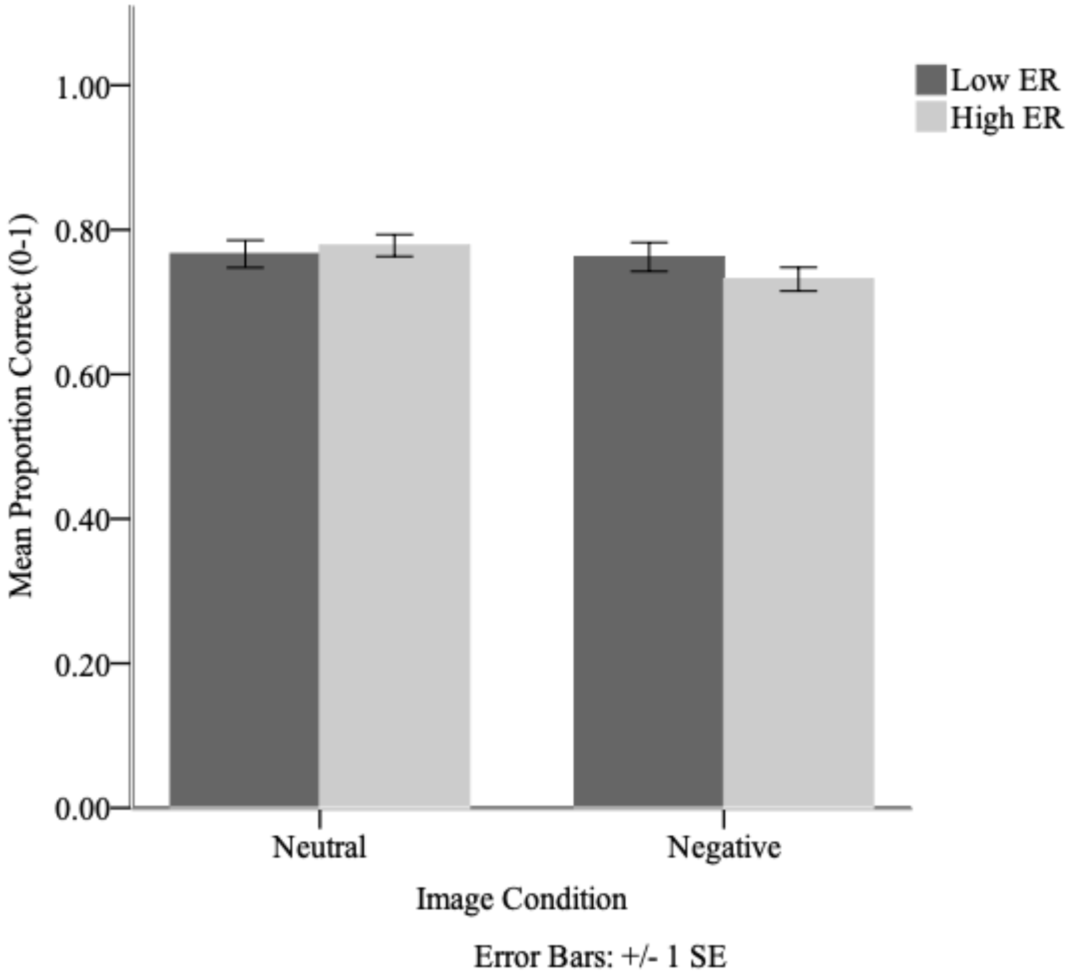
Self-Assessment Manikin (SAM)



Note. The Self-Assessment Manikin (SAM) 5-point scale was used to rate subjective valence, arousal, and dominance for each image viewed during the Modified Shortened Symmetry Span Task.

Figure 4

Mean Proportion Correct by Image Condition and Emotional Reactivity (ER)



Note. Individuals with high emotional reactivity performed worse on the working memory task (mean proportion correct) in the negative condition compared to those with low emotional reactivity. In the neutral conditions, high and low emotionally reactive individuals performed comparably. Standard error bars are shown.

Figure 5

Mean Proportion Correct by Skin Conductance Response (SCR)

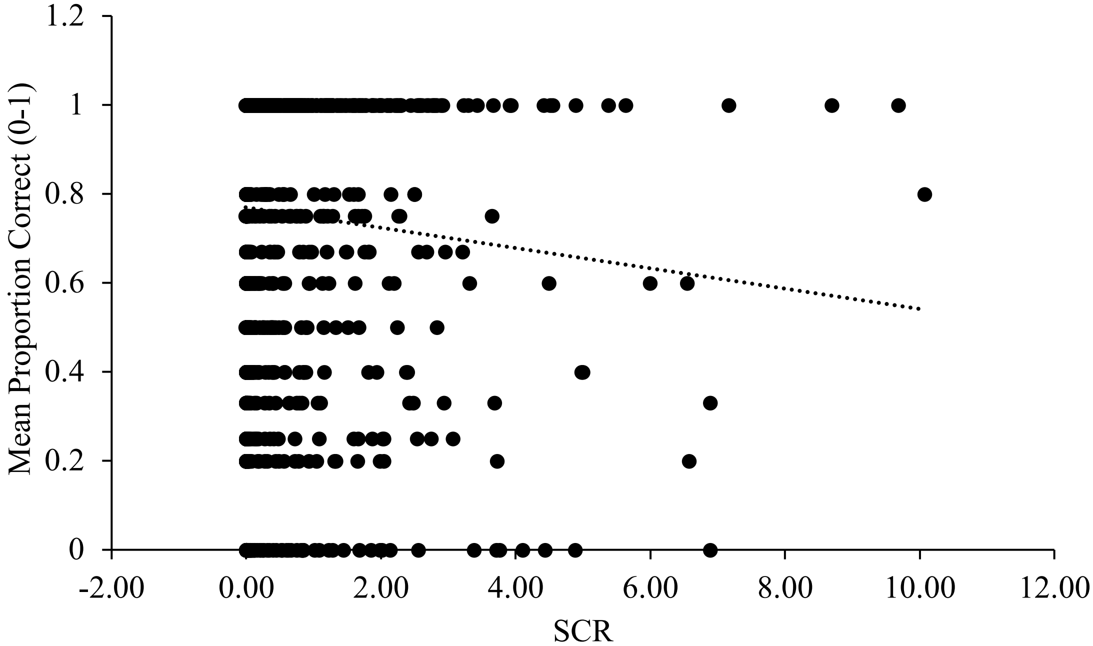
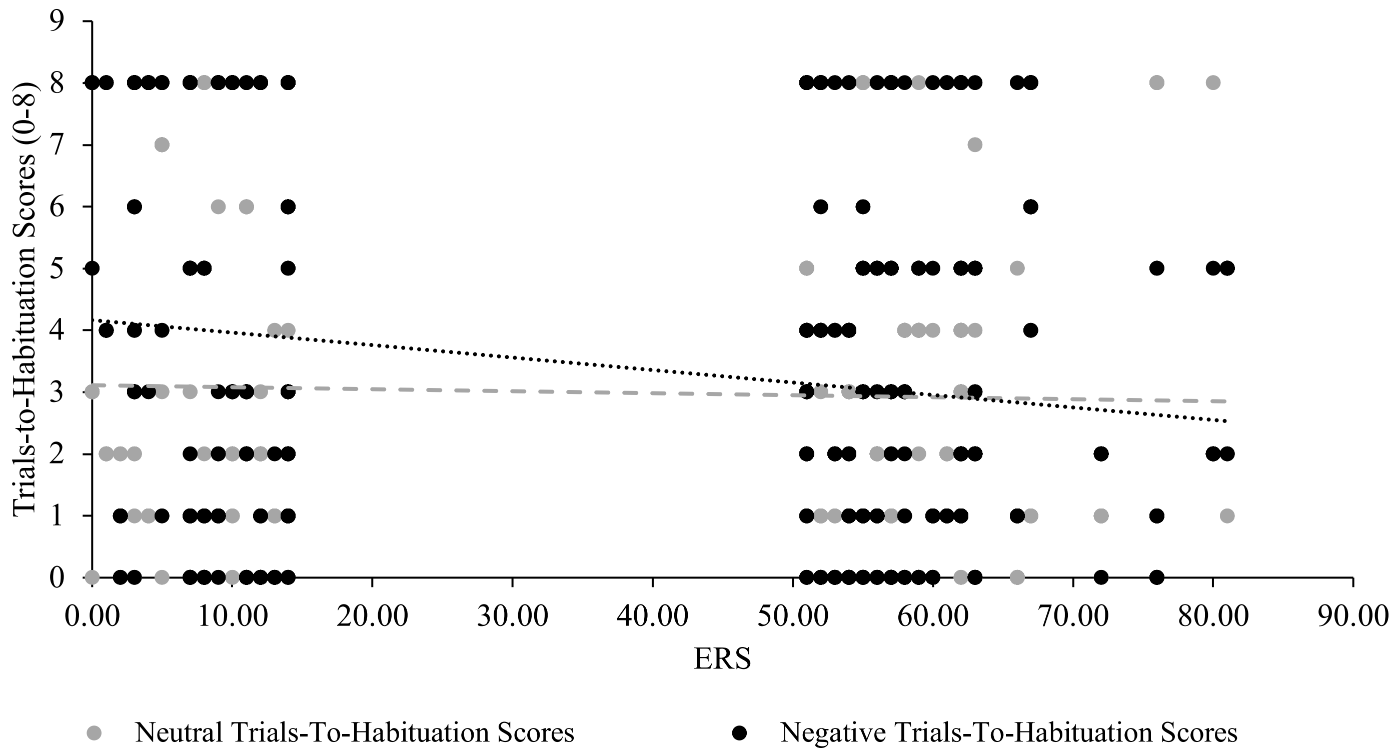


Figure 6

Negative and Neutral Trials-to-Habituation Scores by Emotional Reactivity



Note. ERS = Emotional Reactivity Scale scores (based on pre-study ratings). Individuals higher in emotional reactivity had lower trials-to-habituation scores, indicating that they habituated to the negative condition more quickly than those with low emotional reactivity. Both high and low emotionally reactive individuals habituated equally in the neutral condition.

Table 1

Analytic Approach and Expected Findings Based on Study Research Questions and Hypotheses

Research Question	Hypothesis	Analytic Approach	Expected Findings
Behaviourally: Will individual differences in emotional reactivity (high vs. low) influence how affect (induced by negative and neutral image conditions) impacts working memory performance?	1) Affect will predict performance on the working memory task. 2) High emotional reactivity will result in better working memory performance compared to low-emotional reactivity in negative conditions but not neutral conditions.	1) Multilevel models nested trials within participants to assess whether affect (induced by image condition) predicted performance on the working memory task, with level-1 DV of proportion correct regressed on level-1 IV of image condition. 2) Multilevel models nested trials within participants to test whether emotional reactivity moderated the effect of image condition on proportion correct, while covarying for set size. Level-1 DV of proportion correct was regressed on level-2 IV of emotional reactivity and level-1 IV of image condition with level-1 covariate of set size, along with their cross-level interaction term. Simple effects within image condition were further conducted.	1) Image condition will be a significant predictor of proportion correct on the working memory task. 2) There will be a significant difference in performance for individuals with high and low emotional reactivity, such that those with high reactivity will perform better on working memory task (proportion correct) compared to those with low reactivity in the negative condition. There will be no significant difference in the neutral condition.
Physiologically: Will differences in emotional reactivity (high vs. low) result in varying physiological responses (SCR and trials-to-habituation scores) and performance (proportion correct) on the working memory task?	1) Individuals with high emotional reactivity will experience higher physiological responses (SCR). 2) Physiological responses and affect will predict performance on the working memory task. 3) Individuals with high emotional reactivity will habituate to negative stimuli more quickly than low emotionally reactive individuals.	1) Multilevel models nested trials within participants to assess whether emotional reactivity and image condition predicted SCR. Level-1 DV of SCR regressed on level-2 IV of emotional reactivity and level-1 IV of image condition, with level-1 covariate of set size, along with their cross-level interaction term. 2) Multilevel models nested trials within participants to test whether SCR and image condition predicted working memory. Level-1 DV of proportion correct was regressed on level-1 IV of SCR and level-1 IV of image condition with level-1 covariate of set size, and their interaction term. 3) General linear models (repeated measures ANOVA) were used to assess whether differences were observed in trials-to-habituation scores, based on image condition, emotional reactivity and their interaction.	1) Emotional reactivity will predict SCR, as individuals high in emotional reactivity will experience higher phasic peaks at the onset of negative emotional stimuli. 2) SCR and image condition will predict proportion correct, such that high SCR magnitude will result in lower proportion correct on the working memory task. 3) Individuals high in self-reported reactivity will have fewer trials-to-habituation to the negative stimuli compared to low reactive individuals, leading to more rapid habituation and thus, better working memory performance.

Table 2

Descriptive Statistics of Predictors and Outcome Measures at the Participant Level

Variable	*N*	*Mean*	*SD*
Low ERS	36	8.83	4.14
High ERS	51	59.20	7.36
Partial Span Score	87	39.67	8.48
Symmetry Accuracy	87	0.96	0.03
Partial Span Score (Negative)	87	19.47	4.87
Partial Span Score (Neutral)	87	20.20	4.53
SAM Valence (Negative)	87	1.62	0.43
SAM Valence (Neutral)	87	2.87	0.43
SAM Arousal (Negative)	87	2.64	0.65
SAM Arousal (Neutral)	87	3.13	0.68
SAM Dominance (Negative)	87	2.32	0.81
SAM Dominance (Neutral)	86	2.76	0.91
SCR (Negative)	86	0.42	0.46
SCR (Neutral)	86	0.48	0.48
Habituation Scores (Negative)	86	3.37	3.00
Habituation Scores (Neutral)	86	3.02	3.01

Note. ERS = Emotional Reactivity Scale scores (based on pre-study ratings); SAM Valence, Arousal, and Dominance = the Self-Assessment Manikin subscales; SCR = skin conductance response; Habituation Scores = trials-to-habituation scores. Lower SAM Valence scores indicate higher ratings of unpleasantness, lower SAM Arousal scores indicate greater ratings of arousal, and lower SAM Dominance scores indicate feelings of less control when looking at the images.

Table 3

Bivariate Correlations Between Major Study Variables at the Participant Level

Measure	2	3	4	5	6	7	8	9	10	11	12	13
1. ERS	-.12	.07	-.03	-.05	-.09	.02	.03	.04	-.03	-.04	-.03	-.21†
2. Span (Neg)		.63**	.10	.10	.07	-.05	-.06	.05	.12	-.03	.13	.04
3. Span (Neut)			-.06	.12	.10	.09	-.06	.11	-.07	-.14	.14	.06
4. Valence (Neg)				.21*	.42**	.17	.41**	.33**	.12	.01	.05	-.02
5. Valence (Neut)					.07	.34**	.06	.25*	.11	-.06	.20†	.08
6. Arousal (Neg)						.49**	.39**	.22*	.15	.12	-.02	-.01
7. Arousal (Neut)							.18†	.34**	.02	-.07	.07	-.03
8. Dom (Neg)								.72**	.05	-.04	.03	-.17
9. Dom (Neut)									-.01	-.10	.04	-.07
10. SCR (Neut)										.74**	.46**	.44**
11. SCR (Neg)											.18	.41**
12. Habit (Neut)												.53**
13. Habit (Neg)												

Note. Behavioural data, N = 87; Physiological data, N = 86. ERS = Emotional Reactivity Scale scores (based on pre-study ratings); Span = partial span scores; Neg = negative condition; Neut = neutral condition; Valence, Arousal, and Dominance (Dom) = Self-Assessment Manikin subscales; SCR = skin conductance response; Habit = trials-to-habituation scores.

†$p < .10$. * $p < .05$. ** $p < .01$.

Table 4

Fixed Effects Estimates for Models of the Predictors of Proportion Correct

Model	Parameter	Proportion Correct				
		n	*-2*log likelihood*	Fixed Effects		
Base	Intercept	1368	771.55	0.76	(0.01)	***
	Level 1					
	Image Condition			0.01	(0.01)	
Base (with Cov)	Intercept	1368	415.84	1.22	(0.02)	***
	Level 1					
	Set Size (Cov)			-0.13	(0.01)	***
	Image Condition			0.01	(0.01)	
ERS and Image Condition	Intercept	1368	426.64	1.22	(0.02)	***
	Level 1					
	Set Size (Cov)			-0.13	(0.01)	***
	Image Condition			0.01	(0.01)	
	Neutral Image Condition	674	423.86	-0.02	(0.01)	†
	Negative Image Condition	678	423.86	0.01	(0.01)	
	Level 2					
	ERS			0.00	(0.01)	
	Cross-level Interactions					
	Image Condition*ERS			0.02	(0.01)	*
SCR	Intercept	1352	401.50	1.23	(0.02)	***
	Level 1					
	Set Size (Cov)			-0.13	(0.01)	***
	Image Condition			0.02	(0.01)	*
	SCR			-0.02	(0.01)	**
	Interactions					
	Image Condition*SCR			-0.01	(0.01)	

Note. Image Condition = negative and neutral conditions; Cov = covariate; ERS = Emotional Reactivity Scale score (based on pre-study ratings); SCR = skin conductance response.

†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 5

Fixed Effects Estimates for Moderation of Emotional Reactivity, Image Condition, and Self-Assessment Manikin Subscale Ratings on Proportion Correct (Covarying for Set Size)

Model	Parameter			Proportion Correct				
	Fixed Effects	*n*	*-2*log likelihood*	*b*	*SE*	*df*	*t*	*p*
SAM Ratings (Valence)	Intercept	1368	455.44	1.20	0.03	1365.48	36.81	<.001
	Level 1							
	Set Size (Cov)			-0.13	0.01	1234.53	20.24	<.001
	Valence			0.01	0.01	1342.27	0.99	.324
	Image Condition			0.00	0.02	1312.7	0.04	.965
	Level 2							
	ERS			0.00	0.02	1345.44	0.12	.904
	Cross-level Interaction							
	ERS*Image Condition			0.03	0.02	1291.84	1.44	.151
	Valence*Image Condition			0.00	0.01	1336.80	0.20	.844
	ERS*Valence			0.00	0.01	1358.75	0.18	.860
	ERS*Valence*Image Condition			-0.01	0.01	1328.23	0.64	.524
SAM Ratings (Arousal)	Intercept	1368	452.21	1.20	0.03	1378.04	37.64	<.001
	Level 1							
	Set Size (Cov)			-0.13	0.01	1232.02	20.49	<.001
	Arousal			0.01	0.01	1375.14	0.90	.369
	Image Condition			-0.02	0.02	1285.14	0.78	.434
	Level 2							
	ERS			0.02	0.02	1250.77	1.04	.300
	Cross-level Interaction							
	ERS*Image Condition			0.01	0.02	1261.76	0.52	.604
	Arousal*Image Condition			0.01	0.01	1299.73	1.33	.182
	ERS*Arousal			-0.01	0.01	1372.53	1.40	.161
	ERS*Arousal*Image Condition			0.00	0.01	1285.89	0.36	.722
SAM Ratings (Dominance)	Intercept	1368	455.42	1.22	0.03	1382.56	41.39	<.001
	Level 1							
	Set Size (Cov)			-0.13	0.01	1236.04	20.44	<.001
	Dominance			0.00	0.01	1321.74	0.02	.985
	Image Condition			-0.01	0.02	1261.03	0.63	.528
	Level 2							
	ERS			0.02	0.02	1067.64	1.10	.272

Model	Parameter							
				Proportion Correct				
	Fixed Effects	*n*	*-2*log likelihood*	*b*	*SE*	*df*	*t*	*p*
	Cross-level Interaction							
	ERS*Condition			0.01	0.02	1248.13	0.81	.419
	Dominance* Image Condition			0.01	0.01	1277.37	1.41	.159
	ERS*Dominance			-0.01	0.01	1335.00	1.58	.113
	ERS*Dominance*Image Condition			0.00	0.01	1265.72	0.25	.800

Note. SAM = Self-Assessment Manikin; Cov = covariate; Image Condition = negative and neutral conditions; ERS = Emotional Reactivity Scale score (based on pre-study ratings).

Table 6

Fixed Effects Estimates for Models of the Predictors of Skin Conductance Response

Model	Parameter	Skin Conductance Response						
	Fixed Effects	*n*	*-2*log likelihood*	*b*	*SE*	*df*	*t*	*p*
Base	Intercept	1352	3810.30	0.46	0.03	294.20	13.53	<.001
	Level 2							
	ERS			-0.02	0.03	293.63	0.62	.539
ERS and Image Condition	Intercept	1352	3824.93	0.42	0.09	1355.66	4.96	<.001
	Level 1							
	Set Size (Cov)			0.01	0.02	1136.52	0.47	.637
	Image Condition			0.04	0.03	1136.79	1.40	.161
	Level 2							
	ERS			-0.02	0.03	292.53	0.62	.538
	Cross-level Interactions							
	ERS*Image Condition			0.00	0.03	1110.86	0.09	.931

Note. ERS = Emotional Reactivity Scale score (based on pre-study ratings); Cov = covariate; Image Condition = negative and neutral conditions.

Appendix

Negative and Neutral High Arousal IAPS Images Used in Study.

Negative High Arousing Images:			
IAPS #	Image	IAPS #	Image
2345.1		8230	
2703		9424	
6213		9611	
7380		9635.1	

Neutral High Arousing Images:

IAPS #	Image	IAPS #	Image
1820		7640	
3211		8065	
3310		8192	
6900		8260