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Stress and Eyewitness Memory: Timing of Stressor and Association with Cortisol Stress Responding

Timothy Ryan Robicheaux
University of Nebraska-Lincoln, trrobicheaux@gmail.com

STRESS AND EYEWITNESS MEMORY: TIMING OF STRESSOR AND ASSOCIATION WITH CORTISOL STRESS RESPONDING

by

Timothy R. Robicheaux

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STRESS AND EYEWITNESS MEMORY: TIMING OF STRESSOR AND ASSOCIATION WITH CORTISOL STRESS RESPONDING

Timothy Ryan Robicheaux, Ph.D.

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Witnesses to and victims of criminal events can face significant stress during such encounters. Stress responding consists of a multitude of responses (e.g., anxiety, cardiovascular changes, cortisol responding). In the current study, I utilized a physiological stressor (i.e., the cold-pressor test) and a facial recognition paradigm to examine the relationship between cortisol change following stress exposure and memory accuracy. More specifically, I examined whether cortisol levels at specific memory stages (i.e., acquisition and retrieval) predicted stress responding differently.

Findings suggested that individual differences in cortisol stress responding to the cold-pressor test predicted facial recognition when peak cortisol was at a time of retrieval but not during acquisition. The findings demonstrate that individuals who experienced a stressor but saw a subsequent decline in cortisol from control to the time of retrieval had a higher hit rate in memory for faces than did those in a control group or those who had an increase in cortisol levels from control to retrieval.

These findings provide further evidence that researchers must consider individual differences in stress responding when studying the stress and eyewitness memory relationship. Further, these findings suggest the importance of examining multiple markers of stress responding. Finally, the findings emphasize the importance of considering the relationship between cortisol stress responding and eyewitness memory across different memory stages. Such research suggests a greater need for consideration of stress during retrieval in field.

DEDICATION

To Emmry, whose arrival made this process take a bit longer than planned but makes me smile every single day.

To my siblings, nieces, and especially my parents for your emotional (and financial!) support over these many years. I'll pick a good nursing home, Mom and Dad!

To the late Ms. Carole Fuselier (Ms. Fuse) who taught me how to write…and who would probably find far more grammatical errors in this dissertation than I anticipated.

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CHAPTER 1: REVIEW OF THE LITERATURE

According to Deffenbacher and colleagues (Deffenbacher, Bornstein, Penrod, & McGorty, 2004, p. 687) "witnessing a crime of violence, the response of the eyewitness is almost always one of generating a stress response." Half of surveyed eyewitness memory experts state that they would testify in court that "[v]ery high levels of stress impair the accuracy of eyewitness testimony" (Kassin, Tubb, Hosch, & Memon, 2001, p. 408). Indeed, testimony about the negative effect of stress on eyewitness memory *has* been presented to a jury in criminal cases (e.g., G.R. Loftus, 2002). Among several reviews and meta-analyses written on stress and eyewitness memory (Christianson, 1992; Deffenbacher, 1983, 1994; Deffenbacher et al., 2004), the most recent meta-analysis demonstrated "considerable support of the hypothesis that high levels of stress negatively impact [eyewitness memory]" (Deffenbacher et al., 2004).

For this current project, I investigate the effects of stress exposure and stress responding on memory accuracy using a facial recognition paradigm. In this section, I begin by investigating the methodological procedures and empirical assumptions relevant to several decades of studying the relationship between stress and (eyewitness) memory. I begin by discussing stress responding and measurement, as well as providing a background on research in the field of stress and memory (generally) before discussing trends in the area of stress and eyewitness memory. I conclude this section discussing ways in which the stress and eyewitness literature can benefit from a more salient application of the general stress and memory research. The study that follows is an investigation of relevant issues in the domain of stress responding and facial recognition.

Stress Responding

Stress responding has long been viewed as a set of adaptive psychological and physiological responses to environmental threats to an organism's well-being (Cannon, 1914; de Kloet, Oitzle, & Joels, 1999; Deffenbacher et al., 2004; Dickerson & Kemeny, 2004; Hanoch & Vitouch, 2004; Kemeny, 2003; Nelson, 2005; Pacak & Palkovits, 2001; Selye, 1973; Shalev, 2002; Skosnik, Chatterton, Swisher, & Park, 2000, Wolf, 2009). These responses are associated with immediate, acute, and long-term benefits (see Shalev, 2002). Most body systems are involved in stress responding, whether through excitation (e.g., the autonomic system) or inhibition (e.g., the digestive system) (Charmandari, Tsigos, & Chrousos, 2005), but the current research emphasizes sympathetic, cortisol, and emotional responding.

Sympathetic nervous system responding

In his emergency theory of threat responding, Cannon (1914) proposed that when homeostasis is disturbed or on the verge of being disturbed, an organism enters into a physiological state dubbed *fight or flight* (i.e., the organism either deals with the threat directly or flees from it). When humans perceive an environmental situation as a potential threat, the adrenal medulla almost immediately releases the catecholamine epinephrine into the bloodstream, which is quickly followed by bloodstream elevation of norepinephrine (Nelson, 2005; Skosnik et al., 2000). These hormones trigger a variety of sympathetic responses, such as changes in heart rate and blood pressure, flushing of the skin, and increased perspiration of the palms (Charmandari et al, 2005; Dickerson & Kemeny, 2004; Kemeny, 2003; Nelson, 2005).

It takes only a small increase in epinephrine levels in the bloodstream to lead to strong cardiovascular responses (Kemeny, 2003; Nelson, 2005). These responses occur naturally in situations when an organism engages in exercise, for example. When these responses occur in conjunction with facing an environmental stressor, they are preparatory responses enabling the organism to deal with the impending threat (Kemeny, 2003). The muscular system is also influenced by these adrenal catecholamines; they lead to dilation of skeletal blood vessels and constriction of less crucial deep and superficial veins (Nelson, 2005). Other immediate catecholamine-induced responses include immediate spikes in glucose for immediate energy and decreased insulin production (Nelson, 2005).

HPA axis (cortisol) responding

In a second phase of physiological stress responding (Skosnik et al., 2000), a hormone cascade occurs beginning with the secretion of corticotropin releasing hormone (CRH) by the hypothalamus (Charmandari et al., 2005; Clow, 2004; Dickerson & Kemeny, 2004; Kemeny, 2003; Nelson, 2005)[1]. The CRH, in turn, signals the release of adrenocorticotropin hormone (ACTH) from the anterior pituitary gland. ACTH travels through the blood to the adrenal gland, where adrenal receptors are triggered, and the final hormone of the cascade, cortisol (corticosterone in rodents) is released by the adrenal cortex (Charmandari et al., 2005; Clow, 2004; Dickerson & Kemeny, 2004, Kemeny, 2003; Nelson, 2005).

Cortisol serves a restorative purpose, aiding an organism to recover from any stress responding and any injury caused by the threat. Unlike the near immediate responses of the autonomic system, complete activation and responding of the HPA axis can last for an hour or more (Clow, 2004; Dickerson & Kemeny, 2004; Kemeny, 2003). Peak cortisol levels in the bloodstream are reached approximately 20 to 40 minutes after initial exposure to a given stressor (Dickerson & Kemeny, 2004; Kemeny, 2003). Recovery (i.e., return to pre-stressor levels) occurs between 40 and 60 minutes after the threat ceases (Kemeny, 2003). The complete adaptive effects of cortisol might not occur for several hours after initial exposure to a stressor (Skosnik et al., 2000).

Measurement of HPA axis responding. Levels of two biomarkers of HPA axis responding, ACTH and cortisol, are measurable through blood draws (Dickerson & Kemeny, 2004). However, cortisol is also reliably measured in saliva, which avoids the problems with using venipuncture (see Dickerson & Kemeny, 2004; Vining, McGinley, Maksvytis, & Ho, 1983). A common means of examining cortisol stress responding is to compare levels approximately 20 to 40 minutes post-stressor to a baseline measurement (Dickerson & Kemeny, 2004).

Salivary cortisol measurement is both cost-effective and a reliable measure of HPA axis responding, and responses of the HPA axis are of particular interest in studies of stress and memory due to cortisol's direct effects on memory systems (Lupien, Maheu, Tu, Fiocco, & Schramek, 2007; Wolf, 2008, 2009).

Psychological and emotional responding

The stress response process is often associated with corresponding subjective emotional and cognitive responses (see Lupien et al., 2007). These responses include heightened state anxiety or negative affect (Brigham, Maass, Martinez, & Wittenberger, 1983; Valentine & Mesout, 2009), as well as general feelings of "stress" (for a review see Bornstein & Robicheaux, 2009). Self-report measures of stress responding (i.e., asking participants to report their physiological states) have been employed, but they are uncommon in the empirical literature (Dickerson & Kemeny, 2004). More commonly, researchers measure subjective emotional responses to a particular task or stimuli (see Bornstein & Robicheaux, 2009). These instruments sometimes include single-item self-report measures, such as reporting one's current anxiety state on a 100-point scale (Brigham et al., 1983) or other single-item self-report measures (e.g., "stress" [Buckhout, Alper, Chern, Silverberg, & Slomovits, 1974]; arousal [Heuer & Reisberg, 1990; Libkuman, Nichols-Whitehead, Griffith, & Thomas, 1999]; nervousness [Cutler, Penrod, & Martens, 1987], upset-ness [Bornstein, Liebel, & Scarberry, 1998]; or worry [Shrimpton, Oates, & Hayes, 1998]). Multiple-item questionnaires and scales have also been employed (e.g., Valentine & Mesout, 2004; for reviews see Bornstein & Robicheaux, 2009; Deffenbacher et al., 2004; Dickerson & Kemeny, 2004).

The relationship between subjective stress responding and physiological stress responding appears to be a complex one. For example, self-report scales sometimes indicate negative emotional states in response to a stressor when no HPA axis stress responding has occurred (Lupien et al., 2007). Other studies have demonstrated HPA axis stress responding in the absence of any changes in emotional states or have found no correlation between the two (see Dickerson & Kemeny, 2004). Thus, it is possible for a person to experience state fear or anxiety without any measurable HPA axis responding (Lupien, Wilkinson, Briere, Menard, Ng, & Nair, 2002), just as it is possible for a physiological stress response to occur without subjective awareness of that response. Self-report measures of negative emotional states or other subjective responses to stressors are useful in many contexts, but they might not be the most appropriate measure of physiological stress responding.

Specificity of stress responding

Some views of stress responding assume that stress responding is nonspecific (i.e., that the response was the same to all stressors once HPA axis activation occurred) (Selye, 1973). Nelson (2000, p. 679) defines stress as "the sum of all nonspecific effects or factors that can act on the body to increase energy consumption significantly among some resting basal level." However, researchers have become increasingly interested in specificity in responding to emotional and threatening stimuli (e.g., Hanoch & Vitouch, 2004; Pacak & Palkovits, 2001). A complete discussion of the specificity of emotional and stressor responding literature is beyond the scope of the current dissertation. What is most pertinent for these purposes is that multiple measures of stress are ideal for both methodological and theoretical reasons, particularly when studying stress and memory.

Activation of one system is not necessarily indicative of activation of other systems or responses. For example, HPA axis responding does not always follow sympathetic responding to a given threat or stressor (Dickerson & Kemeny, 2004; Kemeny, 2003; Michaud et al, 2008; Skosnik et al., 2000). *Why* and *when* HPA axis responding to threats does occur are questions still being explored, but some variables of interest include the duration of exposure to a stressor, the severity of the stressor, predictability of stress exposure, cognitive appraisal of a threatening situation, and the controllability of the threat (see Michaud et al., 2008; Skosnik et al., 2000). Thus, the mere presence of sympathetic or emotional responding to a perceived threat is neither necessary nor sufficient to indicate HPA axis responding. As discussed in the next section, HPA axis activation plays a unique role in the relationship between stress and memory.

Stress and Memory

Among the myriad of responses an individual experiences during a potentially stressful encounter (such as exposure to a crime) are responses that can directly or indirectly affect all stages of memory for the event (see, e.g., Christianson, 1992; Deffenbacher et al., 2004; Het, Ramlow, & Wolf, 2005; Lupien et al., 2007; Roozendaal, 2002; Sandi, 1998; Wolf, 2009). The memory effects are likely, at least partially, an adaptive mechanism (Hanoch & Vitouch, 2004). For example, consider someone walking into a grocery store with a mental list of shopping items. The individual is approached by an armed man demanding money. At that moment, it would make little sense for the shopper to use mental resources to continue thinking about the shopping list, but it would make adaptive sense for these mental resources to attend to the dangerous situation.

In the current section, I discuss three factors that merit consideration when studying stress and memory and applying such findings to the field, such as to an eyewitness situation. First, stress exposure seems to influence different stages of memory (i.e., acquisition, storage, and retrieval) differently (Het et al., 2005; Lupien et al., 2007; Wolf, 2008, 2009). Second, various properties of the to-be-remembered (TBR) stimuli can moderate the stress and memory relationship (Hanoch & Vitouch, 2004; Wolf, 2009). The emotional salience and the valence of TBR stimuli can interact with stress to influence memory accuracy. Notably, in eyewitness memory situations, the TBR event should be both a negative emotional event and the source of stress responding (Christianson, 1992; Deffenbacher et al., 2004). Third, the way stress is operationally defined in a given study can impact any relationship between stress and memory, and individual differences in stress responding are related to memory accuracy (Buchanan, Tranel, & Adolphs, 2006).

Memory stage

Attention. Stress exposure and responding do not exert the same memory effects on all memory stages (Het et al., 2005; Lupien et al., 2007; Roozendaal, 2002; Wolf, 2008, 2009). Sudden, startling movement seen in one's peripheral vision, or perhaps exposure to a loud noise, can elicit an immediate reflexive orienting response toward that potentially threatening stimulus (Deffenbacher et al., 2004). This orienting response might lead to heightened attention to some stimuli (e.g., a knife in a person's hand; someone running) at the expense of attention to other stimuli (e.g., the shoes the knife-bearer is wearing). The focused attention on particular stimuli during an emotionally salient or threatening encounter might explain subsequent variability in memory accuracy for that particular event (see Hanoch & Vitouch, 2002).

Acquisition. Meta-analytic findings fail to demonstrate an overall main effect of pharmaceutical cortisol administration prior to acquisition on subsequent memory accuracy (Het et al., 2005). Individual studies have yielded positive effects (e.g., Abercrombie et al., 2003; Buchanan & Lovallo, 2001; Rimmele, Domes, Mathiak, & Hautzinger, 2003), negative effects (e.g., Tops, van der Pompe, Baas, Mulder, ben Boer, Meijman, & Korf, 2003), and no effects (e.g., de Quervain, Roozendaal, Nitsch, McGaugh, & Hock, 2000) of *pharmacologically induced* cortisol levels prior to acquisition on subsequent memory accuracy.

Exposure to environmental stressors, rather than pharmaceutical elicitation of cortisol responding, demonstrates similar inconsistencies (Domes, Heinrichs, Reichwald, & Hautzinger, 2002 [a positive effect but only for those who demonstrated a cortisol response to the stressor]; Domes, Heinrichs, Rimmele, Reichwald, & Hautinzger, 2004 [no effect]; Elzinga, Bakker, & Bremner, 2005 [no effect on immediate recall, but a negative effect on delayed recall after 24 hours]). Measuring stress through sympathetic arousal, Brigham et al. (1983) reported that females who received a moderately intense series of shocks while viewing neutral faces performed less accurately than females who received only a single shock. Those who received the multiple shocks also had heightened heart rates during acquisition (Brigham et al., 1983). Thus, heightened arousal at acquisition was associated with negative effects on memory.

The variability in findings suggests a complex relationship between stress exposure during exposure to TBR stimuli and subsequent recall or recognition. Meta-analytic findings suggest no overall main effect of cortisol administration (Het et al., 2005), and exposure to physiological stress response provoking stimuli prior to learning is associated with disparate findings (e.g., Brigham et al., 1983; Domes et al., 2002, 2004; Elzinga et al., 2005). Further, the relationship between stress at acquisition and subsequent retrieval accuracy seems to interact with other variables, such as the time of day that learning takes place (Het et al., 2005), as well as individual differences in stress responding (Brigham et al., 1983; Domes et al., 2002; Valentine & Mesout, 2009).

Consolidation/storage. Both HPA axis responding and sympathetic responding appear to play modulatory roles in memory consolidation (for reviews see de Kloet et al., 1999; Lupien et al., 2007; Roozendaal, 2002; Sandi, 1998; Wolf, 2008, 2009). For example, administration of epinephrine *following* training of rodents demonstrates a positive effect on subsequent memory accuracy (see Roozendaal, 2002). Glucocorticoids appear to have a similar effect on memory consolidation (see Roozendaal, 2002; Sandi, 1998; Wolf, 2009). While this is not the focus of the current study, it is notable that a delay between a stressor and subsequent retrieval might lead to enhancing effects on memory.

Retrieval. In contrast to the consolidation findings, cortisol responding appears to have an overall inhibitory effect on *retrieval* (Het et al., 2005; Luipien et al., 2007, 2009; Roozendaal, 2002; Wolf, 2009). In their meta-analysis of the effects of cortisol administration on memory accuracy, Het and colleagues (2005) examined four studies involving administration of hydrocortisone prior to memory retrieval (de Quervain et al., 2000; de Quervain, Henke, Aerni, Treyer, McGaugh, et al., 2003; Lupien et al., 2002; Wolf et al., 2001). The analysis demonstrated a moderate negative main effect of cortisol administration on recall (d = -0.49) (Het et al., 2005). Further, exposure to environmental stressors prior to retrieval is also associated with deficits in memory accuracy (e.g., Buchanan et al., 2006; Kuhlman, Kirschbaum, & Wolf, 2005), with individual differences in cortisol responding to the stressor moderating the relationship (Buchanan et al., 2006).

Properties of TBR stimuli

A large body of literature exists examining the relationships between individuals' emotional states, the emotional salience of TBR stimuli, and memory (for reviews, see Christianson, 1992; Hanoch & Vitouch, 2004). For example, Kleinsmith and Kaplan (1964) reported that memory accuracy for emotionally salient words improved across delays. Findings generally support the contention that memory accuracy for events with emotional salience is superior to that for more emotionally neutral stimuli (see Kensinger, 2008), though several critical exceptions exist and many interactions have been demonstrated (Christianson, 1992; Hanoch & Vitouch, 2004).

One relevant interaction is that between stress responding and the emotional salience (and valence) of TBR stimuli (Kensinger, 2008). The relationship between stress responding and subsequent memory accuracy is generally stronger for emotionally salient stimuli than for neutral stimuli (Wolf, 2008). This relationship between stress and stimulus salience has been demonstrated with both pharmacological stress manipulations (Buchanan & Lovallo, 2001; Kuhlmann & Wolf, 2006; Maheu, Joober, Beaulieu, & Lupien, 2004; Rimmele et al, 2003) and laboratory stress manipulations (Smeets, Jelicic, & Merckelbach, 2006; Payne, Jackson, Ryan, Hoscheidt, Jacobs, & Nadel, 2006). Stress responding, particularly cortisol stress responding, at acquisition appears to have a stronger impairing effect on emotionally neutral stimuli than on emotionally arousing stimuli (Lupien et al., 2007; Wolf, 2008, 2009).

Hormones associated with stress responding are considered pertinent to consolidation of memories (Roozendaal, 2002), and some findings also suggest that memory accuracy for emotionally arousing stimuli is preserved or even enhanced when there is a delay of several days between encoding and retrieval (e.g., Kleinsmith & Kaplan, 1964). In humans, stress responding and the emotional salience of TBR stimuli interact such that stress responding has the strongest enhancement effect for memory for emotionally salient stimuli (Buchanan & Lovallo, 2001; Kuhlmann & Wolf, 2006; Rimmele et al., 2002).

In contrast to the enhancing effects of stress responding on memory consolidation, stress responding at retrieval is associated with memory decrements (Lupien et al., 2007; Wolf, 2008, 2009). This relationship is magnified for emotionally salient stimuli such that stress responding has a stronger impairing effect on retrieval of emotionally salient stimuli than for neutral stimuli (Wolf, 2008).

Specificity: The role of cortisol

Studies in rodents and in humans suggest that the specificity of a stress response is often relevant when investigating stress and memory. Of particular interest in the current study is cortisol responding. For example, females who had higher levels of cortisol following a stressful public speaking and mental arithmetic task (i.e., the Trier Social Stress Test [TSST]) prior to learning a word list performed significantly better on subsequent memory tests that those who had no cortisol elevation (Domes et al., 2002). Andreano and Cahill (2006) had participants read a short story immediately prior to a stress manipulation (i.e., the cold pressor test [CPT]) or a control task. A week later, participants returned to the laboratory and "were instructed to attempt to retell the story in writing, staying as close to the original as possible" (Andreano & Cahill, 2006, p. 467). Male participants who underwent the stress task demonstrated significantly higher recall accuracy than did those in the control condition. However, a quadratic relationship between cortisol change to the stress task and subsequent memory accuracy was also reported; those who exhibited the lowest and highest cortisol level changes performed less accurately on the recall test than those who exhibited a moderate cortisol change.

Buchanan and colleagues (2006) had participants view a series of 40 words; they immediately followed the list with a test of free recall. For an hour following the initial test, participants engaged in a variety of nonverbal tasks, and then they were exposed to a stressor (CPT) or to a control task. Ten minutes post stressor, participants engaged in a word recognition task. For analytic purposes, participants who underwent the stress task were split into two groups (i.e., cortisol responders [cortisol increase in response to the task] and cortisol nonresponders [no cortisol increase]). Notably, both the responders and nonresponders exhibited increases in blood pressure in response to the stressor and these increases did not differ as a function of cortisol responding. While there was a negative effect of stressor exposure on memory retrieval, this effect was only descriptive of the cortisol responders (Buchanan et al., 2006).

Another approach to examining the role cortisol plays in human memory is to utilize pharmaceutical intervention to blunt or prevent cortisol responding to stressors. Such techniques further suggest a mediating relationship of cortisol responding on stress and memory. Maheu et al. (2004) buffered cortisol responding using propranolol (40 or 80 mg), then had participants view stories containing both emotional and neutral elements. Compared to those in the placebo condition, those who received the higher dose of propranolol (80 mg) had impaired memory for the emotionally arousing story segments when tested immediately after story exposure and after a delay (Maheu et al., 2004).

Nonetheless, while cortisol responding does seem to play a role in the stress and memory relationship, HPA axis responding is not necessary for all stress-linked memory changes. Jelici et al. (2004) compared to a control group, those participants who underwent a stressful task prior to acquisition of TBR stimuli demonstrated enhanced memory accuracy for emotionally arousing words and memory impairment for neutral words, and this relationship was not mediated by cortisol changes resulting from the stressor. Cahill, Gorski, and Le (2003) reported a moderate effect of stressor exposure on delayed recall (i.e., a week after initial learning) of pictures, but changes in cortisol levels from baseline to post-stressor did not directly correlate with memory accuracy.

Sex differences in stress responding. In addition to the system specificity in stress responding, some evidence suggests that under some conditions there are sex differences in stress responding (e.g., Kirschbaum, Wust, & Hellhammer, 1992 [men exhibited stronger responses than women to a psychological stressor]; Stroud, Salovey, & Epel, 2002 [men showed greater response than women; women showed greater response than men to a task involving social rejection]; for review see Kudielka & Kirschbaum, 2005). However, sex does not always predict stress responding (see Dickerson & Kemeny, 2004; Kudielka & Kirschbaum, 2005).

Others have considered potential sex differences in the literature linking both cortisol and stress with memory. For example Buchanan and Lovallo (2001) found no sex differences in recall of emotional stimuli following pharmaceutical cortisol treatment. Participant sex also did not interact with cortisol responding following exposure to a cold-pressor test on word recall in a sample of volunteers (Buchanan et al., 2006). However, other studies have suggested interactions between sex and stress exposure on memory accuracy (e.g., Wolf, Schommer, Hellhammer, McEwen, & Kirschbaum, 2001). Taken as a whole, these studies on the potential for sex differences in both stress responding and in the interaction between stress and memory merit considering gender (self-reported) in the context of stress and memory, including eyewitness memory.

Stress and Eyewitness Memory

Research in the areas of facial recognition and of eyewitness memory involve a research domain with both basic and applied scientific value. Earlier studies investigating the relationship between stress and eyewitness memory considered stress to involve a series of nonspecific responses (Deffenbacher, 1983). More recently researchers have recognized that stress is more specific in nature (Christianson, 1992; Deffenbacher, 1994; Deffenbacher et al., 2004). Despite this recognition of specific stress responses, neither response specificity nor individual differences in stress responding have been fully studied within the domain of stress and eyewitness memory (Bornstein & Robicheaux, 2009).

Studies of stress and eyewitness memory are predicated on the assumption that witnessing (or being victims of) certain crimes can be inherently threatening to the eyewitness or victim (e.g., Christianson, 1992; Deffenbacher et al., 2004; Wells, Memon, & Penrod, 2006). This assertion is largely intuitive rather than empirically established, in part due to the inherent difficulties of testing stress responding in the field. However, some evidence does suggest that crime victims demonstrate clinical stress responses and cortisol elevations (e.g., Resnick, Yehuda, Pitman, & Foy, 1995).

Studying stress and eyewitness memory in the laboratory requires a balance between internal and ecological validity while remaining within the constraints of ethical principles (see Deffenbacher et al., 2004). In the typical stress and eyewitness memory study, some type of stress manipulation is employed in the context of memory for faces, scenes, videos, or other stimuli; physiological or subjective stress responses are included as manipulation checks (Bornstein & Robicheaux, 2009; Deffenbacher et al., 2004). Sources of stress responding can include the TBR stimulus itself as the stressor (e.g., a violent video [Bornstein et al., 1998; Clifford & Hollin, 1981; Clifford & Scott, 1978; Loftus & Burns, 1982]; a stressful situation [Morgan, Hazlett, Doran, Garrett, et al., 2004; Quas, Yim, Edelstein, Cahill, & Rush, 2011; Valentine & Mesourt, 2009]); or a stressor peripheral to the TBR stimuli (e.g., the use of shock prior to acquisition of faces [Brigham et al., 1983]).

Some researchers have employed creative means of manipulating stress in the context of eyewitness memory. Valentine and Mesout (2009) investigated participants' recognition of an actor (i.e., "scary person") who jumped out at the participants while they traveled through a dark maze in the London Dungeon tourist attraction. They reported a significant negative relationship between self-reported anxiety following the trip through the maze and recognition of the "scary person."

Morgan and colleagues (2004) utilized military special forces training to investigate memory among cadets who underwent highly stressful survival training. The cadets, acting as mock prisoners of war, were interrogated by two individuals: a physically aggressive interrogation was considered a high stress interrogation and a non-physical/non-confrontational interrogation was considered a low stress interrogation. In a subsequent recognition test a few days following the training, cadets performed significantly better when attempting to recognize the low-stress interrogator than the high-stress interrogator. These findings have particular relevance to protracted witnessing and victimization, such as kidnapping and hostage situations, and demonstrate the limitations of human memory under harsh conditions.

Meta-analytic findings.

Deffenbacher et al. (2004) conducted a meta-analysis of studies relevant to the area of stress and eyewitness memory, including studies involving facial recognition as well as more ecologically valid witnessing situations. The inclusion criteria were that studies had to have a statistical test of some relationship between distress or stress responding and some aspect of face identification accuracy (e.g., recognition accuracy, identification accuracy, accuracy of recall of details). Further, studies had to be either experimental or quasi-experimental stress manipulations, and all studies included some manipulation check of distress, physiological stress responding, or perceived violence. Finally, for a study to be included in the analysis the stress manipulation check had to be administered during or immediately after the stress manipulation rather than involving a retrospective measure of stress responding.

The main dependent variables of interest included both facial recognition/identification and accuracy of recall of details surrounding the events. Deffenbacher et al. (2004) analyzed these two categories of dependent variables separately. Applying the inclusion criteria, the meta-analysis included 27 independent effect size estimates for studies involving facial identification and 36 for eyewitness recall.

The general trend was such that there was a negative effect of stress manipulations on memory accuracy. Participants in the low stress conditions had a 54% hit rate on face identifications, compared to 42% for those in high stress conditions. Those in the high stress condition were also somewhat more likely to make false alarms than those in the low stress condition, but this effect was smaller than the hit rate. Further, stress manipulations had a significant negative effect on eyewitness recall (Deffenbacher et al., 2004).

This overall negative relationship between stress and memory accuracy was moderated by several variables. For example, studies involving simulated crimes were more influenced by the stress manipulations than were studies involving other types of manipulations, though the direction of the relationship was the same in both types of studies. The negative relationship between stress and memory did not have a negative effect on recall in children but did for adults (Deffenbacher et al., 2004).

Methodological considerations

Generally, the meta-analytic findings of Deffenbacher et al. (2004) support the notion that encoding of faces under conditions of high stress is associated with lower recognition accuracy. However, findings in the general stress and eyewitness literature do not support this negative relationship to quite the same degree (see Het et al., 2005; Lupien et al., 2007; Roozendaal, 2002; Wolf, 2008, 2009). One goal of the current study is to consider some of the nuances from the general stress and memory literature in the context of eyewitness memory. Thus, several variables could be considered.

Relationship between stressors and TBR stimuli. Due to the applied relevance, most studies of stress and eyewitness memory involve a direct temporal and contextual association between the TBR stimuli and the source of stress or emotional responding (e.g., Bornstein et al., 1998; Buckhout et al., 1974; Burgwyn-Bailes et al., 2001; Christianson, Loftus, Hoffman, & Loftus, 1991; Clifford & Hollin, 1981; Clifford & Scott, 1978; Cutler et al., 1987; Fivush, Sales, Goldberg, Bahrick, & Parker, 2004; Hulse, Allan, Memon, & Read, 2007; Hosch & Bothwell, 1990; Kramer et al., 1990; Loftus & Burns, 1982; Maass & Kohnken, 1989; Quas; Stanny & Johnson, 2000; Valentine & Mesout, 2009). However, in the general stress and memory literature stressors are often peripheral to the TBR stimuli (e.g., Abercrombie et al., 2003; Buchanan & Lovallo, 2001; de Quervain et al., 2000; Domes et al., 2002; Domes et al., 2004; Elzinga et al., 2005; Rimmele et al., 2003; Tops et al., 2003). Generalizing findings from one paradigm to the other might be inappropriate, as some scholars suggest these differences would reasonably lead to different response patterns (Christianson, 1992; Hanoch & Vitouch, 2004).

Hanoch and Vitouch (2004) argue that the adaptive value of emotionally induced memory responses is a critical consideration when designing studies investigating the stress and memory relationship. They argue that during emotionally salient events, individuals will orient toward stimuli that are the most urgent to deal with and are the most critical for survival and that such orientation aids in the mobilization of physiological processes to deal with these events. A practical implication of this assertion is that researchers should consider *arousal-congruent performance* and utilize TBR stimuli that have adaptive relevance congruent with the emotionality of the particular context.

Applying the assertions of Hanoch and Vitouch (2004) to an eyewitness memory paradigm can be challenging, however. An *a priori*, and even a *post hoc*, determination of the critical stimulus in a particular context is generally speculative. Further, critical stimuli for survival in an eyewitness memory event might not be critical stimuli for a successful identification of a suspect and a prosecution. Indeed, the source of the stressor (e.g., an assailant; a gun) and what is most beneficial to orient toward (e.g., an escape route; a defensive weapon) are often mutually exclusive. Nonetheless, studies of stress and memory relying on stressors peripheral to the TBR stimuli might not readily generalize to stress and eyewitness memory contexts (Christianson, 1992; Hanoch & Vitouch, 2004), but further research on what makes a particular stimulus "critical" in a given situation is merited.

Temporal considerations. With some exceptions (e.g., Buckhout et al., 1974; Morgan et al., 2004), most studies of stress and eyewitness memory or facial recognition occur during a relatively brief temporal interval (e.g., Brigham et al., 1983; Clifford & Hollin, 1981; Clifford & Scott, 1978; Hosch & Bothwell, 1990; Kramer, Buckhout, & Eugenio; Valentine & Mesout, 2009). As blood cortisol levels tend to *peak* approximately 20-40 minutes after exposure to a stressor (Dickerson & Kemeny, 2004; Kemeny, 2003), and cortisol plays a non-negligible role in the stress and memory relationship (Buchanan et al., 2006), the short duration of eyewitness memory studies might limit their inferential value.

Of particular concern is that some studies might unintentionally confound the effect of stress responding at acquisition with the effect at retrieval. Cortisol levels at retrieval, especially for negatively salient events, are negatively associated with memory accuracy (Wolf, 2008, 2009). However, there is a trend for cortisol elevations at acquisition to be positively correlated with memory accuracy for negative emotional events (Het et al., 2005). Valentine and Mesout (2009) found an association between recognition accuracy and state anxiety measured at the time of *retrieval* rather than acquisition. It is logical to assume that participants in the study had *higher* levels of anxiety while in the maze, but the findings demonstrate that their accuracy was directly associated with their anxiety at the *time of retrieval.* Many of the findings in the stress and eyewitness literature more readily generalize to situations in which an identification occurs soon after exposure to a stressor *or* if being interviewed by police or making an identification is inherently stressful. What is less certain is whether such findings readily generalize to many eyewitness findings in the field, such as those with a considerable delay between encoding and retrieval.

In addition to the application of this research, the confounding of encoding and retrieval in a study can influence effect sizes reported in meta-analyses (see Lupien et al., 2007). In other words, while the effects of stressor exposure across all experimental settings might be *x*, the effect size of encoding-level responding might by *y* and retrieval-level responding *z*, but the designs of most studies in the field make this relationship extremely difficult to evaluate. Unfortunately, few researchers in the field explicitly acknowledge the possible influence of stress responding on retrieval (see Rush, Quas, Yim, Nikolayev, Clark, & Larson, 2014).

Measurement. The means of measuring stress is a necessary methodological consideration in the domain of stress and eyewitness memory (Bornstein & Robicheaux, 2009). Despite acknowledgment within the field of eyewitness memory that stress responding has both psychological and physiological components (e.g., Christianson, 1992; Deffenbacher et al., 2004), the majority of the research employs only psychological measures of stress responding. Most who have utilized physiological stress measures have relied upon measures of sympathetic responding, such as heart rate, blood pressure, and skin conductance (Brigham et al., 1983; Hosch & Bothwell, 1990; Valentine & Mesout, 2009).

To my knowledge, two published studies (i.e.,Echteroff & Wolf, 2012; Quas et al., 2011) have explicitly examined the role of cortisol responding in a facial recognition or eyewitness memory context[1]. In one study (Echteroff & Wolf, 2012), male college students viewed a video of a burglary followed by either the Trier Social Stress Test [TSST, Kirschbaum, Pirke, & Hellhammer, 1993]) or a control task. The thematic arousal of the video was manipulated through instructions concerning a possible "twist" in the video. Cortisol levels were measured across four time-points (i.e., at baseline then at one, 10, and 20 minutes after exposure to the TSST) with a recognition test of event memory at approximately 20 minutes post-stressor, when average cortisol levels were significantly higher for the TSST group than for the control group. Those who underwent the TSST showed a higher bias toward recognition of central details (compared to peripheral details) when in a high thematic arousal condition, while the pattern was reversed for the low thematic arousal condition (Echteroff & Wolf, 2012).

Quas et al. (2011; Rush et al., 2014) have published findings utilizing a modified version of the TSST (TSST-M, Yim, Quas, Cahill, & Hayakawa, 2010) as both the

[1] A few other studies of stress and eyewitness memory have utilized stressors that were previously associated with cortisol responding among the same research group, most notably Morgan et al., 2005 (studying survival school cadets) and in studies utilizing the TSST-M as both a stressor and a TBR stimulus (Quas, Rush, Yim, & Nikolayev, 2014; Rush et al., 2014). In these studies, they did not provide a direct examination of the relationship between cortisol responding and memory.

stressor and part of the TBR stimuli. In one study with an explicit analysis of the cortisol and memory relationship, Quas et al. (2011) studied the relationship between stress and eyewitness memory among a group of 9- to 12-year olds and 18- to 23-year olds. Participants underwent the TSST-M and provided saliva samples at various times both before (i.e., baseline) and after (+1, 10, 20, 30, 45, 60, and 75 minutes) undergoing the procedure. Two weeks later, participants returned to the laboratory and answered two free recall questions about the previous session (i.e., participants were instructed to discuss their previous session generally), as well as a series of open- and closed-ended direct recall questions (e.g., questions about what the confederate said, etc.). Among the child participants, but not the adult participants, greater cortisol responding to the TSST-M was associated with more accurate recall of details two weeks after the event. There was no relationship among the adults (Quas et al., 2011).

As discussed, the specificity of stress responding can play a key role in both predicting and explaining the relationship between stress exposure and memory accuracy. Deffenbacher and colleagues (2004) suggest that individual differences in stress responding are understudied in the eyewitness memory literature, although some findings suggest that the magnitude of responding (e.g., Brigham et al., 1983; Quas et al.,2011; Valentine & Mesout, 2009) and the specific systems that respond (see Wolf, 2008, 2009) can mediate the relationship between stressor exposure and memory accuracy.

Current study and hypotheses

In the current study, I utilize a face recognition paradigm to examine the roles of timing and of cortisol responding on memory accuracy. I employ a manipulation of the temporal relationship between stressor exposure to acquisition and to retrieval such that participants' cortisol levels are highest at either of these stages. Further, I manipulate the valence of the TBR stimuli at both encoding and at retrieval. Both subjective and physiological measures of stress responding are employed to investigate the role of cortisol responding in the stress and memory relationship. Findings from this study have both theoretical and methodological relevance, and should lead to future research in more ecologically valid settings. Considering the empirical literature, I have developed the following hypotheses:

Hypothesis 1: The timing of the stressor (in relation to acquisition or retrieval) will influence facial memory accuracy.

Peak levels of salivary cortisol occur approximately 20 minutes after exposure to a stressor and return to baseline by approximately 45 minutes post-stressor (Dickerson & Kemeny, 2004). Participants who complete a facial recognition test at this peak cortisol time (i.e., stress at retrieval) should perform less accurately than those who undergo retrieval once cortisol levels return to baseline (Het et al., 2005; Wolf, 2008, 2009). Considering this, I hypothesize that acquisition under peak cortisol timing will exert less of an effect on memory accuracy than will peak cortisol at retrieval.

Hypothesis 2: Accuracy of memory for the procedure will vary as a function of cortisol stress responding condition absent cortisol responding.

Participants in the study will complete the cold-pressor test (CPT) as a manipulation of stress. This manipulation was chosen because it consistently leads to sympathetic and subjective stress responding, while only a subset of those who undergo the task demonstrate any elevation in cortisol (see e.g., Buchanan et al., 2004). In the stress condition, participants place their hand in cold water, while warm water is utilized for the control condition. However, in some studies of stress and eyewitness memory, the stress-provoking nature of a TBR task can lead to differences in memory accuracy (e.g., Quas et al., 2011; for a review see Deffenbacher et al., 2004). Participants in the current study will complete recall and recognition tests of the CPT procedure; I hypothesize differences in accuracy based on the condition assignment.

Hypothesis 3a: Participants will perform more accurately when identifying emotionally valenced faces (positive or negative) than neutral faces.

Hypothesis 3b: An interaction between stressor condition and facial valence will occur such that the differences between (post-hoc) cortisol stress responding conditions will be most pronounced for negatively valenced faces at retrieval, compared to positive and neutral faces.

Acquisition facial valence should lead to greater memory for faces that are valenced (positive or negative) compared to neutral faces (e.g., Kensinger, 2008). As the effects of stressor exposure or stress responding on memory interact with the emotional salience and valence of TBR stimuli (Buchanan & Lovallo, 2001; Buchanan et al., 2006; Kuhlmann & Wolf, 2006; Maheu et al., 2004; Rimmele et al, 2003), I expect an interaction between stressor condition and facial valence. Specifically, cortisol responding at retrieval will be associated with the greatest memory impairment for negatively valenced faces (Buchanan et al., 2006; Domes et al., 2004).

Hypothesis 4: The effects of stress exposure on memory will be more pronounced for cortisol responders than for nonresponders.

The effects of stress exposure on memory are often mediated by individual differences in stress responding, with several studies demonstrating that any effects are predicated on there being some cortisol response (e.g., Buchanan et al., 2006). I hypothesize that cortisol nonresponders' memory accuracy and the accuracy of those in the control group would differ from cortisol stress responders. While psychological and autonomic responses have been demonstrated to mediate the relationship (e.g., Brigham et al., 1983; Valentine & Mesout, 2008), cortisol is particularly relevant to processing of human memory (see Lupien et al., 2007; Roozendaal, 2002).

Hypothesis 5: Those who undergo the stress task will more accurately recall central details about the CPT event than they will peripheral details when compared to those in the control group.

During times of stress, individuals often orient themselves toward the threatening stimulus (see Christianson, 1992; Deffenbacher et al., 2004; Hanoch & Vitouch, 2004). Echterhoff and Wolf (2012) reported superior memory for central details to those who underwent a stress task immediately after viewing a burglary scene. When participants are asked to recall details about the cold-pressor test, I expect those in the cold water condition to show superior memory for those aspects of the task that would be most related to the threat of the task (e.g., the temperature of the water, instructions concerning the time they should keep their hand in the water).

CHAPTER 2: PILOT STUDY FOR CALIBRATION OF FACIAL STIMULI

The AR Face Database (Martinez & Benavente, 1998) contains over 4,000 color images of faces from 126 different people taken across two separate days. Photographs in various poses (e.g., smile, scream, wearing sunglasses, etc.) were taken across the days for each photographed person (hereafter, "faces"). For the purposes of the current study, I selected photographs labeled *neutral expression*, *smile*, and *anger* for each face. These were meant to represent neutral, positive, and negative valences, respectively. The purpose of the pilot study was to examine participants' subjective evaluation of expression valence, as well as to narrow the 126 faces down to 72 to be used as part of the primary study.

Method

Participants. Participants were recruited from three large introductory sociology courses at the Pennsylvania State University. They received extra credit points in the course in exchange for their participation. A total of 388 participants completed the survey. Participants ranged in age from 18 years (21.4%) to 24 years or older (2.3%) with a modal age of 19 years (35.6%). The majority (62.6%) were female and White (72.6%). Almost all (99.0%) were full-time students and just over half (52.6%) were first-year students.

Procedure. The pilot study was conducted online. Each participant followed a link to the study and participated at his/her own convenience. They were allowed to stop and return to the survey if they chose to do so. Upon consenting to participate in the study, participants read the instructions for the task. They were told that they would either see a survey first or a series of faces. Each participant viewed 200 photographs of faces selected from over 600 faces from the AR Face Database. The 200 were randomly assigned for each participant (i.e., each participant saw a 200-face subset chosen randomly) and included faces representing each of the three emotional valences and across both days of photography. No participant would see the same picture twice, but there was nothing that would prevent participants from viewing the same *individual* multiple times.

The instructions stated, "For each face, you will rate the **valence** of each expression. **Valence** is simply a continuum of how *positive* or *negative* a particular stimulus (in this case faces) is." Participants were further instructed that they were not rating on attractiveness or other judgments and were provided with examples of negative valence emotions (e.g., sadness, anger, fear) and positive valence emotions (e.g., happiness, satisfaction, pleasure). They were also told that "[s]ome emotional displays are neither positive nor negative" and reminded that they could use any point on the provided rating scale. Participants responded to each face on a 7-pt scale with the following anchors (in this order): very negative; negative; somewhat negative; neither negative nor positive; somewhat positive; positive; very positive.

Participants also completed the Interpersonal Reactivity Index (IRI; Davis, 1983) as well as a brief demographics questionnaire. The purpose of the IRI was to determine whether empathy was associated with assessments of facial valence, although this was largely exploratory and peripheral to the study at hand.

Results

It was hypothesized that the smiling faces would be more positive than the neutral faces which would, in turn, be more positive than the angry faces. For each individual face I considered the ratings for the three faces for each of the days to choose faces that were rated in such a way that they could be used as positive, negative, or neutral stimuli. This meant comparing within faces and between faces; this was done by manually viewing mean ratings for each face. Upon initial inspection, and without inferential analyses, it was clear that most smiling faces received valence ratings in the high positive range. However, neutral faces and angry faces often received scores that were not all that distinct from each other, particularly amongst male targets. If the neutral ratings went below a mean value of 3.40 then they were excluded; the same for those negative faces receiving a mean rating higher than 3.30. Further the difference in valence ratings between neutral and angry faces had to be at least 0.5 points, otherwise the neutral face was excluded from the pool. Positively valenced faces (i.e., those rated 5.0 or higher) from that given subset were still used in many cases. For example, if the negatively valenced face received a rating of 2.5, the neutral face 2.9, and the positively valenced face a 6.5, then the positively valenced face was still eligible to be in the final pool of 72 faces.

There were 615 pictures of faces remaining in the total pool, across both days, after the initial screening of faces. Figure 1 displays the mean scores across valence for both male faces and for female faces. Ratings of facial valence differed significantly for male faces, F (2, 790) = 3710.09, p < 001; pairwise comparisons demonstrated that each group differed from the others. The same was true for female faces, F (2, 790) = 3741.37, p < 0.001.

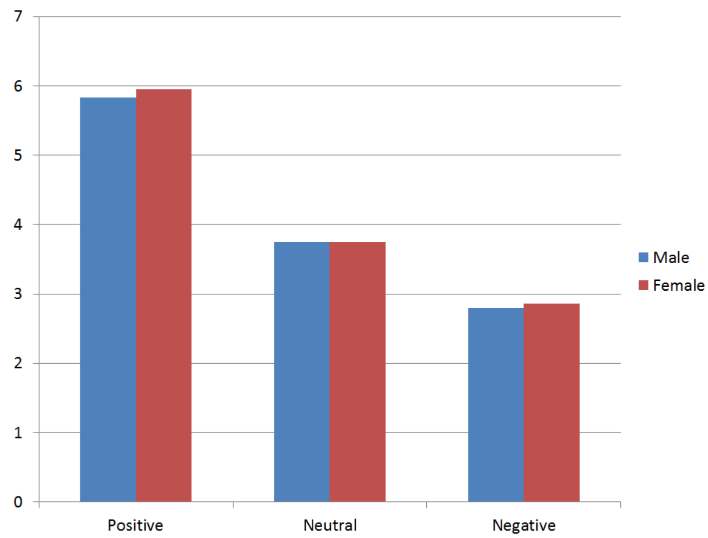

Figure 1: Valence ratings for both male and female faces across the three valence conditions.

Utilizing the mean ratings, I randomly selected 36 males and 36 females from Day 1 photographs. For each gender, there were 12 negative faces, 12 neutral faces, and 12 positive faces. The same faces were selected from Day 2 with an even number of negative, neutral, and positive faces from each, such that twelve total faces were the same valence on Day 1 and Day 2 and 24 each of the two different expressions. Only one version of each photograph was used for each day. For example, if a given male face was positively valenced on the first day of photography then the negative and neutral faces were eliminated from the pool. The final pool included 144 total images (72 for each day), evenly split across genders and across valence.

CHAPTER 3: STRESS AND MEMORY STUDY: METHODS

Participants

A total of 128 individuals participated in the current study. Students at the Pennsylvania State University (PSU) (n = 56) and the University of Nebraska--Lincoln (UNL) (n = 72) participated in the study. The UNL students participated in the study through the Department of Psychology's general undergraduate research pool in exchange for extra credit or course credit. At PSU, students who were enrolled in one of several courses were invited to participate in the study in exchange for extra credit in their respective courses.

A majority (n = 91) of participants were female, and participants predominantly identified as White non-Hispanic (n = 97). Participants also identified themselves as Black (n = 7), Hispanic (n = 9), and Asian/Pacific Islander (n = 17)[2]. Participants ranged in age from 17 to 27 (m = 20.03 years). Participants at PSU (m = 20.66 years) were significantly older than those at UNL (m = 19.54 years), t (126) = 3.93, $p < 0.001$. This was likely because students at PSU were recruited from 400-level courses, whereas most UNL students were enrolled in 100-level courses.

Design

Table 1 displays the primary variables of interest, as well as potential participant variables and control variables. The main analyses in the current study concern stress responding and timing of the stressor as independent variables. Participants were assigned to a stress responding group based on two factors. First, those who underwent the warm water condition were the control group. Second, of those who underwent the cold water task, cortisol change led to *post-hoc* assignment to either a responder group or

[2] Participants were allowed to select more than one racial or ethnic identity.

a nonresponder group. The methods of determining responder and nonresponder are discussed in more detail in a subsequent section.

The emotional valence of faces seen during acquisition and during retrieval was also manipulated within-groups. During acquisition, participants viewed multiple faces that were categorized as either positively valenced, negatively valenced, or neutral valence. The same was the case for faces seen during retrieval (i.e., during test).

Primary Variables of Interest		
Variable	Manipulation	Conditions
Cortisol stress responding	Between-Groups	Control group (i.e., warm water CPT condition) Responders (i.e., cold water/cortisol responders; see below) Nonresponders (i.e., cold water/nonresponders; see below)
Timing of Stressor	Between-Groups	Encoding stress (i.e., peak cortisol at encoding) Retrieval stress (i.e., peak cortisol at retrieval)
Facial Valence at Encoding	Within-Groups	Positive; Negative; Neutral (based on pretesting)
Facial Valence at Retrieval	Within-Groups	Positive; Negative; Neutral (based on pretesting)
Covariates and Control Variables		
Variable	Manipulation	Conditions
Gender	Between-Groups	Male and Female (self-reported)
Site	Between-Groups	Penn State University University of Nebraska--Lincoln
Faces	Between-Groups	Slideshow/Set 1 (i.e., random grouping of faces) Slideshow/Set 2 (i.e., remaining grouping of faces)

Table 1: Primary variables of interest for research design.

While there was no *a priori* expectation of gender effects, participants' self-reported gender was considered as a possible subject-variable that could influence the relationship between stress and memory.

Two variables included in analyses as control variables were the site of data collection and the facial slides utilized during acquisition. Data collection occurred across two sites (i.e., Penn State University; University of Nebraska--Lincoln). In addition, participants were randomly assigned to one of two sets of facial images viewed during acquisition. These variables are discussed in more detail later in this section.

Stress manipulation

To manipulate stress responding, I employed a modified version of the cold-pressor test (CPT), a means of manipulating autonomic reactivity (Greene, Boltax, Lustig, & Rogow, 1965; Hines & Brown, 1936; Hines, 1940; Lovallo, 1975). The test tends to lead to sympathetic responding in a majority of individuals (Buchanan et al., 2006; Lovallo, 1975) and cortisol responding in a subset (Buchanan et al., 2006; Schwabe, Haddad, & Schachinger, 2008). The test involves participants placing their hand, up to their wrist[3], in a bath of cold water (34-36 degrees Fahrenheit) with a control group placing their hand in lukewarm water (74-82 degrees Fahrenheit[4]). The modifications to the task involved introducing several to-be-remembered items concerning the process and stimuli, as described below (see procedure).

The researcher or research assistant (i.e., administrator) entered the room with the equipment for the task: a plastic container with ice or warm water, a thermometer, a

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[3] The first eight participants were not directly told to place their hand in the water up to their wrist; this procedure was adjusted after one of the early participants did not demonstrate a change in blood pressure and some personal testing by the researcher and his research assistants.

[4] In some cases the water was slightly cooler due to hot water limitations, though still well within the warm water range.

colored towel draped over the left shoulder, a separate plastic container with more (ice) water, and a written script. Upon entry the administrator said, “Sorry, bear with me for one second. I’m new to this study. I just need to check something out.” After a few seconds elapsed, the administrator removed the lid from the container and read from the script, informing the participants that they would be placing their hand in the water up to their wrist.

The administrator requested that participants keep their hand in the water for 85 seconds, but informed participants that they could remove it at any time if any pain or discomfort occurred. Buchanan and colleagues (2006) used a slightly longer duration in the water (i.e., 90 seconds), but reported cortisol responding even among those who did not keep their hands in the water for the full duration. Participants were informed that their blood pressure would be checked (using the arm not in the water) after 25 seconds elapsed and were asked to keep their hand near their heart during this check. However, they were also instructed that they could remove their hand from the water during the blood pressure check.

Prior to the participants placing their hand into the (ice) bath, the administrator said, “Some people make funny faces when their hand is in the water.” Then, the administrator placed a piece of paper with a large number “94” written on it onto the open lid. At this point the administrator said, “Let me check the water temperature before we get started just to make sure it is at 36 [78] degrees.” The administrator checked the temperature then said, “I need to add a bit more (ice) water, then you will start.” The (ice) water in the separate container was dumped into the (ice) bath and a timer was readied. Participants were then told, “Go ahead and place your hand in the water bath, palm down, touching the bottom of the container." As participants moved their hand toward the water, they were told, "Good luck."

After 25 seconds elapsed, the administrator pressed the start button on the blood pressure cuff and told the participant, "Remember to keep your hand near your heart during the blood pressure measurement." The device did not start measurement until it was able to detect a pulse, and in some cases measurement took longer than others due to the way the device worked. It usually took between 20 and 50 seconds to get a measurement. Participants who made it the full 85 seconds were told to remove their hand. They were then told, "You can dry your hand with this towel. If you are experiencing discomfort then it helps to massage your hand or rub it briskly with the towel. I'm going to take this [the apparatus] out of the room, then will grab the towel from you and get you started on the next task."

Much of the script was written to be utilized as part of a later memory test; some of the instructions applied more to those in the cold condition, however. For example, being told that people make funny faces might not have made much sense to those in the warm water condition. The instruction *after* the task concerning discomfort probably stood out to those in the warm water condition, and several participants laughed or otherwise reacted to this statement. Nonetheless, it was included for consistency. Some aspects also were probably more salient to those in the cold condition, such as the requested 85-second submersion time.

Components of the task used for later memory testing were also meant to be both central and peripheral aspects of the procedure or apparatus. For example, the temperature of the water was assumed to be a central detail because it directly affected the participants. The inclusion of the number “94” was thought to be peripheral. Below are the various aspects of the procedure used in subsequent tests of memory for the event; each is labeled as either a central detail (CD) or peripheral detail (PD). A full description of the memory questionnaire will be discussed in detail in a subsequent subsection.

- The color of paper used for the script (i.e., yellow) [PD]
- The reason why the administrator asked the participant to bear with him/her (i.e., being “new” to the study or “just starting” the study). [PD]
- The temperature of the water (i.e., 36 degrees or 78 degrees). [CD]
- The color of the thermometer (i.e., black). [CD]
- How long the participant was asked to keep his/her hand in the water (i.e., 85 seconds). [CD]
- How many seconds after beginning the task elapsed prior to blood pressure measurement (i.e., 25 seconds). [CD]
- What the administrator said immediately prior to the participant placing his/her hand into the water (i.e., “good luck”). [PD]
- The suggestion concerning easing discomfort with the towel (i.e., rubbing briskly). [CD]
- The color of the towel used by the participant to dry his or her hand (i.e., purple or green). [PD]
- The number on the paper placed onto the lid (i.e., 94). [PD]
- The color of the container (i.e., clear). [PD]

Faces (at acquisition)

The 72 chosen faces from the pilot were organized by gender (male; female) and by valence (positive; neutral; negative) for a total of 6 groups of 12 pictures. Pictures from each of the grouping were randomly assigned to one of two acquisition stimulus sets with both gender and expression equally balanced. Thus, there were two sets of 36 faces each (6 positive male faces; 6 neutral female faces; etc.).

The facial pictures were randomly ordered through randomization software then placed in this random order onto one of two PowerPoint presentations (i.e., Face Stimulus 1; Face Stimulus 2). The first slide read "The first face will appear shortly." Each subsequent slide included a single face presented for 5 seconds at a time before automatically advancing. A number designating the chronological order of the faces was in the upper-left corner of each slide (see Figure 2 for example).

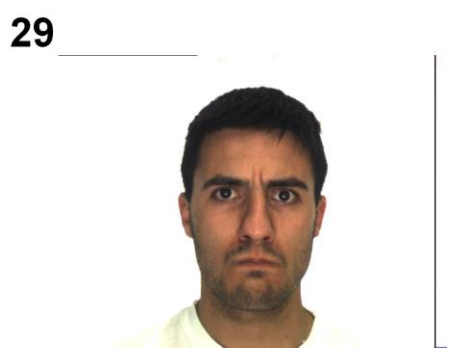

Figure 2: Example of acquisition face slide.

Biological measurement apparatus

Cortisol. Saliva was collected three times during the study via a Salivette (Sarstedt Ltd. Leicester). The Salivette is a plastic tube containing a cotton insert. Participants in the current study were instructed to place the plastic insert into their mouths and were advised to place it toward the back of their mouths while chewing lightly to elicit saliva production. They did this for 30 seconds to a minute then returned the cotton to the tube. Collecting saliva through a cotton apparatus, such as the Salivette, is reliable and valid when dealing with cortisol analysis (see Shirtcliff, Granger, Schwartz, & Curran, 2001).

Sympathetic responding. Sympathetic responding, particularly blood pressure, was measured utilizing an Omron 7 Series wrist blood pressure monitor. The monitor, while primarily for home use, was chosen because it provided an automatic measure of blood pressure. Further, a wrist cuff was utilized because it was easier to put on and to remove. The Omron 7 Series cuff has heart guide technology (i.e., it does not begin measuring blood pressure until in the right position near the heart). Prior to use in the study, I tested the cuff on multiple occasions to deem its reliability. The cuff provides measures of systolic and diastolic blood pressure as well as pulse in beats per minute.

To utilize the cuff, the research assistant placed it on the left wrist of the participants[5]. Participants were instructed to place their hand near their heart, per the Omron 7 Series cuff instructions. The research administrator pressed the start button on the cuff; when the cuff found a pulse it began to measure pressure. This process took between 30-60 seconds depending on the pressure and when the cuff detected a pulse. While no measurements were taken, it seemed to take a bit longer to measure blood pressure during the cold-pressor test (cold water).

Subjective measures

Perceived Stress Scale. The Perceived Stress Scale (PSS) (Cohen, Kamarck, & Mermelstein, 1983) is a 14-item measure of global perceptions of stress (i.e., general

[5] The first 15-20 participants placed the cuff on themselves, but I decided that it would be more consistent if the research assistant placed them. This method was employed for the remaining participants.

perceptions as opposed to acute responses). The items on the scale are intended to examine the degree to which individuals find their lives to lack in predictability and controllability, as well as to overload their cognitive resources.

The version of the PSS employed in the proposed study required participants to report how frequently, in the past month, particular perceptions or events have occurred. For example, participants reported how often something unexpected led them to be upset, how often they have been able to control life irritations, and how often they have felt "stressed" out.

Personality dimensions. Participants completed the 44-item Big Five Inventory (BFI) (John, Naumann, & Soto, 2008). The inventory allows for an efficient assessment of extraversion, agreeableness, conscientiousness, neuroticism, and openness. Participants rated their agreement with 44 phrases with the general qualification of "I see myself as someone who…" Items include "Tends to find fault with others," "Can be moody." The test has respectable reliability and validity levels (for review, see John et al., 2008).

State anxiety. State anxiety was measured utilizing the state anxiety inventory (SAI) of Speilberger's (1983) *State-Trait Anxiety Inventory (Form Y)*. This 20-item inventory provides respondents with a series of statements and asks participants to rate how well a given statement indicates their feelings *right now* on a 4-point scale (not at all; a little; somewhat; very much so). Items included statements such as 'I feel nervous', 'I feel at ease', 'I feel calm', and 'I am worried'. The SAI has been utilized in other studies of facial memory, and Valentine and Mesout (2008) reported that SAI scores correlated with changes in blood pressure.

Empathy. The Interpersonal Reactivity Index (Davis, 1980) measures several dimensions of trait empathy, including distinct measures of affective and cognitive empathy. The complete questionnaire includes twenty-eight statements, such as “Sometimes I don’t feel very sorry for people when they are having problems,” which participants rate on a five-point scale from 1 (“does not describe me well”) to 5 (“describes me very well.”). The test has high test-retest reliability and high internal reliability (Davis, 1983, 1994).

The full IRI questionnaire includes four subscales (i.e., perspective taking, empathic concern, fantasy, and personal distress). Some have criticized the fantasy and personal distress subscales as measuring something other than empathy (Baron-Cohen & Wheelwright, 2004). Davis (1994) emphasized that the subscales appropriately measure aspects of empathy either individually or together. For the current study, trait empathy is defined as the total of two subscale scores (i.e., perspective taking and empathic concern). These subscales measure cognitive empathy and affective empathy, respectively.

Positive and Negative Affect Schedule [Extended] (PANAS-X). The Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988) is a 20-item scale whereby respondents rate how well given adjectives describe them at the moment on a 5-point scale (very slightly or not at all; a little; moderately; quite a bit; extremely). Positive affect items (e.g., attentive, strong, interested) are those characterized by high energy and pleasure, while negative affect items (e.g., upset, scared, hostile) are those characterized by distress and unpleasurable feelings (Watson et al., 1988). For the current study, I employed an extended version of this measure (PANAS-X) (Watson & Clark, 1994).

This 60-item scale provides a global measure of positive and negative affect but also includes four other groupings of items with subscales (e.g., basic negative emotion scales: fear, hostility, guilt, sadness).

Demographics and background information. Participants provided basic background information as part of a brief questionnaire. These items included a dichotomous gender scale, a race measure (participants could indicate more than one racial background), age, enrollment status (i.e., full-time or less than full-time); university standing (i.e., freshman, sophomore, junior, senior, or graduate student); and major. In addition, participants answered a series of questions concerning items that possibly influence cortisol responding, including days since last period, use of oral contraceptives, and use of caffeine.

Memory Tests

Face recognition. The facial recognition test involved participants viewing one face on the screen at a time and answering two questions. First, they were asked if the face was familiar (i.e., seen previously) or unfamiliar (i.e., not seen previously). Second, they were asked to rate their confidence in that decision. Confidence was measured on an 11-pt scale of 0 (not at all confident) to 10 (completely confident). Faces were shown in random order and included 36 faces seen previously (i.e., old) and 36 faces not seen previously (i.e., new) (see below). Both old and new faces depicted 18 males and 18 females. Old faces were each of the same individual seen previously but photographed on a different day. Valence of these faces was randomly assigned.

Recall. Each participant completed a recall test about the CPT procedure. This test included fourteen questions (e.g., “What color was the towel used to dry your hands?”)

about the CPT procedure. Each question was followed by a blank for the participants to type their answers. After answering each question, the participants also rated their confidence with their answer using the same 11-pt scale discussed with the face recognition task.

A research assistant scored each item as correct or incorrect, while I viewed any questions where the answer was not clear to the research assistant. Some of the questions had multiple interpretations and acceptable answers, however. For example, the preferred answer to, “What did the administrator do (i.e., what action did [s]he take) immediately prior to you placing your hand in the water?” was that [s]he poured the (ice) water from the smaller container into the larger container. However, other acceptable answers included “checked the water temperature” or “stirred the ice.” The latter was required in some cases to make room for the participant’s hand. One question asked participants what the research assistant had to do (at the end of the procedure) before the participant could continue. The answers to this question were highly variable, and the question was deemed confusing. Thus, it was dropped from any analyses.

True-false test. Participants also completed a true/false test concerning the procedure (e.g., “The container holding the water was yellow”). This test was on its own page in the protocol. This test also included 14 items, and each item was followed by the same confidence rating. One item referred to when the blood pressure cuff was removed in the task. However, some participants removed the cuff themselves when the administrator was moving the apparatus from the room. This question was dropped from any analyses. Another question asked about when the participant was handed a Salivette during the protocol. This was dropped from analysis because the Salivette was not handed to the participant until after completion of the test.

Administrator characteristics. As a test of eyewitness recall, participants were asked several questions about the administrator of the task (referred to as “research assistant” in the questionnaire). After each question, participants were also asked to rate their confidence using the same 11-pt scale previously described. One of the questions was gender specific (i.e.., describe the research assistant’s facial hair). Others were obvious questions about the race and gender of the research assistants. A research assistant scored each of these questions as correct or incorrect. Participants were also asked if they knew the administrator personally or if they had seen the administrator previously; a discussion of how this was handled is included in the results section.

Procedure and order of tasks

The procedure (order of tasks) varied between the encoding cortisol stress responding and retrieval cortisol stress responding conditions, and these differences will be discussed where relevant. However, the first part of the procedure was identical across groups. Participants were seated and read the consent form. After agreeing to participate in the study, the administrator demonstrated the use of the Salivettes to participants. Next, participants completed the STAI and the PANAS-X. Upon completion, the administrator obtained baseline measures of blood pressure and obtained the baseline saliva sample. At this time, participants completed the modified version of the CPT as discussed in the previous section. Upon completion of the task, the administrator set a timer for 18 minutes and told participants to follow directions. Figure 3 summarizes the tasks across the two time-order conditions.

Acquisition									
1 minute (1 minute)	1 minute (2 minutes)	1 minute (3 minutes)	3 minutes (6 minutes)	18 minutes (24 minutes)	1 minute (25 minutes)	3 minutes (28 minutes)	21 minutes (49 minutes)	1 minute (50 minutes)	10 minutes (60 minutes)
Informed Consent	STAI & PANAS-X	Baseline Measures (1st Blood Pressure and Saliva Sample)	CPT Procedure (Includes Blood Pressure Measure)	Several Questionnaires	Saliva Sample & Blood Pressure Measure & STAI	Presentation of Faces	Several Questionnaires	Final Blood Pressure and Saliva Sample	Recognition Task

Retrieval									
1 minute (1 minute)	1 minute (2 minutes)	1 minute (3 minutes)	3 minutes (6 minutes)	3 minutes (9 minutes)	15 minutes (24 minutes)	1 minute (25 minutes)	10 minutes (35 minutes)	24 minutes (59 minutes)	1 minute (60 minutes)
Informed Consent	STAI & PANAS-X	Baseline Measures (1st Blood Pressure and Saliva Sample)	CPT Procedure (Includes Blood Pressure Measure)	Presentation of Faces	Several Questionnaires	Saliva Sample & Blood Pressure Measure & STAI	Recognition Task	Several Questionnaires	Final Blood Pressure and Saliva Sample

Figure 3: Timeline of tasks across two task order conditions.

Encoding cortisol stress responding condition. Immediately upon completion of the task, participants completed the SAI a second time (i.e., post-stress task measure). Next, they continued to the demographics questionnaire. Following this, the participants completed the recall questions concerning the CPT procedure, then the true/false assessment, and finally the questions concerning the research administrator. Next, they completed a second PANAS-X (used in this case as a filler-task rather than as a measure of any acute change). Participants were then instructed, through on-screen instructions, to work on a provided word-search task until the administrator returned to the room.

Some of the earlier participants stopped at seemingly random points during this interval of tasks. For example, some completed the STAI then failed to continue unless prompted by the administrator who checked in on them. As a result, after approximately 15 participants completed the task, I printed out screenshots of the page with the instructions to “stop” (and work on the word search). Participants were then instructed to “keep clicking forward” through tasks until they reached that point.

After 18 minutes elapsed following the CPT procedure, the administrator returned to the room and took a third blood pressure measure, had the participant provide a second saliva sample, and directed the participant to complete the STAI a third time. Most participants completed this first portion within the allotted 18 min, but those who did not were given an extra 2-3 min to complete it. If they were not done at this point, the administrator went into the room and had them provide a saliva sample so it was in the necessary time window and recorded this information.

This was expected to be "peak cortisol" time for cortisol responders. At this point, the administrator opened a PowerPoint slideshow and set the timer for 25 minutes. The slideshow opened to a blank slide. The administrator informed participants that they would see pictures of faces and were going to rate how positive or negative the facial expression was. This was completed as a paper measure; they rated each face on a 7-point scale. The page was numbered one through 36 with numbers in rows beneath each for the participant to circle the corresponding number. There was no mention of a subsequent test of memory. When the participant indicated that (s)he understood the task, the administrator started the slideshow. Each face picture appeared on the screen for 5 s and automatically advanced. Pictures were numbered in the upper left-hand corner and were randomly ordered *prior* to the task (i.e., all participants saw these faces in the same order).

Upon completion of the slideshow, the administrator returned to the room and directed the participant to continue the tasks until prompted to stop (and to work on the word-search filler task). Participants completed the IPIP, then continued to the PSS and a final PANAS-X. After the PANAS-X they were told to work on the word-search until the administrator returned.

Once 21 minutes elapsed, the administrator returned to the room and took a final blood pressure reading and saliva sample. Then the participant completed the STAI one final time and was instructed to complete the facial recognition task. When participants completed that task they were debriefed and had completed the study.

Retrieval cortisol stress responding condition. The tasks were the same in the retrieval cortisol stress responding condition; however, they were ordered such that participants would be at peak stress during retrieval rather than during encoding. The procedure for the retrieval cortisol stress responding condition did not deviate from the procedure in the encoding cortisol stress responding condition from arrival at the laboratory through the SAI that immediately followed the CPT.

Upon completion of the SAI, participants viewed and rated faces as previously described. This occurred approximately 1-2 minutes following the CPT administration. Next, participants continued by answering demographic information, then completed the questions regarding the procedure and the research administrator. Following these tasks, they completed the PANAS-X. If they finished prior to the arrival of the research administrator, the participants were instructed to work on the word search puzzle.

At 18-minutes post-CPT (i.e., peak cortisol), participants provided a second saliva sample, completed the SAI, and the administrator measured each participant’s blood pressure. Then, participants completed the facial recognition task as described previously. Following the task, participants completed the remaining scales (IPIP, IRI, PSS, SAI, PANAS-X). Participants were instructed to work on the word search puzzle if they completed the scales prior to the administrator returning to the room. After twenty-five minutes elapsed, the administrator returned and conducted the final blood pressure measure and the final saliva sample. They were then debriefed.

Responder Groups

As a key goal of the study was to examine the relationship between cortisol responding and memory accuracy, individuals who underwent the cold task were split into two groups: responders (those who exhibited a rise in cortisol levels from before to after the task; n = 47 [58.8%]) and nonresponders (those who had lower cortisol from before to after the task; n = 33 [41.2%]) (see Buchanan et al., 2006). Buchanan and colleagues, with a much smaller sample, reported similar rates of responders and nonresponders (57.1% and 42.9%, respectively). The proportion of males and females did not differ across cortisol stress responding conditions, *Chi Square* (2) = 5.23, p = 0.072. Among only those in the cold water condition, a higher proportion of females were responders (66.67%) than were males (42.31%), *Chi Square* (1) = 4.30, p = 0.038. However, when examining raw cortisol change from baseline to post-stressor there were no gender differences, F (1, 117) = 0.23, p = 0.63. Further, there was no gender by stress responding group interaction, F (2, 117) = 0.42, p = 0.66.

Face Recognition Recoding

Prior to data analysis, participants' responses to the memory tasks were recoded as either correct or incorrect. A research assistant hand-scored all open-ended questions (see results). For the facial recognition task, responses were recoded depending on the Face Stimulus Set the participants viewed at acquisition (or retrieval). Each response was coded as either a hit, a miss, a correct rejection, or a false alarm. Upon recoding these variables, averages proportions correct were computed. Thus, for each participant I calculated the proportion of correct and incorrect responses for both targets and for lures.

CHAPTER 4: STRESS AND MEMORY STUDY RESULTS

Analysis

The primary analyses in the current study revolve around cortisol responding and the timing of the stressor. Unless otherwise specified, all analyses of variance (*ANOVA*s) included both cortisol responding and the timing of the stressor as between-groups variables. In addition, based on *a priori* assumptions, both collection site and facial slide groupings are included as covariates. Gender was examined as an independent variable in analyses, but only significant findings are reported. Otherwise gender is collapsed for analyses. For analyses involving facial valence, valence is also included as a within-groups variable within the *ANOVA* model. When necessary (i.e., for interactions, for main effects involving responding), *post-hoc* analyses were conducted using Tukey's *HSD* test.

Manipulation Checks

Hand submersion. All participants in the warm water condition kept their hands underwater for the full 85 seconds. For cortisol stress nonresponders, hand submersion duration ranged from 33 seconds to the full 85 seconds, while the range was 19 seconds to 85 seconds for cortisol responders. However, the vast majority of individuals in these groups kept their hand in the water for the full 85 seconds (78.8% and 78.7% for cortisol stress nonresponders and cortisol stress responders respectively).

There was a significant difference in the duration of hand submersion across the CPT conditions with those in the warm-water condition (m = 85 s) maintaining their submersion significantly longer than those in the cold-water condition (m = 77.7 s), F (1, 122) = 8.98, p = 0.003. There was no significant difference in submersion time between cortisol stress responders (*m* = 79.8 s) and cortisol stress nonresponders (*m* = 77.0 s), but the submersion time of both groups was significantly less than that of the control group (*m* = 85 s), *F* (2, 118) = 4.44, *p* = 0.014, *hsd mmd* = 3.62 s.

State Anxiety. There was no significant effect of time on anxiety levels (i.e., anxiety levels did not vary as a function of measurement time), *F* (1, 120) = 1.09, *p* = 0.30. Further, there was no main effect of cortisol stress responding condition on anxiety, *F* (2, 120) = 1.76, *p* = 0.18. However, there was a significant time by cortisol stress responding condition interaction, *F* (2, 120) = 4.58, *p* = 0.012 (see Figure 4).

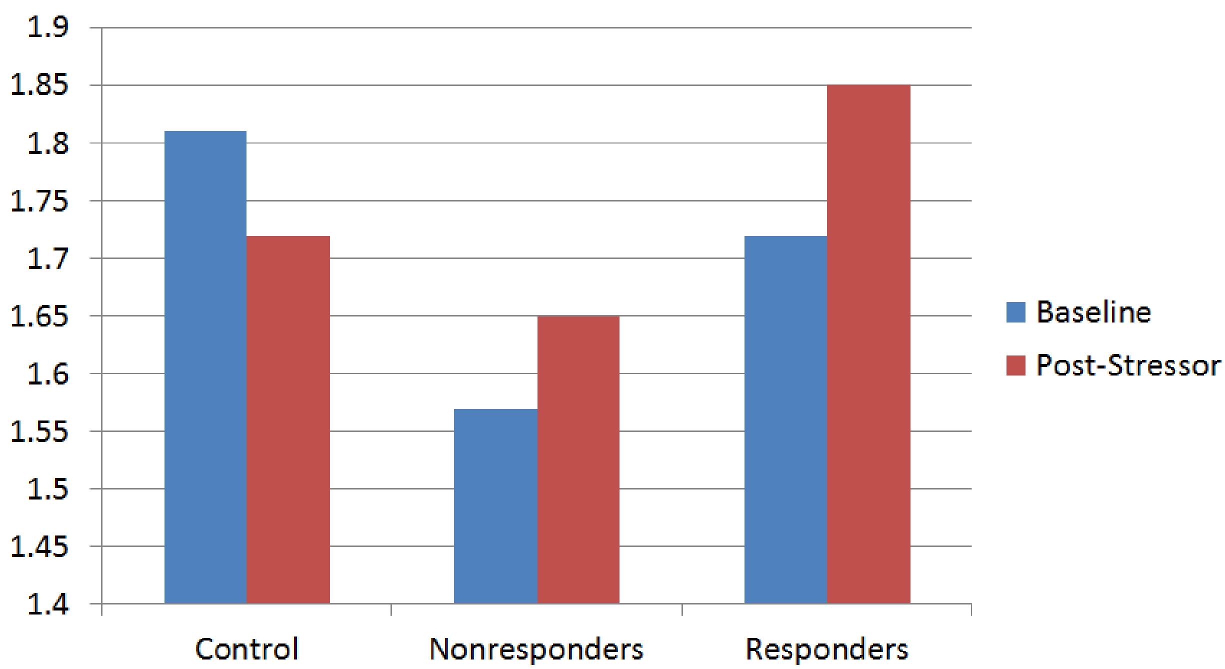

Figure 4: State anxiety levels immediately prior to CPT exposure (i.e., baseline) and immediately following exposure to the stressor across the three CPT conditions (*lsd mmd = 0.11).*

Post-hoc comparisons (*lsd mmd* = 0.11) indicate that cortisol nonresponders exhibited significantly lower levels of state anxiety at baseline than did responders and those in the control group. Responders and the control group did not differ at baseline. In addition, responders reported greater anxiety post-stressor than did both nonresponders and the control group. Post-stressor, nonresponders and those in the control group did not differ. Concerning differences across time, those in the control group had a slight decrease in anxiety from before to after the CPT exposure, although this difference was not significant. Nonresponders exhibited a non-significant increase in state anxiety, while responders' state anxiety increased significantly from baseline to test.

Sympathetic Responding. Sympathetic responding to the task was measured via changes in blood pressure and in heart rate.. I performed a series of 3 (cortisol stress responding condition) x 4 (time of measure) mixed-group *ANCOVA*s with systolic pressure, diastolic pressure, and pulse as dependent variables, respectively. Collection site was included as a covariate. There was no main effect of time on systolic pressure, $F(3, 330) = 2.29$, $p = 0.08$. There was a significant main effect of cortisol stress responding condition on systolic pressure, $F(2, 110) = 5.38$, $p = 0.006$. The findings were such that nonresponders ($m = 120.00$) had higher average systolic blood pressure than did the control group ($m = 110.30$ mmHg), while neither group differed from responders ($m = 113.83$ mmHg).

While the interaction between cortisol stress responding condition and time of measure was not significant ($F [6, 330] = 2.03$, $p = 0.06$), It was expected that responders and nonresponders would experience a significant increase in blood pressure from baseline to the cold-water measurement. Applying a calculated *HSD mmd* (11.07 mmHg), several differences manifested (see Figure 5).

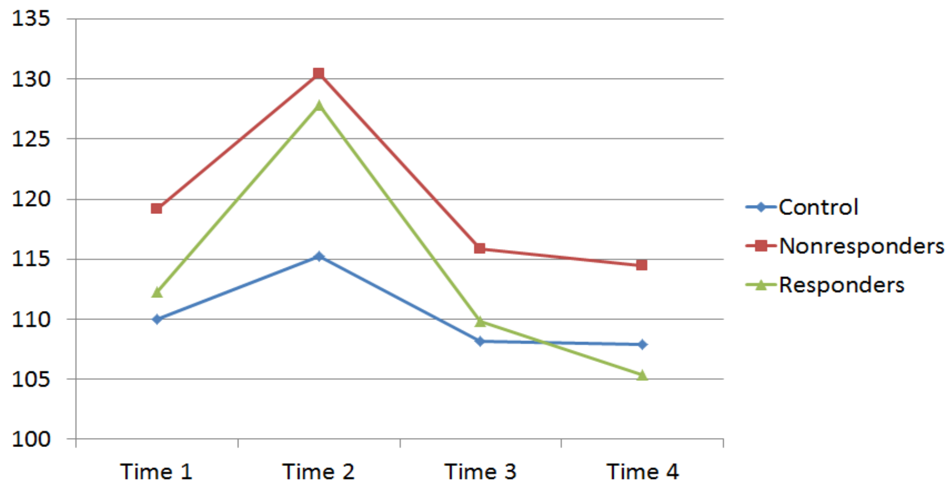

Figure 5: Systolic blood pressure across measurement time points for the three stress responding conditions (*hsd mmd* = 11.07 mmHg).

Across groups, there was no difference in systolic blood pressure at baseline or during either of the post-stress measurements. Systolic blood pressure did differ significantly at the time of the CPT, such that both responders and nonresponders exhibited higher systolic blood pressure than did those in the control group. Within groups, systolic blood pressure increased significantly from baseline to the CPT measurement for both responders and nonresponders. This was not descriptive of those in the control group. Responders and nonresponders returned to baseline levels after the task. No other differences within groups were noticed. Thus, those who underwent the cold-water condition of the CPT experienced increased systolic blood pressure during the task as expected.

Diastolic blood pressure levels followed a similar pattern as systolic levels; I will focus on the interaction between time and cortisol stress responding condition. The interaction approached significance, F (6, 330) = 1.97, p = 0.07, but post-hoc followups (*hsd mmd* = 8.38 mmHg) demonstrated several notable differences (see Figure 6). The pattern matched that of the systolic blood pressure such that diastolic levels only differed across cortisol stress responding conditions at the measure taken during the CPT procedure. Likewise, diastolic pressure increased significantly from baseline to the CPT measurement, then returned to baseline levels for the final two measures among both responders and nonresponders. These findings further support the CPT leading to sympathetic responding.

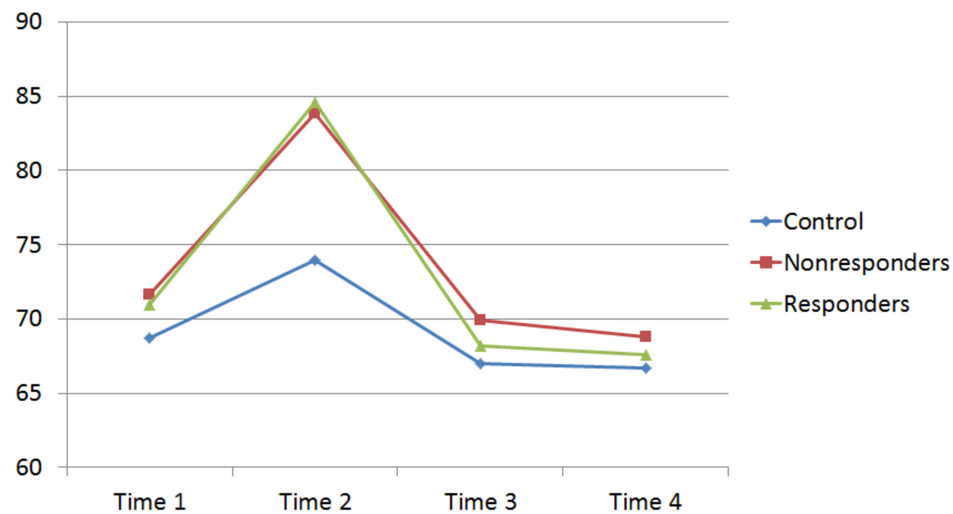

Figure 6: Diastolic blood pressure across measurement time points for the three stress responding conditions (*hsd mmd* = 8.38 mmHg).

Cortisol Responding. Among all three cortisol stress responding groups, cortisol levels did not differ across the three collection points, F (2, 238) = 0.84, p = 0.43. Differences in average cortisol levels across the three groups also was not significant, F (2, 119) = 1.06, p = 0.35. However, there was a significant time by cortisol stress responding condition interaction, F (4, 238) = 11.87, $p < 0.001$. The nature of the interaction is demonstrated in Figure 7.

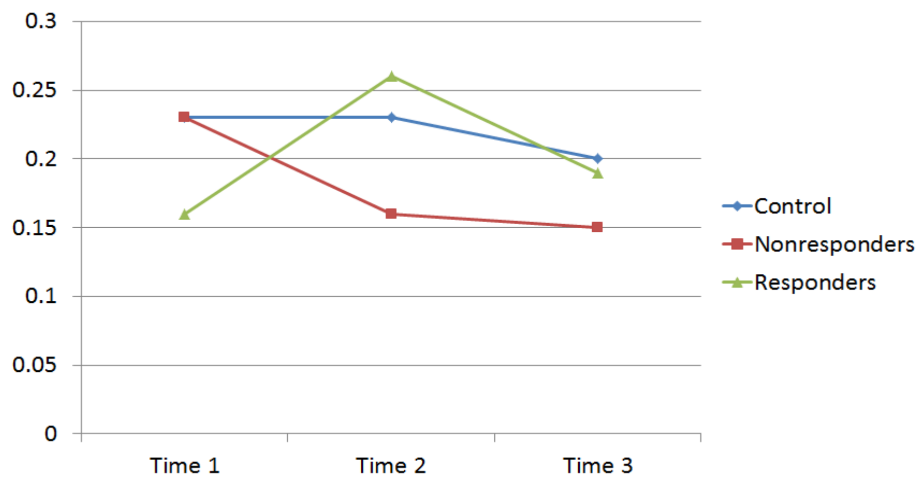

Figure 7: Salivary cortisol levels across measurement time points for the three stress responding conditions (*hsd mmd* = 0.054 µg/dL).

Post-hoc analyses (*hsd mmd* = 0.054 µg/dL) demonstrates differences among groups at baseline such that the control group and nonresponders had higher cortisol levels than did cortisol responders. As expected, cortisol levels of those in the control group remained stable across the three measures. Nonresponders were characterized by a significant decrease in cortisol levels at 18 minutes post-stressor. This level did not change from that measure to the final measure. Cortisol responders exhibited increased cortisol levels at 18 minutes post-stressor, but levels returned to levels that did not differ from baseline at the final measure.

Face Recognition Findings

Face recognition scores were calculated for each participant. Accuracy scores (i.e., percent correct) were calculated as for both targets (i.e., "old" faces) and lures (i.e., "new" faces). Correctly recognizing a target as an old face was classified as a hit; failing to recognize targets as old a miss. Correctly recognizing a lure as new was classified as a correct rejection; failing to recognize the lure as new a false alarm. Findings are reported as hits and correct rejections, but misses = 1 - hits and false alarms = 1 - correct rejections.

Hits. A 2 (task order) x 3 (cortisol stress responding condition) *ANCOVA*, controlling for collection site, indicated no significant main effect of task order on hit rate, F (2, 114) = 0.18, p = 0.67. There was, however, a main effect of cortisol stress on hit rate (see Figure 8), F (2, 113) = 4.84, p = 0.01. These findings were such that nonresponders (m = 0.58) were more accurate than were responders (m = 0.50) and those in the control group (m = 0.49). The main effect was qualified by a significant task order by cortisol stress responding condition interaction, F (2, 114) = 3.78, p = 0.03; *hsd mmd* = 0.12) (see Figure 8). As hypothesized, these findings demonstrate no differences across cortisol stress responding groups in the encoding cortisol stress responding condition. Among those participants in the retrieval cortisol stress responding condition, nonresponders had a higher hit rate than responders and a marginally higher hit rate than those in the control. Contrary to the hypothesis, responders' hit rates did not differ from the control group.

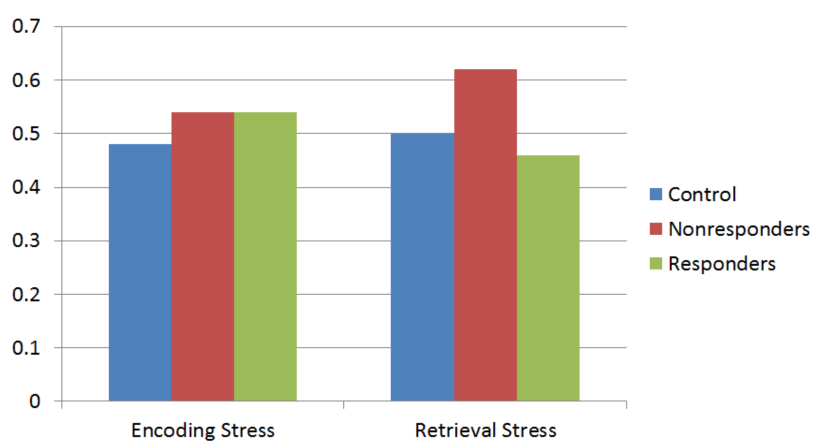

Figure 8: Hit-rate across cortisol stress responding conditions for stress at encoding and stress at retrieval (*hsd mmd* = 0.12)

Correct rejections. There was no main effect of task order on the rate of correct rejections, F (1, 114) = 1.39, p = 0.24. Unlike with hits, there was no main effect of cortisol stress responding on correct rejections, F (2, 114) = 2.31, p = 0.10. Also, there was no task order by cortisol stress responding condition interaction, F (2, 114) = 1.60, p = 0.21.

Gender effects. Gender was added to the previous analyses as an exploratory independent variable in a stress x task order x gender three-way *ANCOVA* with site and face presentation as covariates.For hit rate, there was no main effect of gender on hits (F [1, 107] = 0.81, p = 0.37). Further there were no significant interactions involving gender, Fs < 1.71, ps > 0.18.

Concerning correct rejections, there was no significant main effect of gender, F (1, 107) = 2.56, p = 0.11. However, there was a significant interaction between gender and stress responding, F (2, 107) = 4.07, p = 0.02. The findings, as depicted in Figure 9, indicate that male nonresponders performed significantly less accurately in correct rejections than did female nonresponders or males and females in the control group and the responder group. No other interactions involving participant gender were significant, Fs < 1.29, ps > 0.28.

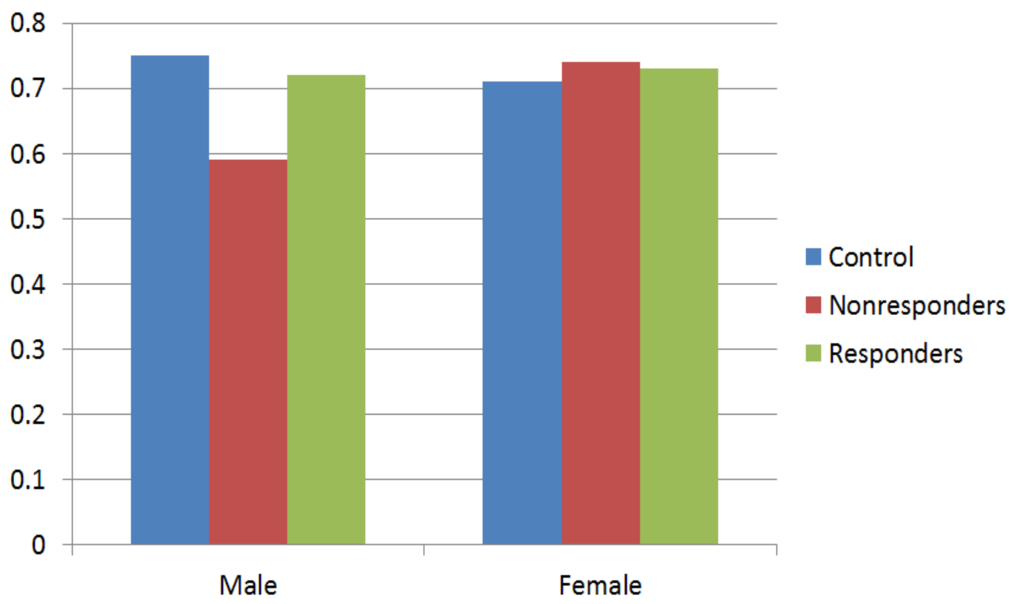

Figure 9: Correct rejections across cortisol stress responding conditions for males and for females.

Confidence/Accuracy Relationship

The confidence accuracy relationship was calculated using several methods. First, I considered the general relationship between overall accuracy (i.e., ratio of accurate versus inaccurate responses) and average confidence (i.e., average confidence across all responses). If a relationship between confidence and accuracy exists, then those participants who were most accurate should also be more confident overall. This was examined using a correlation analysis (Pearson's *r*) and demonstrated a significant, though small, positive relationship between confidence and accuracy, r (125) = 0.18, p = 0.046.

Confidence was separately calculated for hits, misses, correct rejections, and false alarms. For each outcome, I averaged confidence for each participant. For example, for all hits that a given participant made I averaged the confidence just for those hits. Thus, confidence scores for one participant might be based on a different number of faces than confidence scores for another participant on a given outcome. No participant correctly recognized or rejected all faces, so there were no conditions in which an average was based on 0 points (i.e., no issue involving dividing by 0).

These findings were analyzed using a 2 (task order) x 3 (cortisol stress responding) x 4 (outcome confidence) mixed-group *ANOVA* with outcome confidence as within-groups variables. Findings demonstrate a significant differences in confidence across outcomes, F (3, 339) = 3.56, p = 0.015. Utilizing a calculated *lsd* minimum mean difference of 0.49, pairwise comparisons demonstrate that participants were more confident with hits (m = 8.12) than they were with misses (m = 7.41) and with false alarms (m = 7.56). Confidence with correct rejections (m = 7.80) did not differ from confidence in any other decision. This lends partial support for a relationship between confidence and accuracy, particularly confidence within target-present conditions.

These findings were not qualified by significant outcome confidence interactions with the between-groups variables. There was no significant interaction between confidence in the four outcomes and task order (F [3, 339] = 0.77, p = 0.51, nor a significant outcome by cortisol stress responding interaction (F [6, 339] = 0.38, p = 0.89). Further, the three-way interaction between outcome, task order, and responding was not significant, F (6, 339) = 0.37, p = 0.90.

A more appropriate means of calculating the relationship between confidence and accuracy is to use a calibration analysis. Perfect calibration would be such that individuals would be 100% accuracy when stating they are 100% confident, 90% accurate when stating they are 90% confident, etc. across all confidence points. Accuracy was calculated for each confidence point by dividing the number of correct responses for a given confidence rating by the total number of responses for that confidence rating. Some of the confidence ratings were seldom used by participants, particularly on the low end of the scale. Thus, data were collapsed across three confidence levels (i.e., ratings of 1-4, 5-7, and 8-11[6]). A one-way within-groups *ANOVA* comparing accuracy rates across these three intervals demonstrated a significant relationship between confidence ratings and accuracy (F [2,190] =10.35, p = 0.001). Participants were more accurate when rating confidence from 8-11 (m = 0.66) than when they made ratings of 1-4 (m =0.53) and ratings of 5-7 (m =0.53). This finding does further supports a relationship between confidence and accuracy such that participants are more accurate when they are most confident.

Utilizing these same calibration scores, I conducted a 3 (calibration level) x 3 (cortisol stress responding condition) x 2 (timing of stressor) mixed groups *ANCOVA*, including collection site and face presentation as covariates. There was no main effect of cortisol stress responding condition on confidence calibration, (F [2, 86] = 1.48, p = 0.23), nor was there a main effect of task order, (F [1, 86] = 0.002, p = 0.97). Finally, there were no significant interactions, Fs < 0.49, ps > 0.74. These findings suggest that stress responding is unrelated to the confidence/accuracy relationship.

Facial valence

To examine the effects of facial emotion on facial recognition, I calculated accuracy for both targets and lures across valences at encoding and across valences at retrieval. I then conducted a series of 3 (cortisol stress responding condition) x 2 (task order) x 3 (facial valence) mixed-group *ANCOVAs* (controlling for site) for both hit rate

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[6] Thirty participants did not utilize a confidence rating of 1-4.These individuals are excluded from calibration analyses.

and for correct rejections. Facial valence was included in separate models for the encoding and retrieval valence manipulations[7]. Only main effects of and interactions with facial valence are discussed in this section, as general main effects of task order and cortisol stress responding condition have already been discussed.

Hits. The findings (see Figure 10) demonstrated a significant main effect of encoding valence on hit rate, F (2, 234) = 3.30, p = 0.039 (*hsd mmd* = 0.04). Hit rates were significantly higher for faces that were positive at encoding than faces that were negative or those that were neutral. There was no significant difference in accuracy for neutral and negative faces. None of the interactions between valence and the other variables (i.e., task order, cortisol stress responding condition) were significant, Fs < 1.95, ps > 0.11.

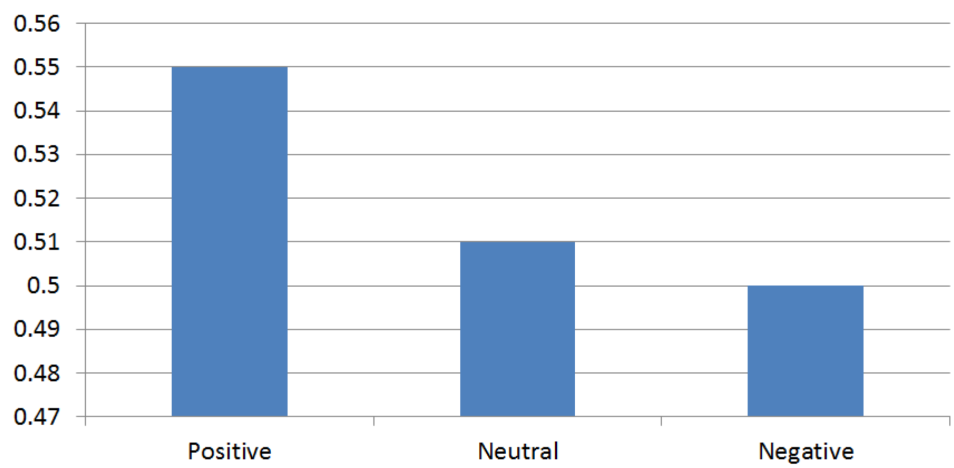

Figure 10: Hit-rates across facial valence at encoding conditions (*hsd mmd* = 0.04).

Valence at retrieval was not associated with differences in hit rates, as there was no main effect of valence, F (2, 228) = 0.28, p = 0.76. Further, there were no interactions

[7] Facial valence at acquisition and at retrieval are analyzed separately because any interaction would have been based on such a small subset of comparisons (i.e., 3 faces each) and because the raw output of data led to a nearly impossible recoding.

between valence at retrieval and the other relevant variables, *F*s < 2.01, *p*s > 0.14. Interactions also were not significant, *F*s < 1.77, *ps > 0.17.*

Recall: Memory for Procedure and Research Administrator

Test of memory for the procedure (i.e., the CPT) and of the experimenter occurred soon after exposure to the stressor. These findings were analyzed using *ANCOVAs* with cortisol stress responding as the independent variable and site as a covariate. The dependent variable for each analysis was the proportion correct of questions answered. Task order was not expected to influence accuracy for these measures because the timing of the test of these items in relation to the stressor was the same for all groups.[8]

Participants did quite well on the true/false test of the CPT procedure with an average proportion correct of 0.87. There were no differences in accuracy between those in the control group (*m* = 0.87), nonresponders (*m* = 0.88), and responders (*m* = 0.88), *F* (2, 120) = 0.47, *p* = 0.63. There was no main effect of cortisol stress responding condition on recall accuracy for the CPT procedure, *F* (2, 120) = 0.08, *p* = 0.92. Proportion of items correct did not differ between those in the control condition (*m* = 0.64), nonresponders (*m* = 0.65), and responders (*m* = 0.66) contrary to the hypothesis.

Participants also completed a test for their memory for the research administrator. They also performed well on this test. Control participants (*m* = 0.78), nonresponders (*m* = 0.81) and responders (*m* = 0.80) did not differ in their proportion of accurate responses, *F* (2, 118) = 0.49, *p* = 0.61. As some of the participants reporting knowing, or previously seeing, the research administrator, a second analysis was conducted with those participants eliminated. The pattern was the same.

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[8] I did conduct analyses with task order included; as expected there was no effect. I do not report these in more detail for the sake of simplicity.

Concerning recall of central and peripheral details of the recall details, I conducted a 2 (peripheral detail; central detail) x 3 (cortisol stress responding condition) mixed-groups *ANCOVA* controlling for collection site. There was no main effect of detail type on recall accuracy, F (1, 120) = 0.005, p = 0.95. More relevant to the current discussion, there was no detail type by cortisol stress responding condition interaction, F (2, 120) = 0.99, p = 0.37. That is, there was no advantage of central details over peripheral details among those in the stress group.

Signal Detection Analyses

In addition to concentrating on hits and correct rejections, I also considered signal detection measures to investigate whether responders, nonresponders, and control participants utilized the same decision processes when making facial recognition judgments. For recognition memory, *d*' was employed as a measure of how well participants were able to discriminate between old items (i.e., targets) and the new items at test. There was no significant main effect of task order (F [1, 114] = 0.53, p = 0.47) or cortisol stress responding condition (F [2, 114] = 0.75, p = 0.47) on *d*' measures.

There was a significant main effect of cortisol stress responding on *C* (i.e., response criterion), F (1, 114) = 3.99, p = 0.02 (*hsd mmd* = 0.18). A follow-up analysis (*hsd mmd* = 0.18) indicated a more liberal response criterion for nonresponders than for responders and those in the control condition (see Figure 11). That is, responders and those in the control condition were more conservative than nonresponders with their judgments (i.e., they responded “new” less often (see Abdi, 2007). There was no significant main effect of task order on *C* values, F (1, 114) = 0.89, p = 0.35.

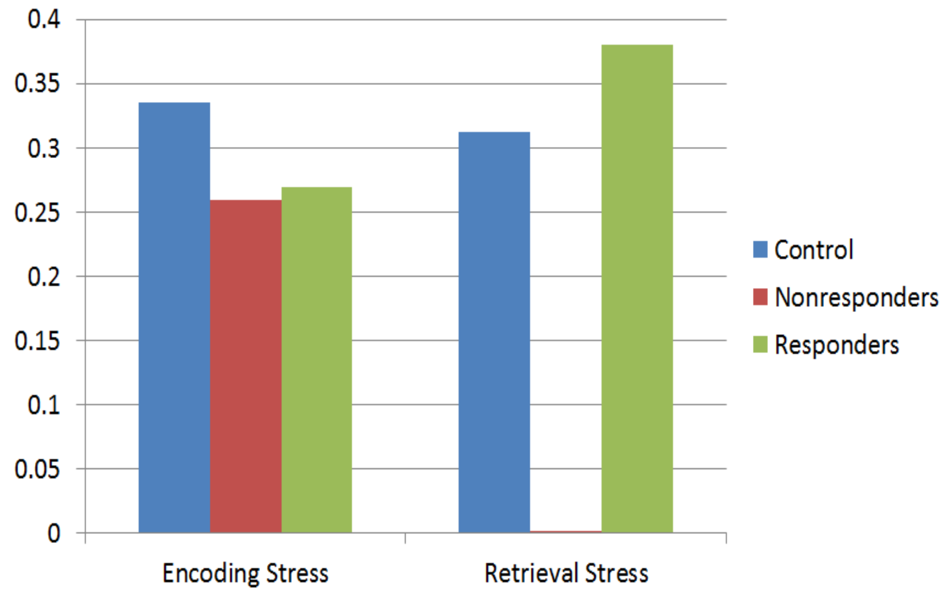

Figure 11: Response criterion (*C*) across stress responding groups and measurement timing conditions (*lsd mmd* = 0.31).

The interaction between task order and responding did approach significance, $F(2, 114) = 2.62$, $p = 0.077$ (*hhd mmd* = 0.31). The findings indicate the strongest liberal bias for nonresponders in the retrieval condition, a more liberal *C* than the control group and responders in the retrieval condition. No other simple effects were apparent.

Exploratory analyses: Self-report measures

I conducted exploratory analyses considering the various self-report measures used primarily as filler tasks (e.g., personality dimensions, affect, perceived stress (week), etc.). First, I considered these as potential predictors of stress responding. Next, I considered them as predictors of memory. Finally, I considered them as mediators of the stress responding and memory relationship. Findings were sparse to non-existent, and none were such that they would merit detailed reporting.

CHAPTER 5: GENERAL DISCUSSION

These findings lend further support to three general hypotheses. First, there are individual differences in physiological responding to a given stressor. Second, these individual differences in responding, particularly cortisol responding, may be associated with differences in memory performance. Third, the timing of stressor exposure, and associated cortisol responding, in relationship to acquisition and retrieval can influence memory accuracy. I will elaborate upon these findings and discuss their relevance to the eyewitness memory literature.

Stress Manipulation

The findings suggest that the cold-pressor test (CPT) was an appropriate stress manipulation to fulfill the primary goals of the study. As with other manipulations utilized in the stress and eyewitness memory literature, the cold-pressor test was associated with a significant change in subjective arousal as measured through the STAI. Those in the cold water condition exhibited a significant increase in state anxiety. Rather than their anxiety levels remaining at baseline, those in the warm water condition exhibited a significant reduction in anxiety levels. A possible explanation for the reduction in anxiety levels among those in the control group is that their baseline anxiety levels were higher than they might normally be due to anticipatory anxiety (i.e., not knowing what to expect from the study). Until participants were exposed to the water bath, after they completed the baseline anxiety measure, they would not have known that they were in the control condition. Thus, the reduction in anxiety might have been influenced by relief that they were in the control condition.

The cold-pressor test has long been used to elicit sympathetic responding in individuals (see e.g., Buchanan et al., 2006), and participants in the current study were no exception. Change in systolic and diastolic blood pressure in response to the CPT was higher for those in the cold-water condition than those in the warm-water condition.

Cortisol. As expected, average cortisol levels did not vary as a function of CPT condition, generally. While studies employing the CPT demonstrate relatively consistent findings concerning sympathetic responding, the CPT is not associated with a consistent change in cortisol levels among all participants (see Buchanan et al., 2006). Instead, studies indicate individual differences in cortisol reactivity to the CPT such that some individuals demonstrate a cortisol increase while others do not (Buchanan et al., 2006). Indeed, the CPT was chosen as the stress manipulation in the current study *because* of the associated individual differences in cortisol responding, in this case 58.8% responders.

General stress and memory findings.

In the current study, facial memory did not differ as a function of exposure to the CPT procedure without taking cortisol responding into account. While studies in the stress and eyewitness memory literature lead to mixed results, the trend is such that stress responding has a negative effect on eyewitness memory accuracy including memory for faces (see Deffenbacher et al., 2004). Unlike others (e.g., Brigham et al., 1983), I found no relationship between sympathetic responding and memory accuracy among those undergoing the stressor (i.e., cold water condition). Further, while the manipulation successfully influenced state anxiety levels, anxiety change also was not associated with memory accuracy in contrast to what others have reported (e.g., Valentine & Mesout, 2009).

One possible explanation for the lack of effect is that the stressor was not severe enough in magnitude to influence memory accuracy. Many studies demonstrating a relationship between arousal and memory accuracy have utilized other physical and psychosocial stressors that might be deemed more serious in contrast to the CPT procedure, such as violent scenes (Bornstein et al., 1998; Loftus & Burns, 1982), a “scary person” (Valentine & Mesout, 2009), shocks (Brigham et al., 1983), or even a mock prisoner of war situation (Morgan et al., 2004). Without empirical testing one cannot state with complete confidence that such stimuli are more stress-eliciting than would be the CPT, but due in part to its brief duration, the CPT might not lead to the level of subjective stress responding necessary for influencing memory.

The adaptive value of memory resulting from a given stressor would emphasize those most relevant to dealing with the stressor (see Hanoch & Vitouch, 2004). The TBR stimuli (i.e., faces) involved information peripheral to the stressor. Although stressors peripheral to TBR stimuli are sometimes employed in stress and eyewitness memory research (e.g., Abercrombie et al., 2003; de Quervain et al., 2000; Domes et al., 2004; Rimmele et al., 2003), some suggest that memory relationships are more likely (or relevant) when the TBR stimuli are the source of any stress responding (see e.g., Christiansen, 1992; Hanoch & Vitouch, 2004).

However, this study also included measures of memory for the stress procedure (i.e., the CPT administration). This was similar to procedures adopted by other researchers. Most recently, Quas and colleagues (2011) manipulated stress responding in children and adults utilizing another standardized laboratory stressor, the Trier Social Stress Test (TSST), and had those participants recall details of the procedure. In the current study, participants' memory for the CPT procedure and the research administrator was not influenced by the water temperature condition overall. Further, there was no superiority of central details among those in the stressor group. Notably, the time gap between the CPT and recall test was brief. And the elements that were relevant and irrelevant were trivial in contrast to those individuals might experience in real stressful situations (e.g., such as when threatened with weapons in a real hostage situation).

Cortisol responding and facial recognition

Although facial recognition accuracy did not differ across the water temperature conditions, cortisol stress responding was predictive of recognition accuracy. Cortisol responders--that is, those who demonstrated an increase in cortisol from baseline to 18 mins post-CPT--made a lower proportion of hits than did nonresponders, although the two groups did not differ in their proportion of correct rejections. In their meta-analysis of stress and eyewitness memory, Deffenbacher et al. (2004) reported a negative effect of stress on eyewitness memory for target-present faces but no overall effect of stress on target-absent lineups. Deffenbacher and colleagues speculated that the different effects of stress on target-present and on target-absent lineups might be due to any stress-related degradation in visual representations of TBR stimuli not being sufficient for influencing determinations of whether an image is *not* in the lineup. The remainder of this section of the discussion will concern *hit rate*.

The hit-rate proportion advantage of nonresponders over responders was as hypothesized and supports findings from an earlier study utilizing a CPT paradigm to examine memory for words (i.e., Buchanan et al., 2006). Buchanan et al. (2006) found that elderly respondents who demonstrated heightened cortisol following the CPT performed less accurately on a subsequent word recall test than did nonresponders. Other studies of general stress and memory have also demonstrated relationships between cortisol responding to a stressor and memory performance (see Lupien et al., 2007; Wolf, 2008, 2009).

Within the stress and eyewitness memory literature, only two other studies have utilized direct examinations of cortisol change in response to a stressor. Echterhoff and Wolf (2012) found that memory encoding of thematically arousing stimuli following exposure to the TSST was associated with superiority of centrality bias over memory for peripheral information. In that study, the TSST was used immediately prior to exposure to stimuli not related to the task, much like the faces in the current study. However, the TBR stimulus was multifaceted and was not associated with any differences in memory accuracy overall. Further, the researchers did not report any individual differences in cortisol among those in the TSST condition, only that cortisol levels were elevated after TSST exposure.

Quas et al. (2011) also utilized a TSST procedure, but they tested memory for the TSST procedure rather than any external stimuli (e.g., faces, words, etc.). They used no control group, as a *control* version of the TSST would be difficult to achieve by design. They reported a *positive* relationship between cortisol responding and memory accuracy among child participants in their study. Thus, child responders performed more accurately than nonresponders. However, they reported no relationship between cortisol responding and memory among the adult participants (i.e., college students).

Findings from these three studies (i.e., Echterhoff & Wolf, 2012; Quas et al., 2011; and the current study) are not contradictory; instead, each utilized the stressor and cortisol measures in different ways. One consideration with the current study, distinguishing it from the others, was the manipulation of timing of the stressor in relation to acquisition and retrieval. In the current study, participants' peak cortisol levels were timed to co-occur with either facial encoding or memory testing. Findings from the general stress and memory literature demonstrate the disparate role of cortisol responding at encoding and at retrieval (e.g., Het et al., 2005; Lupien et al., 2007; Lupien et al., 2002; Wolf, 2008, 2009). While research is mixed on the role of cortisol responding at encoding (Het et al., 2005), cortisol responding at the time of retrieval seems to have a detrimental effect (see e.g., de Quervain et al., 2003; Roozendaal, 2002). Indeed, in the current study the memory advantage of nonresponders was only descriptive when cortisol was at its peak during test. Among those who encoded the faces at peak cortisol (and were tested after cortisol returned to baseline), there were no differences across cortisol responding groups. As hypothesized, cortisol at retrieval was what predicted memory performance, although these findings should be qualified (see Roozendaal, 2002; Wolf, 2008, 2009).

The unexpected finding in the current study was not the relationship between the responders and nonresponders but the memory accuracy of both these groups in relation to the control group (i.e., warm water group). In contrast to Buchanan et al. (2006), who reported that cortisol responders performed worse than nonresponders and those in the control condition, responders and the control group did not differ in their performance in the current study. If cortisol responding is what is influencing post-stressor memory performance, then it would seem that the nonresponders should not differ from the control group.

Thus, a possible explanation for these findings is that any enhancement of memory from exposure to the CPT in this study might have been buffered by *increased* cortisol responding (i.e., enhancement only occurred among those with a decline in cortisol). Some prior work in the eyewitness memory literature demonstrates heightened memory accuracy for those in a high stress condition (e.g., Hosch & Bothwell, 1990; Peters, 1991). Buchanan and Tranel (2007) reported that participants who underwent a stressor and had a cortisol response performed significantly worse at retrieval of words. However, there was a trend for nonresponders to have an enhancement of memory. They concluded, “mild stress (without a cortisol response) may exert a beneficial effect on memory retrieval performance” (p. 138), although for men this effect was only demonstrated with memory for unpleasant terms. Examining stress exposure without cortisol responding as a something that can enhance retrieval merits further testing and replication.

However, there is an alternative explanation for these findings that cannot be ruled out without further research. In most studies of stress and eyewitness memory there is little or no delay between the stressor and acquisition either because the stressor *is* the TBR stimuli (e.g., Bornstein et al., 1998; Buckhout et al., 1974; Hosch & Bothwell, 1990; Morgan et al., 2004; Valentine & Mesout, 2009) or because the researchers intentionally retained a brief interval between the stressor and exposure to the TBR stimuli (e.g., Deffenbacher et al., 1983). Such methods are understandable considering that the prevailing wisdom is that it is the (stressful) crime, itself, that is likely to lead to any relationship between stress and eyewitness memory in the field.

Gender. In the current study, women were more likely than were men to be classified as responders, but in terms of raw values there were no gender differences in cortisol responding to the CPT. Research on stress responding suggests a somewhat complex relationship between gender and cortisol responding (see Kudielka & Kirschbaum, 2005). Such differences seem to depend, in part, on the type of stressor and the age of the sample among other factors.

The concern for the current study was any relationship between stress responding, gender, and memory accuracy. In this regard, only one effect manifested. Male nonresponders made significantly more false alarms than did all other groups. Findings that do suggest gender differences in the relationship between stress and memory have emphasized the role of cortisol responding rather than stress exposure without responding. It is difficult to explain the current finding in light of the research, particularly as it relates to both false alarms *and* to nonresponders who underwent the stress task. As such, this gender difference warrants consideration in future research but fails to support any type of global gender and stress relationship.

Facial valence. Research suggests that both the emotional valence and emotional arousal of stimuli can contribute to memory accuracy (Kensinger, 2008; Kleinsmith & Kaplan, 1964). In the current study, positively valenced faces at encoding were associated with higher hit rates than the hit rates of negatively valenced and neutral faces. There were no effects of retrieval valence on hit rate accuracy.

For the purposes of the current research, the main analyses of interest involved the interaction between cortisol stress responding condition and valence. In this case there were no interactions between valence and the cortisol stress responding conditions. Most research on stress and memory has utilized thematically arousing stimuli, rather than emphasizing valence (see e.g., Ectherhoff & Wolf, 2012). In their meta-analysis of the stress and eyewitness memory literature, Deffenbacher et al. (2004) included studies involving manipulations of thematic arousal and reported overall negative relationships between stress and memory accuracy. Others have reported interactions between stress responding and emotional salience of TBR stimuli on subsequent memory accuracy (e.g., Buchanan & Lovallo, 2001; Maheu et al., 2004; Payne et al., 2006; Smeets et al., 2006). There were no such interactions between facial valence and stress responding in the current study.

The faces in this study conveyed neutral, happy, and angry emotions representing neutral, positive, and negative valence conditions. Valence, however, does not necessarily translate to arousal (see Kensinger, 2008). While the angry face could induce some level of emotional arousal, the faces probably were not as emotionally arousing as other stimuli utilized in the literature including violent scenes, words, and other such stimuli (for reviews see Christiansen, 1992; Hanoch & Vitouch, 2004).

Confidence/accuracy relationship

Many involved in the criminal justice system including jurors, judges, and police officers, believe that eyewitness confidence is a good predictor of eyewitness accuracy (see, e.g., Benton et al., 2006; Kassin et al., 2001). While some research suggests that accuracy is positively associated with confidence, confidence is highly malleable and the small relationship is not large enough to be useful in legal settings (see, e.g., Brewer & Wells, 2006). Using three different means of estimating the confidence/accuracy relationship, the current study supports a significant, albeit small, relationship between confidence and accuracy.

Confidence ratings did not vary as a function of cortisol stress responding condition. In all, these studies fail to lend much support to a meaningful relationship between confidence and accuracy that could generalize to a field setting. Most notably, participants in the current study underwent multiple trials viewing dozens of faces. Confidence might have become inflated (or deflated) as participants were exposed to more and more faces during testing. In the field, an eyewitness would likely view only a single lineup and make a single confidence rating.

SDT analyses

While stress exposure and stress responding can influence encoding and storage of visual representations in memory (see, e.g., Deffenbacher et al., 2004), the findings of the current study suggest that memory findings might also be due in part to decision-making processes. Neither task order nor cortisol stress responding condition affected participants' ability to discriminate between old and new stimuli (i.e., d'). However, nonresponders were less conservative in their decision making than were responders and the control group. Several studies employing facial memory tasks have examined criterion bias differences (e.g., Surguladze, Senior, Young, Brebion et al., 2004; Tooley, Brigham, Maass, & Bothwell, 1987). The more conservative judgments of the control group and responders is not something that can be fully explained without replication, but the findings do suggest that the accuracy differences could be influenced by decision-making processes rather than (or in addition to) memory representations. Future research on stress and memory (generally) should more thoroughly examine decision-making processes through application of SDT methods.

Predictors of cortisol responding

Determining how cortisol responders and nonresponders differ can be useful in understanding why individual differences occur, but it can also allow for future researchers to examine other variables that might be more accessible than salivary analysis. For example, through pilot testing Valentine and Mesout (2009) found sympathetic reactivity during a haunted house related activity was correlated with changes in state anxiety using the STAI. Thus, they justified using only the STAI as a measure of stress responding in their study of stress and memory. Understanding how else responders and nonresponders differ, beyond merely their responses to a given stressor, could elucidate individual differences that might explain why stress exposure lacks a uniform effect on eyewitnesses.

Exposure to a stressor is typically associated with some combination of psychological responding (e.g., anxiety, subjective stress) and physiological responding (e.g., blood pressure, skin conductance, etc.) (for a review, see Bornstein & Robicheaux, 2009). However, these various measures do not always correlate with each other (Bornstein & Robicheaux, 2009; Dickerson & Kemeny, 2004). For example, in the current study most participants (>86%) in the cold-water condition saw an elevation in blood pressure but not in cortisol. In this study, cortisol responding did correlate with both sympathetic responding and subjective anxiety. Only cortisol responding, however, may possibly have been associated with memory differences, demonstrating the system specificity in stress and memory. Cortisol responders did not demonstrate as much positive affect as did nonresponders. Thus, it is likely that cortisol responders exhibited both physiological and psychological responses to stressor exposure.

Limitations of current study

A general criticism of many studies in the eyewitness memory literature is that such studies lack ecological validity (see e.g., Bornstein & Robicheaux, 2009; Christianson, 1992; Deffenbacher et al., 2004). Indeed, in the current study the primary task was a facial recognition task with 72 faces at test. While certainly relevant to the eyewitness memory literature (Deffenbacher et al., 2004), this kind of face recognition task is vastly different from the type of memory testing that would be relevant in the field. An actual eyewitness might be asked to recall details or to attempt to recognize one or more potential culprits, but the number of targets would typically be limited. Thus, although facial identification findings are generally comparable across different research paradigms (Penrod & Bornstein, 2007), more ecologically valid TBR stimuli would be appropriate in future studies (e.g., a video crime scene, a mock crime in the laboratory, etc.).

Further, in the field the source of stress responding is likely to also be part of the TBR stimuli. For example, an armed robbery victim would likely find the event (the robbery itself) to be stress-provoking. Details that the victim might be asked to recall would be directly related to that stress-provoking scenario. In a laboratory (or related) setting, researchers cannot use manipulations such as armed robberies due to ethical constraints. The solution to this problem has been to utilize a potentially stressful procedure and then obtain memory of that procedure (see, e.g., Quas et al., 2011). While I utilized such a procedure in the current study, having participants recall details about the

CPT manipulation, the findings were null. One possible explanation for this is the short amount of time between the procedure and the test. Whereas Quas and colleagues tested participants two weeks after exposure to the TSST, I tested participants within a few minutes of the task. The reason for this procedure was to test individuals *before* peak cortisol levels. Future research should balance the need for testing memory of the stress eliciting stimuli or procedure with care to provide enough time between the procedure and test to allow for normal forgetting processes to occur.

While *most* of those who underwent the cold-water CPT procedure demonstrated an increase in sympathetic responding as measured by change in diastolic blood pressure, and there was an average increase in state anxiety, the task itself was relatively benign compared to what an eyewitness might experience in the field (see Bornstein & Robicheaux, 2009; Christianson, 1992). The task was short in duration (about 3 minutes from start to finish) and was not a threat to the life or overall well-being of participants. Although the task was explicitly chosen because of previous findings demonstrating individual differences in cortisol responding, it is clearly subjectively different than what an eyewitness might experience in the field. However, this is true about almost all studies of stress and eyewitness memory. Even those that took care to use a more ecologically valid scenario (e.g., Valentine & Mesout, 2009) did not really reflect the reality of a street-level crime. With the exception of Morgan et al.'s (2004) study of Special Forces trainees, adult participants in studies of stress and eyewitness memory for *people* were never under any real danger from the TBR individual(s). Despite the ethical limitations placed on researchers, utilizing creativity in selection of stressors can lead to more realistic experiences that might better reflect the field.

The suggestion that stress in the laboratory, and the TBR stimuli, do not generalize to real-crime situations would require empirical testing, however. On its face, the present study and many others in the field do not seem to be as stress-eliciting as truly dangerous crime situations, and the laboratory situation is certainly different from the pressures a true witness might endure. The problem with such an argument is that it is backed by little empirical evidence. As an example, consider the proliferation of violent videos on the Internet. In numerous videos of individuals being victimized (usually assaults), observers often pick up cameras rather than interfering. They might even cheer. The assumption that *observing* a crime is inherently stressful is a suggestion that needs more empirical testing both for understanding stress and eyewitness memory in ecologically valid settings *and* before criticizing findings as failing to generalize to the field.

There is generally a memory advantage for stimuli of a positive or negative valence compared to those that are of a neutral valence (see Kensinger, 2008). In the current study there were few effects of facial valence. Participants exhibited higher hit-rates with positively valenced faces compared to neutral *and* negatively valenced faces. Several studies have found advantages in memory of positively stimuli over neutral stimuli (e.g., Dolcos, LaBar, & Cabeza, 2004). Others have demonstrated a superiority effect of memory for positive stimuli over negative stimuli (e.g., Libukman, Stabler, & Otani, 2004). The stimuli in the current study were chosen for their valence, while others have investigated scenes or stimuli that differed in their perceived arousal level (see e.g., Bornstein et al., 1998; Loftus & Burns, 1982). While pilot testing demonstrated broad differences in valence ratings for the facial pictures, they might have lacked arousal properties leading to an interaction with the stress context (see Hanoch & Vitouch, 2004). Valence and arousal are distinct, and stimuli most relevant to most eyewitness memory relevant encounters are likely to be both arousing and negatively valenced.

Finally, the current study utilized two collection sites. While care was taken to ensure that procedures matched across locations, multiple collection sites can lead to unexpected variability. For example, at the Penn State location samples were immediately moved to a professional deep freezer, while at UNL the samples were stored in a smaller freezer set at -20 degrees Fahrenheit. Further, in the current study samples from UNL had to be shipped from the collection site to the Biomarker Core Lab at Penn State. While shipping conditions do not necessarily influence subsequent cortisol analyses (Clements & Parker, 1998), shipping might still be a concern. Including site as a covariate should alleviate most of these concerns.

Implications and future directions

The current study presents two primary implications. First, individual differences in responding to stressors may play an integral role in the relationship between stress and memory for faces. Second, stress responding may influence memory differently across stages of memory (i.e., encoding vs. retrieval). Both of these possible findings have broad research *and* practical implications.

Importance of individual differences. Stress responding is an evolved, adaptive response to perceived threats in one's environment. Such responses are associated with a myriad of physiological and cognitive changes serving to better cope with the given stressor (e.g., Cannon, 1914; Deffenbacher et al., 2004; Dickerson & Kemeny, 2004; Nelson, 2005; Selye, 1973). However, there are few universal stressors (see Dickerson &

Kemeny, 2004). Some individuals might perceive certain stimuli as threatening, whereas others might consider the same stimuli benign (e.g., snakes, heights, etc.). The act of observing a criminal act or even being victimized might not lead to consistent stress responding across individuals. Some individuals might exhibit a stress response whereas others do not, and the degree of such a response (e.g., the amount of anxiety one experiences; the degree of physiological responding) can also be highly variable.

In much of the eyewitness memory literature, the variable of interest is mere exposure to a stressor with measurement of a stressor utilized as a manipulation check. However, wide variability exists in responses to a given stressor (see, e.g., Dickerson & Kemeny, 2004). The current study supports findings throughout the general memory literature (e.g., Buchanan et al., 2006; Wolf, 2009) and in the eyewitness memory literature (e.g., Brigham et al., 1983; Quas et al., 2011; Valentine & Mesout, 2009) that the *response* to a stressor, rather than mere exposure to the stressor itself, plays a crucial role in stress-induced memory differences. Nonetheless, much of the research literature has emphasized mere exposure and a *general* (i.e., average) stress response among the group as a whole rather than considering individual differences in stress responding among those who experience stressor exposure (for reviews see Christianson, 1992; Deffenbacher et al., 2004).

Those conducting future research should keep the importance of individual differences in stress responding in mind when examining findings and when considering measures of responding. Even with subjective measures of stress responding, a measure that leads to wide variability would allow for more flexibility in examining the relationship between the magnitude of stress responding and memory. An assumption by those in the field (e.g., law enforcement, prosecutors) that everyone has a similar response to a given stressor is likely inaccurate. As such, further care should be undertaken to utilize reasonable field methods to investigate the level of stress responding of eyewitnesses.

The current study also further demonstrates that the type of response one has to a given stressor is an important consideration when discussing the relationship between stress and memory. There are multiple methods of measuring stress responding (see Bornstein & Robicheaux, 2009), but these measures have been largely collapsed (i.e., treated equally) in the stress and eyewitness memory literature (see, e.g., the inclusion criteria of Deffenbacher et al., 2004). Stress responding, however, is multimodal and effects of responding are often system specific. The effects of stress exposure on memory can be contingent on how stress is measured. Here, while most participants demonstrated both increased anxiety and blood pressure in response to stress exposure, only cortisol responding may have influenced differences in memory performance. Although this is not to suggest that cortisol responding is *necessary* to elicit a stress exposure and memory relationship, a great deal of research shows that activation of the HPA axis does appear to play a crucial role in the memory process (see e.g., Lupien et al., 2007; Roozendaal, 2002; Wolf, 2008, 2009). Although physiological measures might be impractical in the field, further use of physiological measures in laboratory research could (potentially) lead to more valid subjective stress measures for use in the field.

Memory stages should be considered. A large body of research in the general stress and memory literature has demonstrated that (cortisol) stress responding has different effects across the stages of memory (see e.g., Het et al., 2005; Roozendaal, 2002; Wolf, 2008, 2009). Stress responding has been shown to narrow attention (see Christianson, 1992). Further, cortisol stress responding plays a critical role in memory consolidation (Roozendaal, 2002) and seems to have a strong negative effect at the time of retrieval (Het et al., 2005; Wolf, 2008, 2009). The research on encoding is mixed (see Het et al., 2005). The current study suggests stage specificity in a facial recognition paradigm. Researchers should not ignore such a possibility when making both theoretical and logistical considerations for research (e.g., by adjusting the interval between stress exposure and retrieval to investigate this timing in relation to when peak cortisol *should* occur).

Memory stage specificity in the effects of stress responding is of particular importance in the field. The prevailing assumption is that stress responding from witnessing the crime is what would impact subsequent memory. Thus, research in the area of eyewitness memory has focused exclusively on stress at acquisition. However, the act of an eyewitness interview or lineup selection could be inherently stressful (Bornstein, Hullman, & Miller, 2013; Levine, Burgess, & Laney, 2008 [in children]; Rush et al., 2014). Determining the stressful nature of an eyewitness interview would require empirical testing, but on its face it would seem that it could be viewed as a stressor.

If retrieval stress has a stronger and more consistent effect on memory than stress at acquisition, it follows that law enforcement could take steps to reduce the stressfulness of an interviewing procedure. While not explicitly inducing stress at retrieval, Rush and colleagues (2014) found that child and adolescent participants who underwent the TSST two weeks prior to viewing a target-absent lineup (TSST administrator as a target) had a greater proportion of correct rejections when interviewed by a supportive interviewer than by a nonsupportive interviewer. A simple conversation prior to the interview and plain clothes (rather than police uniforms) might reduce anxiety and stress responding (Lowenstein, Blank, & Sauer, 2010 [child sample]), mitigating the deleterious effects of stress on memory. Indeed, Kuhlman and Wolf (2006) reported that a non-arousing test situation (i.e., sitting in the researcher's office prior to test) buffered the deleterious effects of pharmaceutically administered cortisol on retrieval in an all-female sample. As Rush et al. (2014) have suggest there is a need for "greater attention in future research to potentially complex associations among encoding stress and interview context in relation to [memory]."

Further, while not the focus of the current study, retrieval need not be limited to the time of *test*. The practical implications of the effects of stress on retrieval seem most relevant to stress at the time of recall or recognition involved in a police interview or lineup selection. However, someone who witnesses a stressful event might retrieve that event many times between the event and viewing a lineup. For example, they might discuss the event with friends, family, and others. Many victims of crimes report intrusive rumination and involuntary recall of memories surrounding victimization (e.g., Orth, Montada, & Maercker, 2006). Thus, retrieval at the time of viewing a lineup is merely one point of retrieval that might be influenced by stress responding.

Future directions. Moving forward, research must emphasize individual differences in stress responding as a moderator of the stress and memory relationship. Such research would also allow us to better differentiate between memory effects of emotionally salient events (generally) and emotionally salient events that provoke a physiological response in some individuals but not others.

Replicating previous studies of stress and eyewitness memory, but adding a cortisol measure, would be an ideal future direction. While studies utilizing videos, slideshows, and some live action are all included in the stress and eyewitness literature (Deffenbacher et al., 2004), physiological manipulation checks are seldom employed (see Bornstein & Robicheaux, 2009). It is my contention that while such studies have led to significant differences in memory performance (see Deffenbacher et al., 2004), they fail to demonstrate that these differences are directly related to (physiological) stress responding rather than to emotional salience or valence. Perhaps this would not be an issue from a practical standpoint as applied to real-world crime situations, but triangulated measures are particularly important to further theoretical understanding of this relationship.

The current study demonstrated that dichotomous cortisol responding (i.e., responders compared to nonresponders) to a stressor was associated with differences in memory performance. However, the CPT tends to only lead to cortisol responding in a subset of individuals. Utilizing a stressor that leads to a more consistent cortisol response (i.e., the TSST) would allow for further investigation of the relationship between cortisol responding and memory for faces. The design would be essentially the same as the current study, but the TSST would replace the CPT as the stress manipulation. As the TSST should lead to a varied, but relatively consistent, response it would be a more appropriate stressor to investigate a potential linear (or quadratic [inverse-U]) cortisol responding and memory relationship.

Finally, the current study was conducted across a single day. While the pattern in cortisol responding was such that cortisol levels returned to near baseline by the final measure, acquisition and retrieval occurring days apart would allow for a more thorough examination of the stage-by-stress responding interaction.

Conclusions

The primary goal of the current study was to examine whether cortisol change following exposure to a stressor would predict memory for faces, and whether that effect would interact with the timing of the stressor exposure in relation to memory testing. To that end, this study suggested that individual differences in cortisol responding to the cold pressor test predicted hit rates when peak cortisol was at retrieval (rather than encoding). Although facial valence at encoding did predict subsequent memory accuracy (i.e., superiority for positive faces), there was no expected interaction between facial valence and stress responding. Further, stress responding did not predict memory for the stress procedure, perhaps because of the short interval between the task and test.

These findings provide further evidence that researchers must consider individual differences in stress responding when studying the stress and eyewitness memory relationship (Deffenbacher et al., 2004). It also further emphasizes the relationship between stress and stages of memory as demonstrated widely in the general stress and memory literature (e.g., Wolf, 2008, 2009). These findings support others who have expressed interest in examining the stress-provoking properties of eyewitness interviews and how that might impact retrieval accuracy (e.g., Quas et al., 2012). Several studies would logically follow the current one, including studies presenting a delay between stress and retrieval, studies using more ecologically valid stressors, and studies investigating stress at retrieval more thoroughly.

CHAPTER 6: REFERENCES

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