The Impact of Psychosocial Stress and Biological Sex on False Recognition Memory

Michelle Henry – HNRMIC006

A minor dissertation submitted in partial fulfilment of the requirements for the award of the degree of Masters in Psychological Research

Faculty of Humanities
University of Cape Town
2009/2010

Compulsory Declaration: This work has not been previously submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in, this dissertation for the work, or works, of other people has been attributed, and has been cited and referenced.

Signature: _____ Date: _____

Acknowledgments

Dr Kevin G. F. Thomas: Supervisor of this project. His dedication and hard work made this project possible.

David Gallo: For his help setting up the false memory tests.

Ernest, Ethyl, Eriksen Trust and the University of Cape Town: For their funding towards my Master's degree.

Dr Vreede: Employee of the National Health Laboratory at Groote Schuur hospital. Her lab conducted the cortisol analyses for this project.

Table of Contents

List of Figures

List of Tables

Abstract

Based on the premise that both the hippocampus and pre-frontal cortex are affected by cortisol and involved in declarative memory processes, the current research aimed to confirm that psychosocial stress can lead to increased rates of false recognition memory errors in humans. In addition, it attempted to show that false recognition error rates differ depending on biological sex and the original stimulus type, thus extending and validating the research done by Gallo and colleagues (2004) on material specificity in false memory. Participants in a Stress group (15 males and 13 females) were exposed to a procedure designed to induce mild psychosocial stress, whereas participants in a Relax group (15 males and 14 females) were exposed to a period of relaxation. Salivary cortisol, heart rate, and subjective self-report measures were used to determine participants' stress levels. All participants completed a false memory task, entailing 3 different recognition tests, on 2 consecutive days. Results showed that under both stressful and non-stressful conditions, pictures were better remembered than words, and that this effect was not mediated by biological sex. However, false recognition errors were greater for pictures compared to words, and neither experimental condition nor biological sex mediated this effect. It was also found that the amount of false memory recognition errors made was not affected by the presence of a stressor, as participants in the Stress and Relax groups performed equally. This result is in contrast with previous studies which indicate that false memories increase under stressful conditions. Furthermore, the impact of stress on false memory was not mediated by biological sex, as both male and female participants in the Stress group performed equally. False memory rates increased over a 24-hour retention period in all participants', however the decay of true memory yielded inconsistent results. This was the first study to examine the material specificity of false memory under stressful conditions. It was also the first study to examine whether the amount of false memory errors made under stressful conditions differed between male and female participants. Therefore, the question of whether the material specificity of false memory is affected under stressful conditions and mediated by biological sex remains open for further research. The use of varying false memory paradigms and larger sample populations would help clarify this question.

Keywords: hippocampus, cortisol, stress, false recognition errors, sex, material specificity

Psychological stress, in both chronic and acute forms, is associated with a variety of cognitive, physiological, and behavioural responses. These responses arise, at least in part, because hormones released by the body during stressful experiences regulate particular brain regions (Lupien et al., 1997; Sapolsky, Krey, & McEwen, 1986). One of the most studied effects of stress is its impact on memory, with results from both human and animal studies suggesting a negative relationship between the two (e.g., Newcomer et al., 1999). False memory (misremembering an event that has or has not occurred) is one type of memory process that empirical studies have shown can be affected by stress (J. D. Payne, Nadel, Allen, Thomas, & Jacobs, 2002). There is a definite need for further research in this area, with results possibly having important implications for real-life situations such as criminal cases in which eyewitness testimony is required. Even though artificially conducted laboratory tests may not truly represent such real-life situations, they provide a practical means of examining the impact of stress on false memory.

False Memory

Memory is a reconstructive process that most often achieves high levels of accuracy, but is susceptible to a variety of distortions and illusions (Roediger, 1996). False recognition (claiming to have previously encountered a novel word or event) is one type of memory distortion that has recently received much attention from psychological scientists (Budson, Dodson, et al., 2005; Roediger & McDermott, 1995).

The empirical study of false memories has a reasonably long history, however. Bartlett (1932) is usually accredited with conducting the first experimental investigation into this phenomenon. He asked subjects to read an Indian folk tale and to then recall it repeatedly. His results showed distortions in subjects' memories over repeated attempts to recall the story. Although many of those results have not been replicated in subsequent studies, Bartlett made a major contribution in distinguishing between *reproductive memory* (accurate material from memory) and *reconstructive memory* (filling in missing elements while remembering, with errors often occurring; Roediger & McDermott, 1995). Bartlett predicted that materials rich in meaning (such as stories and real-life events) would give rise to reconstructive memory processes and therefore errors, while simplified material (such as nonsense syllables and word lists) would give rise to reproductive memory, and therefore more accurate memory.

Numerous subsequent studies have shown that this is not the case, with nonsense syllables and word lists providing an adequate means of inducing false recall and recognition memory in the laboratory (e.g., D. G. Payne, Blackwell, & Neuschatz, 1996; Roediger & McDermott, 1995).

In an example of a recent study of false memory phenomena using simplified material, Gallo, Weiss, and Schacter (2004) tested false memory in a laboratory experiment. Twenty-four healthy undergraduate students were required to study a list of 288 words, presented consecutively on a computer screen. Each word, which was printed in black font, was either followed by the same word printed in red font or a corresponding picture of that word. Some black words (i.e., words printed in black font) were followed by red words (i.e., words printed in red font), others by pictures, and others by both red words and pictures. At the end of the study phase, participants were given three recognition tests: A standard recognition test, and then two criterial recollection tests. On the standard recognition test participants were merely required to say whether an item was presented during the study phase or not. In contrast, on the red word criterial recollection test, participants were required to say whether an item was or was not presented as a red word during the study phase. Similarly, on the picture criterial recollection test, participants were required to say whether an item was or was not presented as a picture during the study phase (see the *Materials* section for a more detailed description of each type of recognition test).

Gallo and colleagues (2004) reported a *picture superiority effect*, in which (a) true memory for pictures was significantly higher than that for red words on the standard recognition test, and (b) the number of picture hits (i.e., correct identification of a studied picture) in the picture recollection test was significantly higher than the number of red word hits (i.e., correct identification of a studied red word) in the word recollection test. In addition, the number of false alarms (i.e., incorrect identification of an item as having been studied when it was not) was lower in the picture recollection test than in the word recollection test.

This picture superiority effect, as observed in the Gallo et al. (2004) study, is well-known to psychologists as being part of the more general *material specificity* effect. The latter term refers to the fact that different brain areas are involved in processing different kinds of stimuli, and that this processing of information is dependent on the type of original material used (Grady, McIntosh, Rajah, & Craik, 1998). A picture superiority effect is often seen with regard to memory: pictures (and other events rich in detail) are more likely to be remembered

than words (and other events lacking such detail and specificity; Budson, Droller, et al., 2005; Rajaram & Roediger, 1993; Snodgrass & Vanderwart, 1980). Furthermore, several studies have shown that true recognition is higher for pictures compared to words; this result is also consistent with the general picture superiority effect (Budson, Sitarski, Daffner, & Schacter, 2002).

Numerous studies have reported lower false recognition for pictures compared to words, a result consistent with the general picture superiority effect (Budson, Dodson, et al., 2005; Budson, Droller, et al., 2005; Gallo et al., 2004, Gallo, Kensinger, & Schacter, 2006; Israel & Schacter, 1997; Schacter, Israel, & Racine, 1999). One cognitive mechanism that has been proposed to account for this pattern of data is that pictures, compared to words, have more perceptual details associated with them, which reduces the amount of source monitoring errors made and consequently lowers rates of false recognition (Budson et al., 2002; Johnson, Hashtroudi, & Lindsay, 1993). Another proposed mechanism involves retrieval ease: The ease with which a person is able to bring an event to mind increases the probability that the person will attribute the event as being an actual memory (Jacoby, Kelley, & Dywan, 1989). Therefore, events with more vividness and distinctiveness are more likely to be believed to be actual veridical memories (Johnson & Raye, 1981).

The latter phenomenon can be understood in terms of the *distinctiveness heuristic* (Schacter et al., 1999), a retrieval orientation which assumes that recollective expectations guide our memory decisions, with more distinctive events being easier to separate from one another during recall/recognition tasks (Gallo et al., 2004). Distinctiveness, in this context, refers to the complexity and uniqueness of the perceptual features of a stimulus. Memory monitoring processes capitalise on such uniqueness by evaluating memory for their match with the expected characteristics of a given source, thereby reducing source-monitoring or familiarity-based errors (Gallo et al., 2006; Johnson & Raye, 1998). According to the distinctiveness heuristic, people rely more on detailed recollections (as opposed to more on familiarity) when memory is tested for pictures compared to words, thereby reducing false recognition (Gallo et al., 2004, 2006). The distinctive features of pictures result in greater confidence and accuracy, therefore false recollections will fail to correspond with subjects' actual recollective expectations.

Reduced false memory for pictures compared to words has been found in experimental paradigms involving semantically-related pictures (Budson, Droller, et al., 2005); this is not the case for word lists. Numerous studies have repeatedly demonstrated high false recognition rates for semantically-related words, for example, in the Deese-Roediger-McDermott paradigm (DRM; Roediger & Mc Dermott, 1995; see Appendix A for a full explanation). These high rates of false memories are most likely attributable to confusions of familiarity between the overall theme of the list and specific items (McDermott, 1996).

Studies have also shown a faster response reaction time for individuals remembering pictures compared to words (Gallo et al., 2006). Gallo and colleagues (2006) speculate these differences in response rate might be accounted for by the additional post-retrieval monitoring processes (such as searching for additional recollective information) used when trying to remember words. Moreover, participants remembering pictures rely solely on the distinctiveness heuristic to eliminate false intrusions, resulting in faster reaction times.

A number of theories attempt to explain why and when false memories occur, some of which have already been introduced above. Although all remembering is a product of information from both encoding and storage processes, as well as information from the retrieval environment (Tulving, 1985), some theorists argue that false memories primarily originate during encoding processes, while others emphasise retrieval processes. Researchers who endorse encoding-based theories note that during encoding people must differentiate between what occurs externally and the thoughts aroused by these external events (reality monitoring); an inability to make such differentiations might lead to false memories (Boyer, Phillips, Rousseau, & Ilivitsky, 2007; Underwood, 1965). On the other hand, researchers who endorse retrieval-based theories note that during retrieval, strategic monitoring processes are used by individuals to determine whether the information they are remembering is accurate or not (Dab, Claes, Morais, & Shallice, 1999; Roediger & McDermott, 1995). Optimal functioning of these monitoring processes depends on a variety of factors, including presentation rate, format, modality, and number of presentations (Gallo & Roediger, 2002; McDermott & Watson, 2001). Importantly, Roediger and McDermott's (1995) original DRM paper suggests false memories may be created in part during the testing phase (when participants are completing the recognition tests), with retrieval processes contributing

significantly to false recall and recognition phenomena (suggesting that false memories originate during retrieval processes).

Although theories regarding false memory abound, the review below only discusses those relevant to this study. According to *dual process theories* of false memory (retrieval based theory), both recollection (recalling details of prior occurrence of an event) and familiarity (feeling that an event had previously occurred without recall of detailed information) contribute to our ability to discriminate between studied and non-studied items (Curran & Cleary, 2003; Gallo et al., 2004). Tulving (1985) developed the Remember/Know procedure to estimate participants' subjective experience of recollection and familiarity. Participants are first asked to decide if an item was studied or not. If they label the item as having been studied they are then asked to make a forced-choice judgement about their level of awareness for those items. 'Remember' items are those for which a person can mentally relieve the experience of when the item was presented (i.e., recollection), whereas 'know' items are those for which a person is confident it was presented to them earlier but cannot mentally re-experience the event (i.e., familiarity). A sense of familiarity leaves individuals with the difficult task of deciding whether they actually encountered an event or merely thought of it during the encoding process (Tulving, 1985). By this account, the semantic overlap between presented words and the non-critical lure in the DRM paradigm would leave participants with a feeling of familiarity, leading them to falsely recognise the non-presented lure (J. D. Payne et al., 2002).

Familiarity might also lead to source monitoring errors, where people retrieve fragments of an episode but are unable to recollect how or when the information was acquired (Johnson & Raye, 1998). In this context, the term source monitoring refers to the set of processes involved in making attributions about the origins of memories. Deficits in source monitoring may be due to impairments in attribution processes as well as disruptions in encoding qualitative characteristics of an event resulting in the construction of false memories (Dab et al., 1999). Retrieval of memory includes activation of the memory trace, its evaluation of the memory trace, and attribution of that trace to particular sources. The attribution of a memory trace to an incorrect source can lead to the formation of false memories (Johnson et al., 1993). Qualitative characteristics of an event define it as belonging to a certain situation; therefore disruptions in encoding of these qualitative characteristics leave a person with the difficult

decision of deciding whether an event occurred in a certain context. It is important for a person to be able to distinguish whether a memory trace is something they have *ever* encountered, or whether they encountered it in a certain context.

In many recognition tests, good performance is not merely a matter of remembering whether one has *ever* (gist representations) seen the presented words, but rather, remembering whether one has seen those words in the *specific* (verbatim representations) experimental context (i.e., the study phase of the experiment). Whereas gist representations specify more general content, and not uniqueness of items, verbatim representations specify contextually specific information/the uniqueness of an item (D. G. Payne et al., 1996, J. D. Payne et al., 2002). Furthermore, contextual information decreases confusion about the source of an event (J. D. Payne et al., 2002).

Under normal circumstances, both gist and verbatim representations are available. Stress, however, impairs context-based (i.e., verbatim) representations, allowing gist-based representations to dominate. Stress has been shown to impact a variety of brain structures. One of these regions is the hippocampus, which is essential for representing contextual information; it does so by binding together the unique elements of a memory that makes it a distinct episode. Another of these regions is the prefrontal cortex (PFC), which is also involved in this binding process. Binding processes link together certain elements of a memory trace that define it as belonging to a distinct episode, thereby playing a role in successful source monitoring (Mitchell, Johnson, Raye, & D'Esposito, 2000). Therefore, through its impact on the hippocampus and PFC, stress may impair encoding of contextually-specific information that defines an event as belonging to a certain situation, thereby increasing the probability of false memory errors when individuals are exposed to stressful conditions.

Stressors and the Physiological Stress Response

The effects of perceiving an environmental stressor are mediated through a neuroendocrine cascade, the final result (in humans) being the secretion of cortisol. This physiological stress response begins when the brain perceives an environmental stressor. The thalamus and prefrontal cortex (PFC) integrate sensory information, and evaluate the meaning of environmental stimuli. This evaluation can lead to the generation of emotional responses

via connections from the PFC to limbic system structures, including the amygdala and the hippocampus. These limbic structures connect to the hypothalamus and serve as a pathway for activating the hypothalamic-pituitary-adrenal (HPA) axis (Lovallo, 1997). The perception of a stressor in this way triggers the release of corticotrophin-releasing hormone (CRF) from the hypothalamus. This release in turn triggers the anterior pituitary to release adrenocorticotrophic hormone (ACTH), and this release triggers the secretion of glucocorticoids from the adrenal gland (Sapolsky et al., 1986).

In humans, the glucocorticoid hormone cortisol is involved in a wide range of processes, many of which serve a protective function, while others serve to help an individual cope with environmental stressors. The secretion of cortisol from the adrenal gland protects the brain against adverse events, such as susceptibility to infectious diseases and chronic fatigue syndrome, and is essential for optimal cognitive and physiological functioning (de Kloet, Oitzl, & Joëls, 1993; Kudielka & Kirschbaum, 2005). In the brain these corticosteroids, along with other components of the stress system, co-ordinate an organism's ability to cope with environmental stressors by increasing the amount of readily available energy, increasing cardiovascular tone and altering cognition (Sapolsky et al., 1986).

Stress-induced secretions of glucocorticoids have multiple effects on the human central nervous system, but have particularly dramatic effects on the hippocampus, a brain region critical for new learning and memory (Kim & Diamond, 2002). Increased levels of glucocorticoids reduce hippocampal glucose uptake (de Leon et al., 1997) and neuronal excitability (Joëls, 2003), impair synaptic plasticity (Diamond, Bennett, Fleshner, & Rose, 1992; Pavlides, Ogawa, Kimura, & McEwen, 1996), decrease the number of newly-generated neurons, and alter synaptic density in the CA1 and CA3 regions of the structure (Shors, Chua, & Falduto, 2001).

The brain-based effects of stress are not limited to the hippocampus: Stress induced cortisol release enhances dopaminergic activity and increases glutamate levels in the PFC (Moghaddam, 2002). This brain structure plays an important role in declarative memory retrieval, particularly in post-retrieval monitoring processes. More specifically, during post-retrieval monitoring the PFC is involved in search and decision-making processes necessary to determine whether an event occurred in a specific context (Burgess & Shallice, 1996), thereby allowing the accurate reconstruction of memories.

Most of these effects of cortisol on the human hippocampus and PFC are mediated by the interaction of glucocorticoids with two intracellular receptors (Wolf, 2003). More specifically, glucocorticoids readily enter the brain and alter gene expression by binding to intracellular receptors. Corticosteroid hormone action involves binding to two intracellular glucocorticoid receptors: type 1 mineral corticoid receptors (MRs) and type 2 glucocorticoid receptors (GRs), which bind cortisol with different affinities (de Kloet, Oitzl, & Joëls, 1999). MRs bind naturally circulating cortisol with high affinity, whereas GRs have a lower affinity for cortisol and only become heavily occupied after a stressor (Newcomer et al., 1999; Wolf, 2003). MRs are involved in behavioural reactivity to novel situations necessary to encode new information, whereas GRs are involved in consolidation and storage of learned information (e.g., Kirschbaum, Wolf, May, Wippich, & Hellhammer, 1996). Furthermore, de Kloet et al. (1999) showed that activation of both types of receptors are a prerequisite for optimal memory functioning.

Exposure to short-term acute stress leads to transient receptor loss (Sapolsky et al., 1986), whereas prolonged chronic stress may produce permanent degeneration of hippocampal neurons, atrophy of dendrites in the CA3 region of the hippocampus, and alteration of dendritic organisation in the PFC (McEwen & Magarinos, 1997; Sapolsky et al., 1986). For example, Galea et al. (1997) showed that female rats exposed to 21 days of chronic restraint stress displayed decreased numbers of dendritic branch points in the hippocampus.

These effects on the hippocampus and PFC can affect memory processes because, as noted earlier, both of those regions play integral roles in memory processing and both have dense concentrations of glucocorticoid receptors (Alderson & Novack, 2002; Kim & Diamond, 2002; Schacter & Wagner, 1999). Consequently, researchers hypothesize that exposure to environmental stressors (and consequent increase in glucocorticoid levels) can impair contextual and declarative memory tasks that are known to require hippocampal and PFC function (de Quervain et al., 2003; D. G. Payne et al., 1996). These hypotheses have been confirmed by numerous studies showing that contextual and declarative memory tasks are particularly impaired by exposure to environmental stressors (e.g., Lupien et al., 1997).

Although a certain level of arousal is needed for an individual to cope with an environmental stressor, it is only when extreme acute (Kirschbaum, Wolf, et al., 1996; Lupien, Gillin, & Hauger, 1999) or chronic (Mendl, 1999; Wolkowitz et al., 1990) elevations in

cortisol levels are present that result in cognitive dysfunction, including memory and attention problems. For example, Cushing's syndrome (a neuroendocrine condition featuring chronic elevated cortisol levels) is characterized by memory and attention deficits, as well as decreased hippocampal volume (Starkman, Gebarski, Berent, & Schteingart, 1992). Furthermore, HPA axis dysregulation is associated with a number of psychiatric disorders and medical diseases (Kelly, Tyrka, Anderson, Price, & Carpenter, 2007), many of which are characterized by hippocampal-dependent memory impairments. Such disorders or diseases include depression, posttraumatic stress disorder, and Alzheimer's disease (Alerson & Novack, 2002; Kim & Diamond, 2002).

Psychological versus Pharmacological Stress Induction

Cortisol reactivity can be elicited not only by naturally-occurring events, but also in response to artificial events created in the laboratory (Stroud, Salovey, & Epel, 2002). In laboratory settings, stress is induced in three major ways: through the use of a psychosocial stressor (such as the Trier Psychosocial Stressor Test (TSST)), by pharmacological stimulation (either orally or injected), or by the use of intense physical exercise (Kudielka, Hellhammer, & Wüst, 2009). Animal and human studies show that psychosocial stress, like physical stress and pharmacological stimulation, can activate the HPA axis, which, as described above, regulates the release of cortisol (Dickerson & Kemeny, 2004; Kirschbaum, Pirke, & Hellhammer, 1993). There are some differences in the mechanics of how this activation occurs, however. For instance, while psychosocial stress requires processing at higher brain levels, pharmacological stimulation acts at a different level of the HPA system (acting directly on the pituitary and adrenal glands) and effects are dose dependent (Kudielka et al., 2009; Kudielka & Kirschbaum, 2005). Additionally, pharmacological increases in cortisol tend to be larger than those induced by psychosocial stress (Uhart, Chong, Oswald, Lin, & Wand, 2006).

Nonetheless, both pharmacological increases in cortisol and exposure to a laboratory psychosocial stressors have been shown to impair memory processing (Kirschbaum, Wolf, et al., 1996; Lupien et al., 1997; Newcomer, Craft, Hershey, Askins, & Bardgett, 1994; Wolf, Kudielka, Hellhammer, Hellhammer, & Kirschbaum, 1999).

Impact of Stress on Various Kinds of Memory

Not all memory systems are equally affected by the experience of stress and consequent raised cortisol levels. For instance, hippocampal-dependent forms of memory, particularly declarative memory (the conscious recollection of previously learned information), are affected by increased cortisol levels, whereas non-declarative forms of memory, such as procedural memory, appear to be unaffected (Kirschbaum, Wolf, et al., 1996). Furthermore, verbal declarative memory is impaired by increasing cortisol levels, whereas non-verbal declarative memory seems to be unaffected (e.g., Lupien et al., 1997, 1999). In an illustration of the latter effect, Newcomer and colleagues (1999) found that administering cortisol to healthy subjects over a 4-day period impaired their verbal declarative memory performance, but led to no change in non-verbal memory performance.

Moreover, de Quervain and colleagues (2003) showed that impairment on declarative memory tests following increased cortisol levels are specific to retrieval processes. Declarative memory retrieval relies upon the medial temporal lobe (MTL), and de Quervain and colleagues (2003) used neuroimaging to determine whether increased glucocorticoid levels reduced blood flow to the MTL during declarative memory tasks. Over four different declarative memory tasks they found that a single dose of corticosterone reduced blood flow to the MTL. Therefore, they attributed the decrease in memory performance after stress to impairments in retrieval processes.

Numerous experiments also suggest that working memory is negatively affected by increases in cortisol levels (Wolf, Schommer, Hellhammer, McEwen, & Kirschbaum, 2001) and that, in fact, this form of memory may be more sensitive to increases in cortisol levels than declarative memory (Wolf, Convit, et al., 2001). For instance, Lupien and colleagues (1999) found that acute doses of corticosteroids caused significant decreases in working memory function, without significant changes in declarative memory.

Finally, a decrease in performance on a variety of spatial memory tasks following exposure to increased cortisol levels has been observed in numerous experiments (Luine, Villages, Martinex, & McEwen, 1994; Schwabe et al., 2007). For example, Bonito Attwood (2008) exposed participants to either an acute psychosocial stressor (namely the TSST) or a relaxation period, followed by a spatial navigation task modeled on the Morris water maze (Morris, 1984). Results showed that participants in the non-stress control group located and

relocated a hidden target equally well, whereas participants in the stress group took longer to locate that hidden target.

Since the current studies memory tests only include episodic memory; semantic, spatial, and non-declarative memory processes will not be further elaborated on.

Stress and false memory. Only one study has examined the effect of stress on false memory directly. J. D. Payne and colleagues (2002) used the DRM paradigm (see Appendix A) to elicit false memories in stressed (exposed to the TSST) and non-stressed (exposed to a relaxation period) participants. They found that stressed participants made significantly more false memory errors than did non-stressed controls, with the former finding it more difficult to distinguish between previously presented and non-presented words. Furthermore, they reported that although exposure to the psychosocial stressor did increase the number of false memory errors committed by participants, it did not affect the accuracy of their memory for presented words (i.e., it had no impact on true memory).

Overall, these results point to an inability of stressed participants to correctly discriminate between material that was and was not studied. Importantly, the effects of stress were specific to false recognition, as accuracy for true memory did not differ between stressed and non-stressed participants. Therefore, the impact of stress on memory cannot be considered as a general impairment, but rather an impairment on aspects of retrieval that allow accurate reconstruction of previous experiences (J. D. Payne et al., 2002).

Another study in the same laboratory, although not intended to examine false memory directly, noted that false memory rates differed between stressed and non-stressed participants. Specifically, J. D. Payne et al. (2006) found that participants in their stress group displayed more false memories than did control participants both immediately after the study phase and 1 week later. The stress induction procedure for this study was the TSST. Following the TSST, participants viewed a narrated slide show containing neutral and emotional material. They were then given a recall and recognition task, and false memories on the recall task were defined as those which clearly were not part of the slide show. On the recognition task participants had to make a judgment of whether an item was presented in the slide show or not and give a confidence rating of how sure they were about their decision. False memories on the recognition task were defined as those that were incorrect choices (saying an item was

presented in the study phase when it was never presented) and participants showed a high confidence in even though those items were incorrect.

Sex Differences in Stress Responsivity

Biological sex is one of the main factors shown to affect cortisol levels in humans and corticosterone levels in animals. Animal studies suggest a marked difference in HPA axis response to both acute and chronic stress, with female rats consistently showing larger responses (Handa, Burgess, Kerr, & O'Keefe, 1994; Kitay, 1961, 1963). Furthermore, studies consistently show that female rats have higher baseline cortisol levels and larger cortisol responses to pharmacological provocation compared to males (Griffin & Whitacre, 1991).

Sex differences in HPA axis response in young adult human populations are not quite as clear-cut, however (Seeman, McEwen, Singer, Albert, & Rowe, 1997; Wolf, Schommer, et al., 2001). For instance, numerous studies show men to have higher baseline cortisol levels compared to females (Kirschbaum & Hellhammer, 1992; Kirschbaum, Pirke, & Hellhammer, 1995), and to have more pronounced increases in cortisol after exposure to a psychological stressor (Kirschbaum & Hellhammer, 1992; Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999; Kirschbaum, Wolf, et al., 1996; Kirschbaum, Wüst, & Hellhammer, 1993; Kudielka & Kirschbaum, 2005; Uhart et al., 2006). On the other hand, numerous studies have found no sex differences in cortisol response after a psychosocial stressor (Herman, Arthur-Smith, Hammock, & Josephs, 1988; Kelly et al., 2007; Smeets, Dziobek, & Wolf, 2009; van Stegeren, Wolf, & Kindt, 2008), while others have found that women subjectively experience more stress than men (Kessler, Brown, &, Broman, 1981; Kroenke & Spitzer, 1998) and show higher increases in cortisol compared to men (Haleem, Kennett, & Curzon, 1988; Richman & Jonassaint, 2008; Seeman, Singer, & Charpentier, 1995).

Gender-specific patterns of HPA axis responsivity may be due to differences in the applied stimulation procedure. In other words, the type of stressor applied might play an important role in determining the magnitude of the physiological stress response. For instance, adrenocortical activity in response to pharmacological provocation varies widely, depending on the type of drug used and the dosage. Women show greater hormonal reactivity to pharmacological stimulation with naloxane (Uhart et al., 2006) and clomipramine, whereas men show greater reactivity to stimulation with desipramine and 5-hydroxytryptophan (Filip et

al., 1989). However, men and women show similar cortisol responses to injections with corticotrophin-releasing hormone (CRH).

With regard to psychosocial stressors, women tend to show larger cortisol responses to those associated with social rejection (e.g., interpersonal stressors and marital conflict; Kudielka et al., 2009; Richman & Jonassaint, 2008; Stroud et al., 2002), whereas men tend to show larger cortisol responses to those that are achievement orientated such as the TSST (e.g., verbal and mathematical tasks; Kirschbaum & Hellhammer 1992; Stroud et al., 2002). However, in their meta-analysis, Dickerson and Kemeny (2004) found that cortisol responses to the TSST were not impacted by biological sex.

It remains unclear as to whether sex differences in HPA-axis response to stressors are due to biological (e.g., the actions of sex hormones on the human brain) or psychological (e.g., particular psychological reactions to certain situations) phenomena, or to some combination of the two. Whatever the mechanism, it seems that HPA axis responses can and do vary by sex, largely depending on the type of stress induction utilized.

Sex Differences in Cognitive Performance

Empirical data suggest there are slight differences in mental ability across sexes, with men generally performing better on visuospatial tasks and mathematical reasoning, and women generally performing better on tests of verbal tests ability, fine motor skills, and perceptual speed (Hyde, Fennema, & Lamon, 1990; Postma, Winkel, Tuiten, & van Honk, 1999). Although the mechanisms are not fully understood, sex differences in cognitive abilities are due, at least in part, to the actions of sex hormones on the brain (Hampson, 1990b).

Circulating levels of gonadal sex hormones and corticosteroid binding hormone (CBG) are thought to mediate sex-specific HPA axis responses (Kirschbaum et al., 1999). With regard to CBG, cortisol binds to this hormone, thereby lowering free cortisol concentrations. Blunted cortisol responses in oral contraceptive users could be due to the modulatory role of CBG, because the use of oral contraceptives increases CBG levels (Kirschbaum & Hellhammer, 1992; Kirschbaum, Schommer, et al., 1996). Additionally, CBG levels are elevated in older females compared to males, whereas no such sex difference is found in younger people. Therefore, elevated total plasma cortisol levels in older women, and higher

salivary cortisol responses in older men, may be partially attributed to differing CBG levels (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004a).

With regard to gonadal sex hormones, studies show that estrogen enhances HPA axis activity by increasing responsiveness and sensitivity to glucocorticoids, and reducing negative feedback which would otherwise reduce HPA axis activity (Burgess & Handa, 1992; Young, 1995). In animal studies, ovariectomy (which leads to a lack of estrogen) can cause attenuated HPA axis responses (Norman, Smith, Pappas, & Hall, 1992). In human studies, short-term estradiol treatment has been shown to enhance cortisol reactivity to stress in males (Kirschbaum, Schommer, et al., 1996).

Furthermore, with regard to the female estrous cycle, consistent animal literature shows higher stress responses in the luteal phase (when estrogen and progesterone are elevated) relative to the follicular phase (Kirschbaum et al., 1999; Roca et al., 2003). During a human menstrual cycle there are natural variations in estrogen and progesterone, among other hormones (Rosenberg & Park, 2002). Estrogen levels are low in the follicular phase, peak shortly before ovulation, and decrease throughout the luteal phase (Kirschbaum et al., 1999; Rosenberg & Park, 2002). Therefore, during the late luteal phase estrogen levels are relatively low, which may explain why women in the late luteal phase have comparable cortisol responses to males.

Nonetheless, the extent to which hormonal factors contribute to sex differences in cognition is relatively poorly understood. The natural variations in hormone levels during the human menstrual cycle provide a practical and non-invasive means of studying these effects (Hampson, 1990b). Some studies have shown that increased estrogen levels favour implicit and explicit memory (Maki, Rich, & Rosenbaum, 2002; Sherwin & Tulandi, 1996), while impairing spatial abilities (Hampson 1990a; Hampson, Finestone, & Levy, 2005; Maki et al., 2002). Hampson (1990b) found that women in the mid-luteal phase performed better on tests that women generally excel at (such as verbal ability and perceptual speed). Therefore, the study concluded, in women, higher levels of estrogen and progesterone favour skills that are inherent to women, but are detrimental to the skills inherent in males (such as visuospatial abilities and mathematical reasoning). However it was noted by Hampson (1990b) that not all sexually dimorphic cognitive skills are subject to the activational influence of sex hormones and further investigation is needed. Researchers should therefore be aware of the important

role gender-specific cognitive abilities play when testing any kind of cognitive functioning. Another important consideration when looking at gender-specific cognitive abilities is how those abilities differ under stressful conditions and due to hormone levels.

Under the influence of a stressor Andreano, Arjomandi, and Cahill (2008) found no memory differences between women with varying hormone levels (he used female participants at varying stages of their menstrual cycle when estrogen and progesterone levels differed). The stressor in the study was a cold-pressure stressor (where participants had to immerse their hand in ice water for 3 minutes), and was applied during encoding. In that study, when encoding occurred during the mid-luteal phase (i.e., when estrogen levels were higher), recall was better compared to when encoding occurred during the late luteal or follicular phase (i.e., when estrogen was lower).

Additionally, age seems to be a mediating factor here, as the literature is consistent in demonstrating that, under stress, elderly females show poorer memory performance compared to elderly males (Seeman et al., 1997; Wolf et al., 1999). A possible explanation for this age-related effect is that there are significant hormonal changes across the life span, with post-menopausal women having lower estrogen and progesterone levels compared to younger women (Wolf, Schommer, et al., 2001). The idea that hormone levels modulate the relationship between cortisol and memory has been shown in numerous studies. For example, in elderly females, basal cortisol levels were associated with poorer memory for hormone replacement therapy (HRT) non-users (lower estrogen and progesterone) compared to HRT users (higher estrogen and progesterone) (Carlson & Sherwin, 1999). In summary, then, it seems that glucocorticoids' effects on memory are modulated by sex hormone levels. However, sex hormone levels are not the only factor that influence memory under stress, as the magnitude of cortisol response to that stressor seems to play an important role.

J. D. Payne et al. (2006) found that exposure to a stressor (namely the TSST) was associated with better performance on both immediate and delayed recall tasks in males but not in females. Numerous studies suggest that men show poorer memory performance after stress induction than females, possibly due to their greater magnitude of increase in cortisol in response to that stressor (i.e., men tend to be better cortisol responders; Kirschbaum, Wolf, et al., 1996; J. D. Payne et al., 2006; Wolf, Schommer, et al., 2001). For example, Wolf, Schommer, et al. (2001) exposed 29 healthy young subjects to the TSST, and the other 29

served as controls. After their various experimental manipulations, each participant had to learn a list of words, and was then given a recall test. Within the stress group, cortisol increase was negatively correlated with memory performance, however this effect was only found in male participants. Buchanan and Tranel (2008) noted, however, that when male and females have equally high cortisol responses, retrieval deficits are similar. Therefore, the observed gender differences in memory performance under stress seem to be related to the magnitude of cortisol response, with higher responders displaying more memory impairments.

Summary

The above review of the literature suggests that that stress has a deleterious effect on memory processing, and that biological sex also influences such processing (under both normal and stressful conditions). Additionally, the reviewed literature shows that, with particular regard to the phenomenon known as false memory, false recognition error rates are not only affected by the presence of an environmental stressor, but also by the kinds of materials that one is tasked with remembering. One gap in the literature, however, is that it is not clear whether these errors of memory originate during encoding, consolidation, or retrieval processes. Another gap in the literature is that, until now, no study has investigated whether there are sex differences on false recognition memory tasks, or whether a material specificity effect is maintained on these memory tasks under conditions of stress.

Specific Aims and Hypotheses

The major aim of this study was to investigate whether acute stress affects two different types of false recognition errors: a) false memory for words, and b) false memory for pictures. Another aim was to determine whether biological sex impacted the material specificity of false memory under stressful conditions. A related minor aim was to assess the decay of both true and false memory over a 24-hour period. This is the first study to investigate the effects of stress on the material specificity of false memory, and to involve a study of sex differences therein.

More specifically, this study aimed to systematically replicate Experiment 1 from Gallo and colleagues (2004), adding stress, sex, and time retention as three new independent variables.

As noted above, this study makes three major additions to Gallo et al. (2004, Experiment 1). First, whereas Gallo et al.'s study only used one group of participants (24 participants, biological sex not specified), the current study used two groups (one exposed to a psychosocial stressor and the other not) to investigate the effects of stress on the material specificity of false memory. Second, whereas Gallo et al. did not specify the sex of their participants, the current study used both male and female participants to investigate whether sex had an impact on the material specificity of false recognition memory under conditions of stress. Third, whereas Gallo et al. only tested participants' memory immediately after they had studied the original word/picture lists, the current study featured memory tests of the original lists both immediately after presentation and 24 hours later. This procedure enabled the investigation of the decay of true and false memory (for both pictures and words) over time.

One reason for the interest in rate of decay is that true and false memory differ in number of ways, one of which being the rate at which they decay over time. D. G. Payne et al. (1996) found that true memories in a recognition test decline with increasing time delay, whereas false memories remain relatively stable over a 24-hour delay. Similarly, other studies have found that true memory in recall tests is more affected by increasing retention intervals than are false memories (Bartlett, 1932; Brainerd & Reyna, 1990; J. D. Payne et al., 2006). As noted before, Gallo et al. (2004) did not investigate the effect of retention time on the decay of memory, and this effect has never been studied with reference to the material specificity of false memory.

The main hypotheses of the current study are therefore as follows:

1) Pictures will be better remembered than words, and false memory for words will be greater than false memory for pictures, in all participants (following predictions based on picture superiority effects).
2) False memory (for both pictures and words) will be greater in stressed participants than in non-stressed participants, and will be greater in stressed male participants than in stressed female participants (due to predicted higher cortisol increases).
3) False memories will not increase over the 24-hour retention period in all participants (following predictions that false memory remains relatively stable over a 24-hour retention period).

4) True memories will decrease over the 24-hour retention period in all participants (following predictions that true memory is more susceptible to decay over a 24-hour retention period than false memory), with stressed participants showing a larger decrease than non-stressed participants, and stressed male participants showing a larger decrease than stressed female participants (due to predicted higher cortisol increases).

Design and Methods

Design

This study was a true experimental, cross-sectional, 2 x 2 x 2 factorial design. It compared a specific cognitive process (false memory for items studied in both pictorial and word form) in two groups of subjects: one that was exposed to an acute psychosocial stressor, and the other that was not. Additionally, each group was composed of an equal number of males and females. The independent variables in this study were therefore stress manipulation (or lack thereof) and sex (male versus female), as well as time (whether the memory tests were given immediately after or 24-hours later). The major outcome variables were false and true memory (discussed in further detail in results section).

Participants

One hundred and two undergraduate students (42 male, 60 female) from the University of Cape Town were recruited for this study. They were between the ages of 18 and 27 years, and participated in exchange for course credit. Exclusion criteria included the presence of current psychoactive medication and current psychopathological conditions, certain medical conditions involving HPA axis dysregulation (e.g., Cushing's Syndrome, ACTH secreting tumours), and a history of neurological insult.

These exclusion criteria are typical of studies into the effects of stress on cognition. Numerous studies have reported that patients suffering from major depressive disorder and depression in general, show elevated cortisol levels and have different phase shifts in adreno-cortical functions compared to people with no current mood disorder (Kudielka & Kirschbaum, 2005; Sapolsky et al., 1986). In the current study, severely depressed participants (BDI score > 29) were excluded on the basis that their baseline cortisol levels differ from

everyone else's. These participants were given the telephone number for Student Health at the University of Cape Town if a counsellor was required. With regard to age, elderly individuals show higher cortisol levels than younger indivduals (Kuldieka & Kirschbaum, 2005). Furthermore, numerous studies have shown that hippocampal neurons are lost with age (e.g., Bodnoff et al., 1995) and in individuals who have chronic illness in which elevated cortisol levels are present (e.g., Kahn, Rubinow, Davis, Kling, & Post, 1988). These factors could partly explain why elderly individuals and individuals with certain pathological conditions (such as depression or Cushing's disease) display poorer memory functioning (Kirschbaum, Wolf, et al., 1996).

Ethical approval was granted by the Health Science Faculty Committee. With regard to the recruitment procedures, participants put their names on sign-up sheets posted in the Department of Psychology and around campus. Females were enrolled in the study if they were not taking any oral contraceptives and reported having a regular 30-day menstrual cycle. Female participants were emailed, and those who remembered the precise dates of their previous menstrual cycle were given an appointment 6 days before the first day of their next menstrual cycle (to ensure they were in the late luteal phase of the menstrual cycle). Women in the late luteal phase have comparable salivary cortisol stress responses to men, whereas women in the follicular phase of the menstrual cycle, or those taking oral contraceptives, have significantly lower salivary cortisol responses (Kirschbaum et al., 1999). For the above reasons it was vital that women who participated in this study were in the late luteal phase during the experimental procedure. Male participants were emailed once they signed up, and an appointment was set up to the most convenient date.

Potential female participants who did not remember the exact dates of their menstrual cycle were asked to contact the experimenter on the first day of their next period. An appointment was then set up in a similar manner as described above. Menstrual cycle phase was checked post-experiment by having participants email the experimenter and informing them of the first day of their next period. As shown in Figure 1, this recruitment procedure worked exceptionally well; all but four female participants were in the late luteal phase of their menstrual cycle at the time of their participation. Even those four who were not in the correct phase showed cortisol responses in the correct direction (i.e., if they were in the Stress group their cortisol levels increased in response to the stress induction procedure, and if they

were in the Relax group their cortisol levels decreased in response to the relaxation period). Therefore these four participants remained in the final sample for analysis.

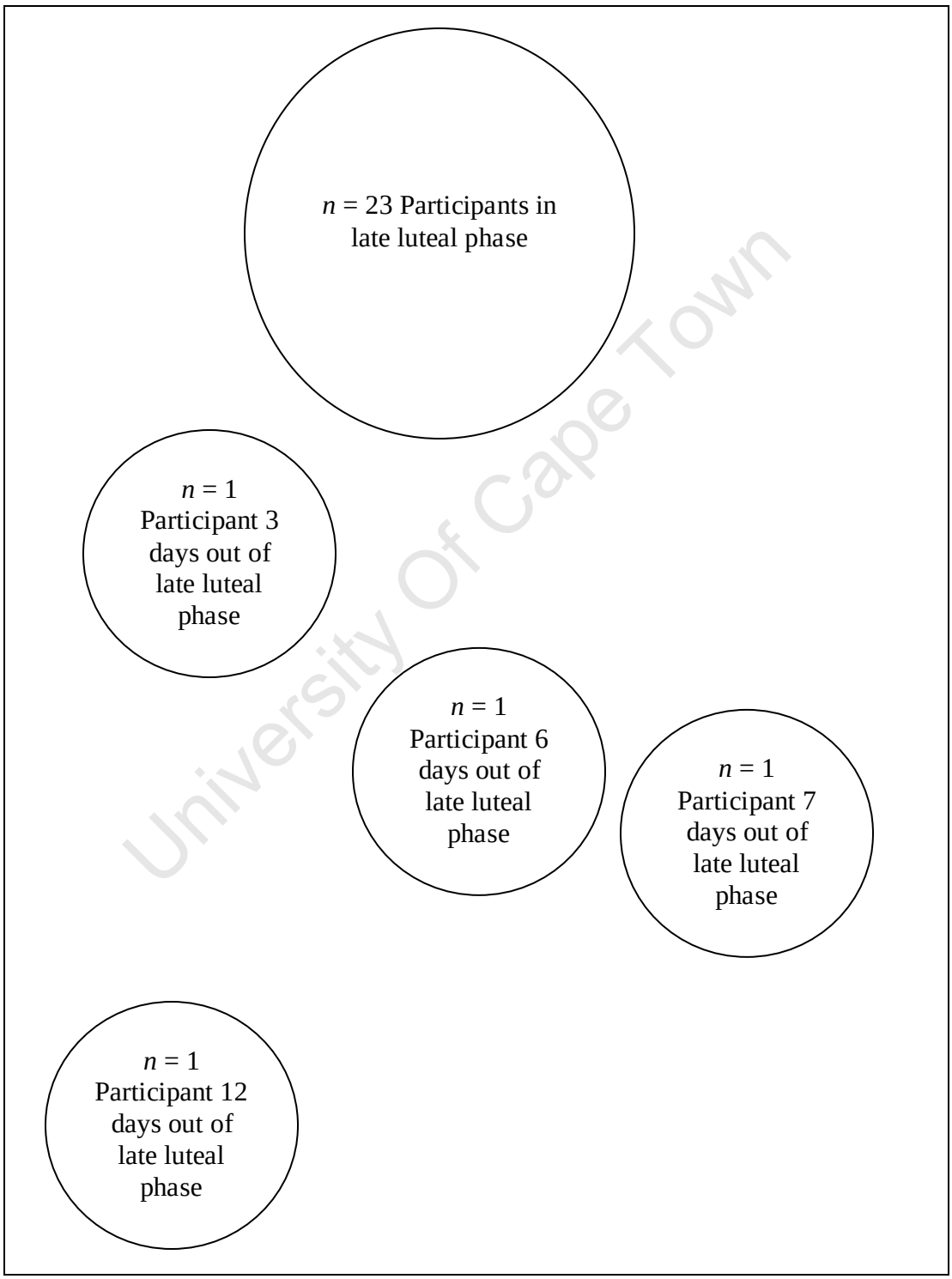
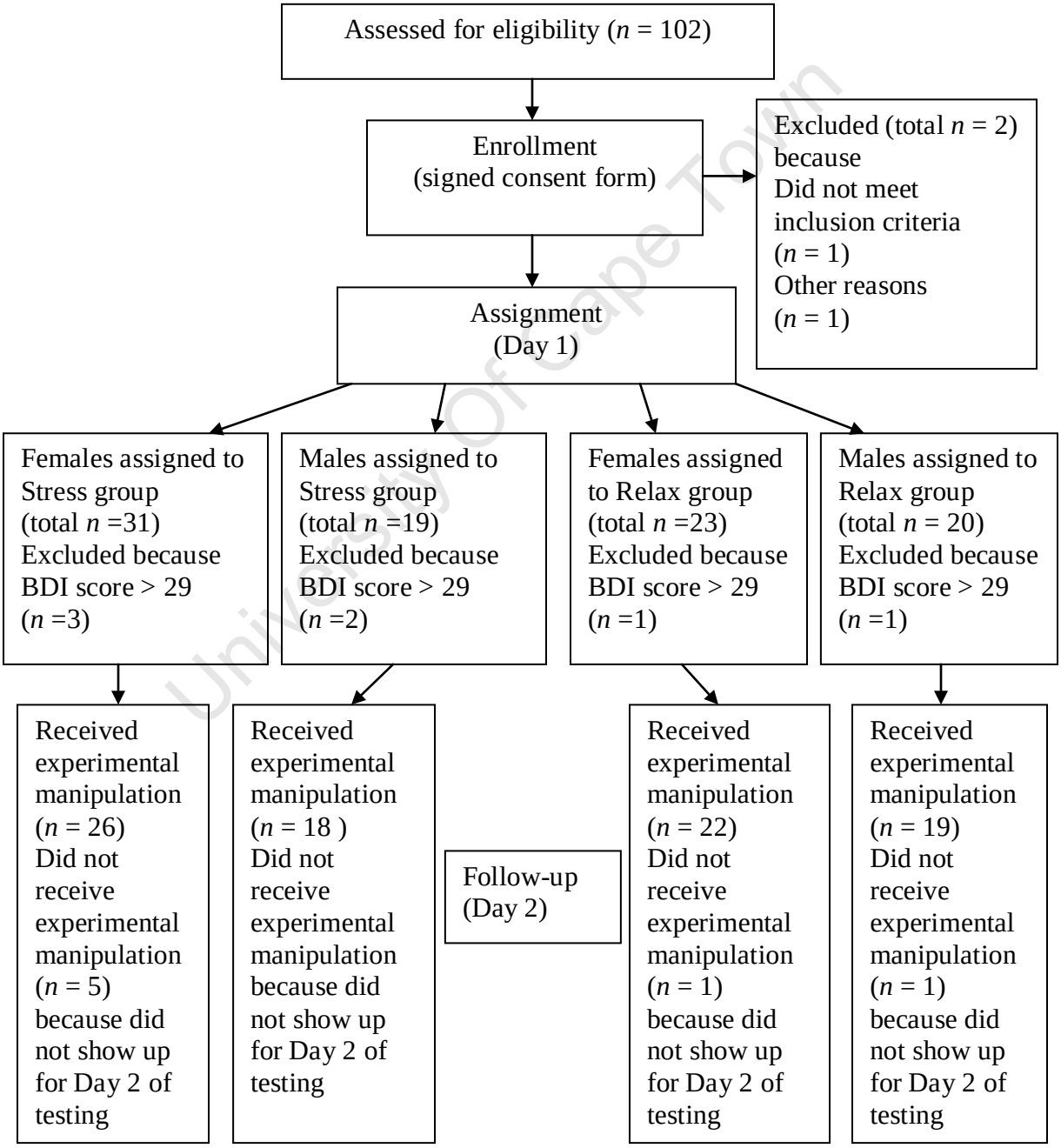


Figure 1. Distribution of female participants' menstrual cycle phases.
Note. Female participants not in the late luteal phase were all out by their specified number of days after the first day of their menstrual cycle. Three of these participants were in the Stress group and one was in the Relax group.

Participants were pseudorandomly assigned to either the Stress or Relax group to ensure equal numbers of males and females in each group. For instance, if a pair of male and female participants was assigned to the Stress group, the next pair was assigned to the Relax group. As shown in Figure 2, numerous participants were excluded from the study at varying stages of the experimental procedure. It is a common practice in studies investigating the effects of stress on memory to exclude participants who are cortisol non-responders (i.e., participants who do not show an increase in cortisol levels after a stress induction procedure; Buchanan & Tranel, 2008; Elzinga & Roelofs, 2005; Lupien et al., 1997). For example, Buchanan and Tranel (2008) started off with a stress group of fourty participants, but due to the exclusion of cortisol non-responders, ended up with a final sample of only six participants. Interestingly, out of the twenty female participants, only one was a cortisol responder, whereas out of the twenty male participants, five were cortisol responders. In the current study, it was also found that more females compared to males were cortisol non-responders (see Figure 2). Furthermore, in the Buchanan and Tranel (2008) study, cortisol responders showed a decrease in memory retrieval performance, whereas cortisol non-responders showed increased memory retrieval after the stressor. Supporting this is the study by Lupien et al. (1997), who divided participants into either cortisol responders or non-repsonder. Responders showed a lower declarative memory performance post-TSST compared to the non-responders. When investigating whether increased cortisol levels impair memory, participants who do not show an increase in cortisol after experiencing a stress manipulation should not be included in the final statistical analyses as any memory impairments they may or may not show cannot logically be attributed to an increase in cortisol. Therefore, in the current study, participants who had been assigned to the Stress group were excluded as non-responders if they did not show an increase in cortisol levels from baseline to post-stress induction. Participants who

were in the Relax group were excluded as non-responders if they did not show a decrease in cortisol levels from baseline to post-relaxation period.

After these exclusions, as well as exclusions for other reasons (see Figure 2), the final sample size was 57 participants: Stress group *n* = 28 (15 males and 13 females), and Relax group *n* = 29 (15 males and 14 females).



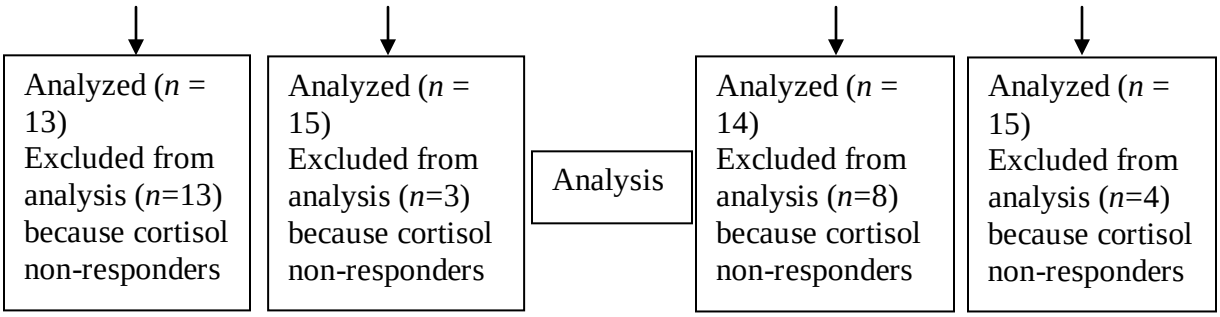


Figure 2. Participant flow chart.

Materials

Depression screening measure. The Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996) is a 21-item self-rated multiple-choice instrument that was developed to measure the intensity, severity, and depth of depression in patients' as well as the general community. Higher ratings indicate greater symptom severity and more intense depression. Each item consists of four statements that correspond to ratings from 0 to 3, with higher ratings indicating characteristics of more severe depression.

The BDI-II has been shown to be a reliable measure of depression in numerous studies and clinical settings (e.g., Beck, Steer, & Garbin, 1988; Ward, Flisher, Zissis, Muller, & Lombard, 2001). It possesses high internal consistency (alpha = 0.91) and shows a high 1-week test-retest reliability (Pearson r = 0.93), which suggests that it is not sensitive to daily variations in mood (Beck et al., 1988). This instrument also correlates positively with other depression measures, such as the Hamilton Depression Rating Scale (Pearson r = 0.71; Weeks & Heimberg, 2005).

Self-reported anxiety. The Spielberger State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) consists of two 20-item self-report scales, with each item having four possible answers. The 20-item State scale requires the respondent to describe the intensity of his/her feelings of anxiety at the current time. The 20-item Trait scale requires the respondent to describe the frequency with which he/she generally experiences anxiety-related symptoms. Psychometric studies indicate that the scale has a high degree of internal consistency (alpha = 0.92), as well as high test-retest reliability (Spielberger & Vagg, 1984). In addition, the STAI correlates positively with the Taylor Manifest Anxiety Scale and the IPAT Anxiety Scale, both of which are reliable measures of anxiety levels (Spielberger & Vagg, 1984).

In the current study, the Trait scale was used to assess participants' general anxiety levels, while the State scale was used to assess participants' subjective experiences of anxiety throughout the experiment.

Physiological measures. As in previous studies of this kind, heart rate and salivary cortisol measurements were taken as objective measures of stress levels (e.g., Bonito Attwood, 2008; Kirschbaum, Pirke, et al., 1993; Schwabe et al., 2007).

Saliva samples were collected using Sarstedt Salivette's (Sarstedt, Nümbrecht, Germany). Participants were instructed to chew a cellulose-cotton swab for 1 minute. After removal, the cotton swab was placed into a conical tube, immediately stored in the laboratory's freezer, and later transported to the National Health Laboratory at Groote Schuur Hospital for cortisol analyses.

Assessment of cortisol in saliva has proven a valid and reliable reflection of the unbound hormone in the blood (Kirschbaum & Hellhammer, 1994). Salivary cortisol measurements as an objective measure of stress have numerous advantages over blood cortisol measurements, including: stress-free sampling, lab independence, lower costs, non-invasive collection methods and the ability to obtain an unlimited frequency of measurements (Kirschbaum & Hellhammer, 1994). In addition, blood cortisol measurements are not always reliable measures of free cortisol levels (Kirschbaum et al., 1999).

Heart rate was measured using the Vreije Universiteit Ambulatory Monitoring System (VU-AMS; Vrije Universiteit, Amsterdam, Holland). Participants were attached to the device via electrodes, which were attached to their chest and torso. These electrodes were attached to a small box which stored the measurements on a memory card. This allows the benefit of mobility, as participants can walk around with the machine attached; allowing constant measurements to be obtained in various settings. Measurements were taken continually throughout the experimental procedure on Day 2 and stored as computer files for further analysis.

The acute social stressor: The trier social stress test (TSST). The Trier Social Stress Test (TSST) is a highly standardized and widely used laboratory test used to induce psychosocial stress (for a full description of the procedure, see Kirschbaum, Pirke, et al., 1993). Compared with other laboratory-based stress induction tasks, the TSST provokes the most reliable and robust physiological stress (Dickerson & Kemeny, 2004). Six independent

studies reported it producing a 2-4 fold elevation in salivary cortisol levels, with consistent increases in ACTH concentration and heart rate across different populations (Kirschbaum, Pirke, et al., 1993). Furthermore, a large number of studies have reported that laboratory tasks such as public speaking and mental arithmetic (both of which are included in the TSST) can increase cortisol levels reliably (Het & Wolf, 2007; Kuhlmann, Piel, & Wolf, 2005). Finally, a meta-analysis reviewing conditions capable of evoking increased cortisol responses found that motivated performance tasks elicited the largest cortisol and ACTH responses if they were uncontrollable or characterized by social evaluative threats (Dickerson & Kemeny, 2004). The TSST is a motivated performance task, is uncontrollable, and contains an element of social evaluation, which would explain why it is so good at eliciting a stress response.

In accordance with the original TSST procedure, participants in the Stress group were read a set of standard instructions designed to introduce them to the task of the TSST. Participants were then asked to assume the role of a job candidate for a job of their choice, and given 10 minutes to prepare a speech detailing their suitability for the position. They were then told that they would present their speech in front of an interview panel who, with the help of a video recording, would analyze their verbal and non-verbal behaviour. The interview panel consisted of one male and one female interviewee.

After a 10-minute speech preparation period, the participants were given 5 minutes to deliver their speech to the panel. If the participant stopped speaking before the 5 minute period was over, the panel would say, “You still have time left, please continue.” If the participant was still unable to continue delivering the speech, the following set of standard questions was asked: 1. “Please tell us what are some of your weaknesses”; 2. “What is the most difficult experience that you have had that would help you on the job?”; 3: “For what reasons should we not take you?”

After completion of the speech, the participants were asked by the panel to serially subtract the number 13 from 1022. Each incorrect subtraction required the participant to start again at 1022, and this mental arithmetic task lasted a full 5 minutes.

False memory task. The false memory task used in this study is an exact replication of one used by Gallo and colleagues (2004) in Experiment 1 of their study. Study materials consisted of 288 unrelated common words (average word length was 6.1 letters), presented in black font on a white background (see Appendix B). Each of those words (e.g., *house*) was

followed either by a picture (e.g., *a picture of a house*), or the same word printed slightly larger in a red font. Some of the black words were presented once (either followed by a corresponding picture or a red word), and others were presented twice (once followed by a picture, and once followed by a red word).

Study and test materials were presented on a standard desktop computer, the former via PowerPoint slides and the latter using E-Prime software (Version 1.1, Psychology Software Tools, Inc., Pittsburgh, PA, 2002). Participants studied 216 unique items, with ⅓ presented as red words, ⅓ as pictures, and ⅓ as both red words and pictures. Each studied item was first presented in black lowercase letters using Courier font (size 44 font) for 700 ms. The black word was then replaced by either a corresponding picture of that word, or by the same word in red-coloured Eros Bold ITC font (visibly larger than the Courier font, size 54 font) for 2000 ms. A 700 ms blank computer screen separated each picture or red word from the next study item. The study phase took 16.5 minutes to complete. Figure 3 illustrates the presentation of items during the study phase of the false memory test.

Figure 3. An example of items presented during the study phase of the false memory test.

After the study phase participants were given three recognition tests: a S*tandard Recognition Test*, followed by two *Criterial Recollection tests*. All words on the Standard Recognition Test and two Criterial Recollection tests were presented in the same black font used for the study items. Each test contained items that had been studied (as either red words or pictures or both) and non-studied items, with each test containing a total of 96 items.

For the Standard Recognition Test, participants were instructed to say "yes" to any item that had been studied (regardless of whether it had been presented as a red word, a picture, or both) and "no" to any item that was new (i.e., had not been studied). For this test, ¾ of the items were targets (i.e., items presented during the study phase) and ¼ non-targets (i.e., items not presented in the studied phase. Of the target items,⅓ were items originally studied as both pictures and red words (i.e., 24 items),⅓ were items originally studied as pictures only (i.e., 24 items), and⅓ were items originally studied as red words only (i.e., 24 items). Of t he non-target items, all 24 were items that were never originally studied.

The two criterial recollection tests were the *Red Word Test* and the *Picture Test*. For both of these tests, ½ the items were targets (items presented during the study phase) and ½ non-targets (items not presented during the study phase). For the Red Word Test, participants were required to say "yes" to any item they remembered studying as a red word. In addition, they were reminded that some red words were also studied as pictures (i.e., these were the items studied as both red words and pictures), which they could still respond "yes" to. For the target items, ½ were items originally studied as both pictures and red words (i.e., 24 items), and ½ were items originally studied as red words only (i.e., 24 items). For the non-target items, ½ were items originally studied as pictures only (i.e., 24 items), and ½ were items that were never studied during the study phase (i.e., 24 items). For the Picture Test, instructions were the same as for the Red Word Test, except participants were instructed to say "yes" only if items had been studied as pictures (this could include items studied as both pictures and red words). For the target items, ½ were items originally studied as both pictures and red words (i.e., 24 items), and ½ were items originally studied as pictures only (i.e., 24 items). For the non-target items, ½ were items originally studied as red words only (i.e., 24 items), and ½ were items that were never studied during the study phase (i.e., 24 items).

To prevent sequencing effects, four counterbalancing conditions were created. This ensured that every fourth subject received a different study and recognition test. Furthermore,

the two criterial recollection tests were counterbalanced across participants, resulting in total of eight counterbalancing conditions.

Procedure

Following conventions established by numerous studies (e.g., Kirschbaum, Wolf, et al., 1996), participants were tested between 16h00 and 20h00. Several studies have shown that time of day is a crucial factor when performing experiments featuring cortisol measurements. Evidence shows that HPA axis responses depend on the time of day, with larger cortisol responses in the afternoon and evening compared to the morning (Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004). HPA axis activity follows a circadian rhythm, with highest hormone levels in the early morning hours followed by continual decreases over the course of the day (Kirschbaum & Hellhammer, 1994). These high levels of cortisol in the morning result in smaller endocrine responses to pharmacological or environmental provocations.

The study procedures were completed over 2 days, with each participant tested individually. On the first day all participants were treated exactly the same, regardless of group assignment. On the second day of testing, participants were treated differently depending on group assignment. The Stress group underwent the TSST procedure, whereas the Relax group engaged in a 20-minute relaxation period.

Upon arrival in the laboratory on Day 1, participants were given a consent form (see Appendix C), which gave them a brief outline of the study requirements and listed their rights as research participants. After reading and signing the consent form, participants were instructed to fill out the BDI-II and the STAI-Trait. Following this, the false memory task (including the study phase, the recognition test, and the two criterial recollection tests) was administered. Participants were dismissed from the laboratory after a reminder to refrain from smoking, chewing gum, physical exercise, eating large meals, and drinking alcohol, fizzy drinks, tea or coffee 2 hours prior to their appointment on Day 2. These factors may cause fluctuations in baseline cortisol levels (Kirschbaum, Pirke, et al., 1993), which need to be kept

constant prior to experimentation. Table 1 presents a timeline for the Day 1 experimental events.

Table 1

Timeline of Experimental Events on Day 1

Time (minutes) from start of experiment	Event
0.00	Read and sign consent form
5.00	Complete BDI and STAI Trait Anxiety scales
15.00	Study phase of False Memory Test
32.00	1 x Recognition Test and 2 x Criterial Recollection Tests
47.00	Reminder about Day 2 appointment and what to refrain from doing 2 hours before that appointment
50.00	Dismissed from laboratory

On Day 2, participants were again tested between 16h00 and 20h00, exactly 24 hours after their Day 1 testing in the same laboratory. Upon arrival, they were asked to complete a STAI State questionnaire and a saliva sample was taken. Participants were then attached to the

VU-AMS device, after which a 5-minute normalization and 2-minute baseline reading were taken. Participants in the Stress group were then administered the TSST. Participants in the Relax group were not administered any part of the TSST procedure. Instead, they relaxed in a room for 20 minutes, seated in a comfortable chair and given non-political magazines (*Femina* and *Men's Health*) to read while listening to relaxing music (*Enya*). The TSST induction and relaxation period occurred in a different room to the testing laboratory.

Following the 20-minute TSST and relaxation periods, participants in both groups returned to the laboratory, where they were instructed to relax for 5 minutes, after which a second saliva sample was taken. Participants were then instructed to complete the STAI State scale again. Following this, the false memory tests were administered in the same order as they were administered on Day 1 of testing, with participants completing the same recognition test and the two criterial recollection tests they did on the previous day.

After testing was complete, participants underwent a second short relaxation period of 5 minutes, after which the VU-AMS device was removed. A third saliva sample was taken and participants completed their third and final STAI State questionnaire. All participants were then fully debriefed as to the purpose of the study; those in the Stress group had the TSST explained to them. All participants were asked not to discuss any aspect of the study with anyone else so as not to confound the results. Female participants were asked to contact the experimenter on the first day of their next period. Table 2 presents a timeline for Day 2 experimental events.

Table 2

Timeline of Experimental Events on Day 2

Time (minutes) from start of experiment	Event: Relax Group	Event: Stress Group
0.00	First STAI State completion and saliva sample taken	First STAI State completion and saliva sample taken
5.00	Heart Rate machine attached; 5minute normalization period; 2 minute baseline reading	Heart Rate machine attached; 5minute normalization period; 2 minute baseline reading
15.00	Relaxation period instructions	TSST instructions
17.00	Relaxation	TSST: 10 minute speech preparation
27.00	Relaxation	TSST: 5 minute speech, 5 minute mental arithmetic
37.00	Begin short relaxation period	Begin short relaxation period
42.00	Second STAI State completion and saliva sample taken	Second STAI State completion and saliva sample taken
45.00	1 x Recognition Test and 2 x Criterial Recollection Tests	1 x Recognition Test and 2 x Criterial Recollection Tests

60.00	Begin short relaxation period	Begin short relaxation period
65.00	Heart Rate machine removed	Heart Rate machine removed
70.00	Third STAI State completion and saliva sample taken	Third STAI State completion and saliva sample taken
75.00	Debriefing	Debriefing

Statistical Analysis

Saliva samples were stored in a freezer within 30 minutes after collection. They remained there for the duration of data collection, after which they were delivered to the National Health Laboratory Services at Groote Schuur Hospital for analyses. Salivary cortisol levels, STAI State scores, and heart rate measurements were used in the analysis as measures of stress to check whether the stress manipulation and relaxation period were effective in, respectively, increasing and decreasing participants' stress levels.

The E-Prime software used for the false memory recognition tests generated a unique data file for each participant after each recognition test. The data file included whether the participant's response to each item on the recognition test was correct (a true memory) or incorrect (a false memory). These outcome variables were used in the analysis of recognition test performance on both Day 1 and 2 of testing.

As noted earlier, on the Standard Recognition test and each Criterial Recollection test, ¼ of the items were originally studied as both red words and pictures, ¼ were items originally studied as pictures only, ¼ were items originally studied as red word only, and ¼ were items that had never been studied. Within the Standard Recognition test and each Criterial Recollection test, each item type occurred 24 times; therefore scoring of each item type was done by counting the number of correct responses and dividing these scores by the total number of each item type (i.e., 24). Scores were therefore given as a proportion, with a score of zero indicating that nothing was correctly remembered, and a score of one indicating that all items were correctly remembered.

Four groups were used in the analyses (namely the Female Stress, Male Stress, Female Relax, and Male Relax groups). In addition, analyses looked at the Stress and Relax groups irrespective of biological sex to determine whether stress induction or lack thereof had an

effect on the dependent variables. Certain analyses also looked at male and female participants irrespective of their group assignment to determine whether sex alone had an effect on the dependent variables. Both between-group and within-group differences were investigated.

All statistical analyses were performed using the software package Statistica (Version 8, StatSoft, Inc., Tulsa, OK, 2004). If assumptions for the statistical analyses were violated they were stated in the results section, otherwise all assumptions were upheld. The threshold for statistical significance used for all subsequent tests was set at $\alpha = 0.05$. All analyses used experimental condition (Stress versus Relax) and sex (Male versus Female) as the independent variables, and priori planned comparisons were used to check certain hypotheses.

Results

Depression Screening

To establish that there were no between-group differences with regard to depressive symptomatology, a 2 x 2 factorial ANOVA was used to compare participants' BDI-II scores. Experimental condition (Stress versus Relax) and sex (male versus female) were used as the two independent variables.

The ANOVA revealed a statistically significant main effect main effect of sex, $F(1, 53) = 3.65$, $p = .061$, $\eta^2 = .06$, in the absence of a statistically significant main effect of experimental condition, $F(1, 53) = 1.38$, $p = .245$, or Sex x Experimental Condition interaction, $F(1, 53) < 0.01$, $p = .991$. These results suggest that scores for participants in the Stress ($M = 10.82$, $SD = 6.77$) and Relax group ($M = 12.93$, $SD = 6.56$) did not differ significantly, whereas scores for female participants ($M = 13.67$, $SD = 6.84$) were statistically significantly higher than male participants ($M = 10.30$, $SD = 6.23$). Studies show that females are more likely to develop depressive disorders (Weissman et al., 1996); therefore it is not surprising that female participants had a higher average BDI score compared to males. However, while studies have reported that patients suffering from major depressive disorder and depression in general, show elevated cortisol levels (Kudielka & Kirschbaum, 2005; Sapolsky et al., 1986), female participants in the current study fall in the range conventionally described as "minimally depressed" (a score between 0-13.99) (Beck et al., 1996), therefore cortisol increases, and subsequent memory performance should not be altered by female

participants being more depressed than other groups.. The mean scores for the other groups also fell in the range conventionally described as "minimally depressed" (a score between 0-13.99) (Beck et al., 1996). With regard to mood, then, it appears that participants were representative of the general population.

Measures of Stress

All analyses for the measures of stress were two-tailed, unless otherwise specified.

Table 3

Measures of Stress in all Groups

	STRESS *n* = 28		RELAX *n* = 29	
	Female *n* = 13	Male *n* = 15	Female *n* = 14	Male *n* = 15
STAI Trait	38.38 (9.02)	36.53 (6.99)	46.00 (10.76)	41.07 (9.12)
STAI State – baseline	35.69 (7.09)	34.40 (7.76)	38.21 (8.61)	34.80 (10.48)
STAI State – post-manipulation	48.62 (10.85)	42.33 (11.64)	31.79 (7.53)	28.80 (6.20)
STAI State – end	33.23 (7.18)	29.60 (7.70)	31.79 (8.50)	29.67 (6.06)
Heart Rate – baseline	81.26 (4.71)[a]	71.23 (12.57)[b]	78.91 (10.48)[c]	77.23 (17.16)[d]
Heart Rate – post-manipulation	118.44 (13.24)[a]	95.78 (15.95)[b]	72.59 (9.46)[c]	69.52 (13.07)[d]
Heart Rate – end	78.69 (7.32)[a]	71.23 (9.63)[b]	73.46 (8.15)[c]	69.18 (11.38)[d]
Cortisol – baseline	3.34 (1.23)	1.85 (1.82)	1.21 (1.27)	1.95 (2.60)
Cortisol – post-manipulation	4.99 (2.82)	7.86 (4.66)	0.99 (1.23)	1.27 (1.86)
Cortisol – end	1.37 (0.87)	3.30 (2.70)	0.80 (0.91)	0.83 (0.78)

Note. Means are presented with standard deviations in parentheses. [a]Data based on 7 participants. [b]Data based on 12 participants. [c]Data based on 8 participants. [d]Data based on 12 participants.

Table 4

Measures of Stress in the Stress and Relax Group (irrespective of sex)

	GROUP	
	Stress	Relax
	n = 28	*n* = 29
STAI Trait	37.39 (7.90)	43.45 (10.08)
STAI State – baseline	35.00 (7.35)	36.45 (9.61)
STAI State – post-manipulation	45.25 (11.52)	30.24 (6.92)
STAI State – end	31.29 (7.55)	30.69 (7.28)
Heart Rate – baseline	74.92 (11.34)[a]	77.90 (14.55)[b]
Heart Rate – post-manipulation	104.13 (18.44)[a]	70.75 (11.59)[b]
Heart Rate – end	73.97 (9.39)[a]	70.89 (10.21)[b]
Cortisol – baseline	1.62 (1.57)	1.59 (2.07)
Cortisol – post-manipulation	6.53 (4.11)	1.13 (1.57)
Cortisol – end	2.40 (2.25)	0.82 (0.83)

Note. Means are presented with standard deviations in parentheses. [a]Data based on 19 participants. [b]Data based on 20 participants

Trait anxiety. Tables 3 and 4 present participants' self-reported trait anxiety scores. To establish that there was no between group differences with regard to general anxiety levels, a 2 x 2 factorial ANOVA was used to compare participants STAI Trait scores. Experimental condition (Stress versus Relax) and sex (male versus female) were used as the two independent variables.

There was a statistically significant main effect of experimental condition, $F(1, 53) = 6.41$, $p = .014$, $\eta^2 = .11$, in the absence of a statistically significant main effect of sex, $F(1, 53) = 1.99$, $p = .163$ or Sex x Experimental Condition interaction, $F(1, 53) = 0.41$, $p = .523$. These results suggest that STAI Trait scores for male ($M = 38.80$, $SD = 8.31$) and female ($M = 42.33$, $SD = 10.51$) participants did not differ significantly; on the other hand, scores for participants in the Relax group were statistically significantly higher than those of participants in the Stress group.

To ensure that participants in the current sample were representative of the general population in terms of trait anxiety, their scores were compared to normative data for college students presented in the STAI test manual (Spielberg et al., 1983). Male participants ($n = 30$; $M = 38.80$, $SD = 8.31$) were not significantly different from the normative male population ($M = 38.30$, $SD = 9.18$), $t(29) = .33$, $p = .744$. Female participants ($n = 27$; $M = 42.33$, $SD = 10.51$) were also not significantly different from the normative female population ($M = 40.40$, $SD = 10.15$), $t(26) = .96$, $p = .348$. These results suggest that, with respect to trait anxiety, the current sample was representative of the general population of individuals of similar age and education.

State anxiety. To ensure the effectiveness of the TSST stress induction and relaxation procedure; and to check that participants entered the experimental protocol with the same general level of anxiety and did not leave the experiment at a higher level of anxiety than when they arrived, a repeated-measures factorial ANOVA was used to compare participants' STAI State scores at the beginning of the experimental protocol (i.e., baseline measurement), post TSST/relaxation period, and at the end of the experimental protocol.

The analysis showed there was a statistically significant main effect of time, $F(2, 106) = 23.16$, $p < .001$, $\eta^2 = .30$, and a statistically significant Experimental Condition x Time interaction, $F(2, 106) = 38.99$, $p < .001$, $\eta^2 = .42$, in the absence of a Sex x Time interaction, $F(2, 106) = 0.68$, $p = .509$, or a Sex x Experimental Condition x Time interaction, $F(2, 106) = 0.91$, $p = .407$.

Planned Comparisons revealed the following: With regard to self-reported state anxiety at the beginning of the experimental protocol (i.e., before the stress manipulation or relaxation period), male ($n = 30$; $M = 34.60$, $SD = 9.06$) and female ($n = 27$; $M = 37.00$, $SD = 7.87$) participants ($p = .320$), as well as participants in the Stress and Relax groups, were not

statistically significantly different (p = .309 and .526, respectively). These results confirm that participants entered the experiment in the same general state of mind.

As shown in Figure 4, participants in the Stress group showed a significant increase in self-reported state anxiety in response to the TSST stress induction procedure (p < .001; one-tailed), whereas participants in the Relax group showed a significant decrease in state anxiety score in response to the relaxation period (p < .001; one-tailed). Furthermore, state anxiety scores post-TSST differed significantly between the Stress and Relax groups (p < .001; one-tailed), with the Stress group having a higher score compared to the relax group (see Table 4). See Appendix D for the magnitude of STAI responses within the Stress group.

From an ethical standpoint, it was important to know whether participants departed the laboratory in approximately the same state of mind as when they arrived; therefore, state anxiety levels at the beginning of the experimental procedure were compared to state anxiety levels at the end of the experimental procedure. Participants in the Stress group showed a statistically significant decrease in state anxiety score between the beginning and end of the experiment (p = .017), as did participants in the Relax group (p < .001). These results suggest that these participants left the experiment with a lower level of anxiety than when they entered. Furthermore, state anxiety levels at the end of the experimental protocol were not statistically significantly different between the Stress and Relax group (p = .727).

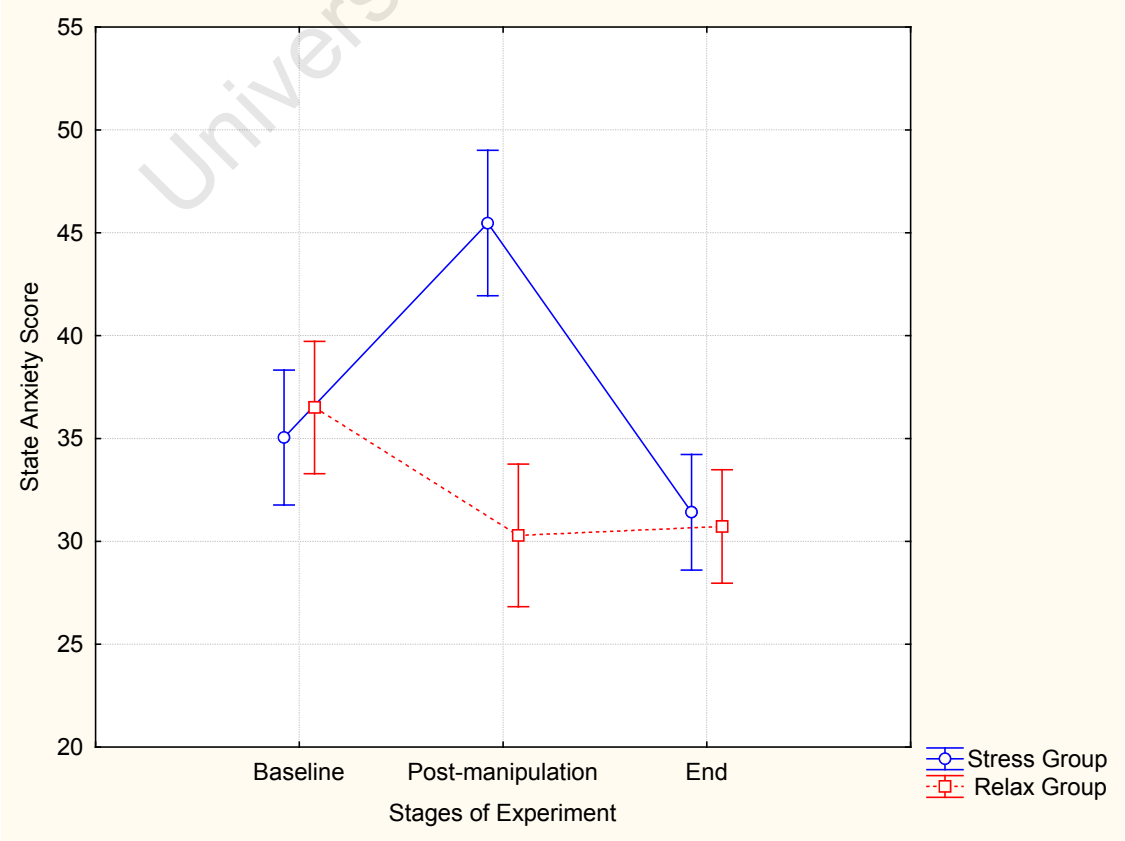


Figure 4. Stress and Relax groups' self-reported state anxiety during the experiment. Vertical bars denote 0.95 confidence intervals.

Cortisol levels. To ensure the TSST and relaxation procedures were effective in increasing and decreasing participant's cortisol levels respectively; and to check that participants did not leave the experiment at a higher level of stress than when they arrived, a repeated-measures factorial ANOVA was used to compare participants' salivary cortisol levels at the beginning of the experimental protocol (i.e., baseline measurement), post TSST/relaxation period, and at the end of the experimental protocol. The assumption of normality was violated; therefore a log transformation was performed on the cortisol data. Subsequent analyses were performed on the transformed data. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 8.48$, $p = .014$. Therefore, degrees of freedom were adjusted using Greenhouse-Geisser estimates of sphericity, $\epsilon = 0.87$.

The analysis detected a statistically significant main effect of time, $F(1.74, 92.14) = 32.18$, $p < .001$, $\eta^2 = .38$, and a statistically significant Experimental Condition x Time interaction, $F(1.74, 92.14) = 52.66$, $p < .001$, $\eta^2 = .50$, in the absence of statistically significant Sex x Time and Sex x Experimental Condition x Time interactions, $F(1.74, 92.14) = 0.66$, $p = .499$ and $F(1.74, 92.14) = 1.33$, $p = .267$, respectively.

Planned comparisons revealed the following: With regard to cortisol levels at the beginning of the experimental protocol (i.e., before the stress manipulation or relaxation period), participants in the Stress and Relax groups were not statistically significantly different ($p = .633$) (see Table 4), nor were male ($n = 30$; $M = 1.90$, $SD = 2.21$) and female ($n = 27$; $M = 1.27$, $SD = 1.23$) participants ($p = .440$). These results confirm that participants entered the experiment with same general salivary cortisol levels.

As shown in Figure 5 and in Table 4, participants in the Stress group showed a statistically significant increase in cortisol levels in response to the TSST stress induction procedure ($p < .001$; one-tailed), whereas participants in the Relax group showed a statistically

significant decrease in cortisol levels in response to the relaxation period (p = .014; one-tailed). Furthermore, cortisol measurements post-TSST were statistically significantly different between the stress and relax group (p < .001; one-tailed), with the Stress group having a higher cortisol level compared to the Relax group.

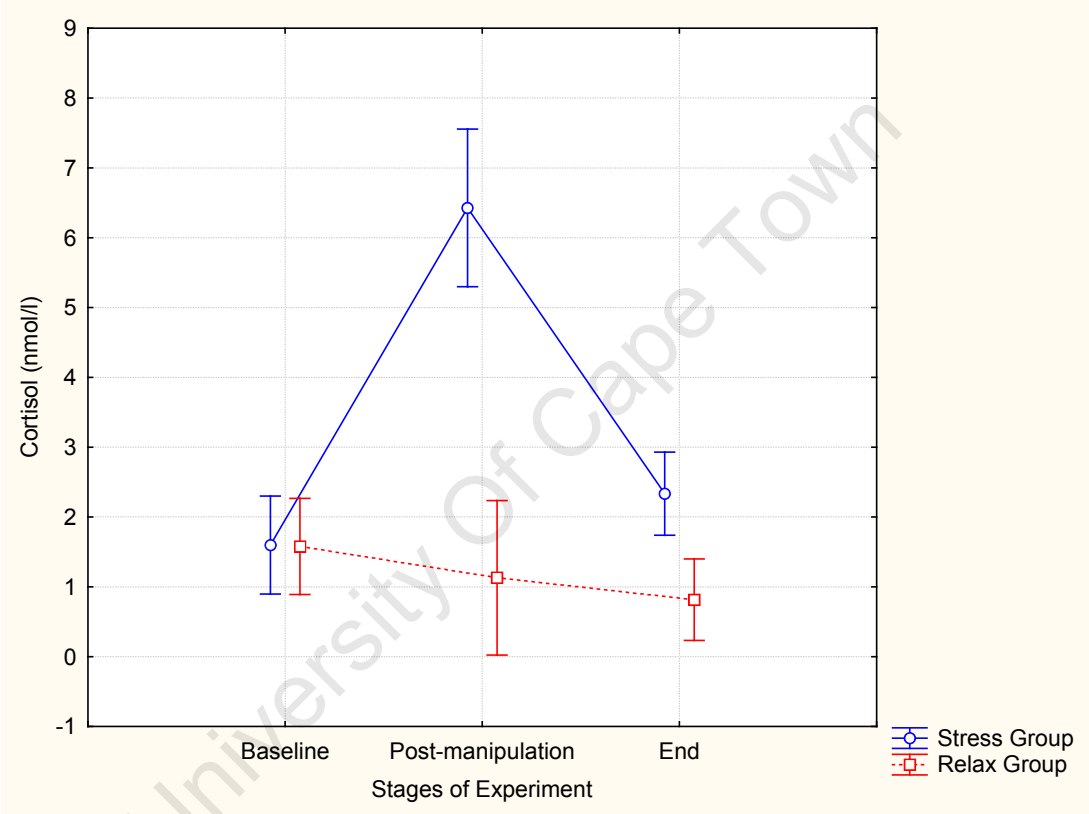


Figure 5. Stress and Relax groups' cortisol levels during the experiment. Vertical bars denote 0.95 confidence intervals.

As shown in Figure 6 and in Table 3, both male and female participants in the Stress group showed statistically significant increases in cortisol levels in response to the TSST (p < .001 in both cases; one-tailed). Male participants in the Relax group showed a statistically significant decrease in cortisol levels in response to the relaxation period (p = .029; one-tailed), whereas female participants showed no statistically significant decrease in cortisol

levels (p = .106; one-tailed). However, female participants in the Relax group did still show a decrease in cortisol levels in response to the relaxation period (see Table 3 and Figure 6).

From an ethical standpoint, it was important to know whether participants departed the laboratory at approximately the same or a lower cortisol level as when they arrived; therefore cortisol levels at the beginning of the experimental procedure were compared to those at the end of the experimental procedure. Participants in both the Stress and Relax groups showed statistically significant decreases in cortisol levels between the beginning and end of the experiment (p = .008 and .011, respectively; see Figure 5). Cortisol levels at the end of the experimental protocol were statistically significantly different between the Stress and Relax group (p < .001), with participants in the Stress group showing a higher mean cortisol level (see Table 4). However, participants in the Stress group had a higher basal cortisol level compared to the Relax group, and their higher end cortisol levels could merely be an effect of the stress induction procedure.

Many studies report that men have larger cortisol increases in response to a stressor compared to females (Kirschbaum et al., 1999; Kirschbaum & Hellhammer, 1992; Kirschbaum, Wüst, et al., 1993), as was predicted in the current study. This prediction was confirmed as there was a statistically significant difference between the magnitude of male and females cortisol responses to the TSST (t(26) = 1.84, p = .038, d= .71; one-tailed), with males showing a larger increase compared to females (see Figure 6).

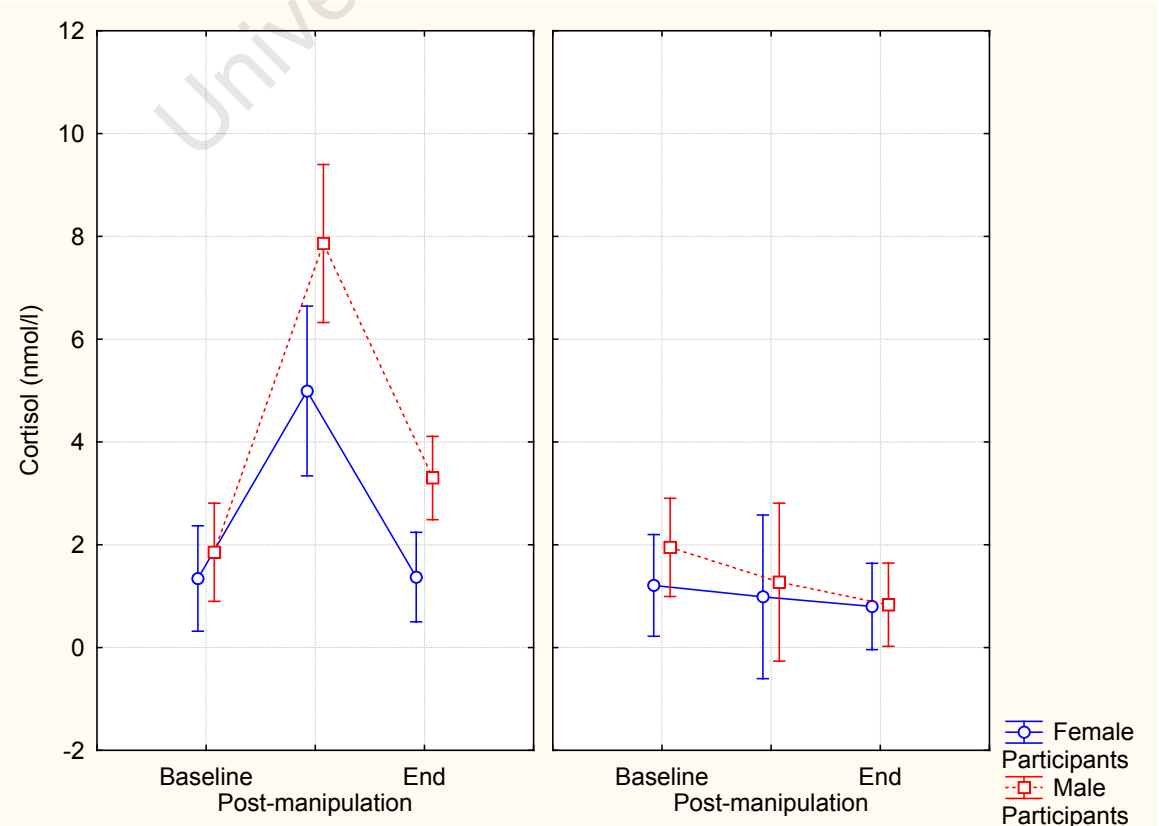


Figure 6. All groups cortisol levels during the experiment. Vertical bars denote 0.95 confidence intervals.

Heart rate levels. No heart rate data were obtained for 18 participants (6 females and 3 males in the Stress group; 6 females and 3 males in the Relax group) due to hardware malfunctions. These participants were therefore omitted from the analyses reported in this section; data for the remaining participants are presented in Table's 3 and 4.

To ensure the TSST and relaxation procedures were effective in increasing and decreasing participant's heart rate levels respectively; and to check that participants entered the experimental protocol with the same heart rate level and did not leave the experiment with a higher heart rate level than when they arrived, a repeated-measures factorial ANOVA was used to compare participants' heart rate levels at the beginning of the experimental protocol (i.e., baseline measurement), post TSST/relaxation period, and at the end of the experimental protocol. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 10.13$, $p = .006$. Therefore, degrees of freedom were adjusted using Greenhouse-Geisser estimates of sphericity, $\epsilon = 0.80$.

The analysis detected the following statistically significant effects: main effect of time, $F(1.59, 55.66) = 64.14$, $p < .001$, $\eta^2 = .65$, Experimental Condition x Time interaction, $F(1.59, 55.66) = 97.79$, $p < .001$, $\eta^2 = .74$, Sex x Time interaction, $F(1.59, 55.66) = 3.81$, $p = .037$, $\eta^2 = .10$, and Sex x Experimental Condition x Time interaction, $F(1.59, 55.66) = 4.11$, $p = .030$, $\eta^2 = .10$.

Planned comparisons revealed the following: With regard to heart rate levels at the beginning of the experimental protocol (i.e., before the stress manipulation or relaxation period), participants in the Stress and Relax groups were not statistically significantly different ($p = .671$), nor were male ($n = 24$; $M = 74.23$, $SD = 15.03$) and female ($n = 15$; $M = 80.01$, SD

= 8.12) participants (p = .179). These results confirm that participants entered the experiment with the same general heart rate levels.

As shown in Table 4 and Figure 7, participants in the Stress group showed a statistically significant increase in heart rate levels in response to the TSST stress induction procedure (p < .001; one-tailed), whereas participants in the Relax group showed a statistically significant decrease in heart rate levels in response to the relaxation period (p = .002; one-tailed). Furthermore, heart rate levels post-TSST differed significantly between the Stress and Relax group (p < .001; one-tailed), with the Stress group having a higher heart rate level compared to the Relax group. See Appendix E for the magnitude of heart rate responses within the Stress group.

From an ethical standpoint, it was important to know whether participants departed the laboratory at approximately the same or a lower heart rate level compared to when they arrived; therefore heart rate levels at the beginning of the experimental procedure were compared to heart rate levels at the end of the experimental procedure. As shown in Table 4 and Figure 7, participants in the Stress group showed no statistically significant difference in heart rate levels between the beginning and end of the experiment (p = .396), indicating that participants departed the laboratory with the same heart rate level as when they arrived. Participants in the Relax group showed a statistically significant decrease in heart rate levels between the beginning and end of the experiment (p < .001), indicating that participants departed the laboratory with a lower heart rate level than when they entered. Furthermore, heart rate levels at the end of the experimental protocol were not statistically significantly different between the Stress and Relax group (p = .259).

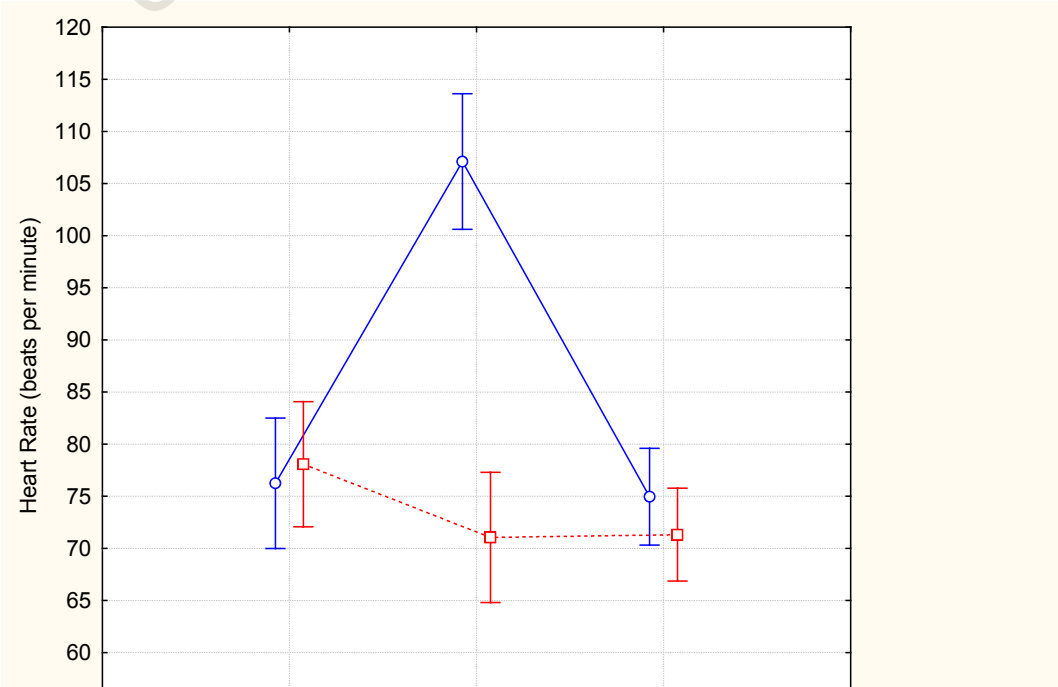


Figure 7. Stress and Relax groups' heart rate levels during the experiment. Vertical bars denote 0.95 confidence intervals.

Standard Recognition and Criterial Recollection Tests

Abbreviated terms are used when describing items on the tests (e.g., for items presented as both red words and pictures during the study phase, the abbreviated term *Both Hits* was used); a full explanation of each term is given in the Glossary.

Before hypotheses for the current study were tested, analyses were run on data from Day 1 of testing to establish whether the current data replicated Gallo et al.'s (2004) work.

Analyses: Day 1 memory performance. For these initial analyses, participants were not split into groups as all were treated identically on Day 1. Participants' combined scores for each of the three recognition tests (the Standard Test as well as the two Criterial Recollection Tests) are presented in Table 5.

The analyses of the Day 1 data were conducted to see whether the current data (a) replicated those reported by Gallo et al. (2004), and (b) confirmed predictions made by those authors. Therefore, individual dependent-samples *t*-tests were done so as to replicate the analyses conducted in that previous paper. Furthermore, all analyses were one-tailed as they all tested directional hypotheses.

Table 5

Combined Scores for all Participants Recognition of Each Item Type as a Function of Test Type on Day 1

	n = 57
Standard Test	
Both Hits	0.87 (0.10)
Red Word Hits	0.59 (0.15)
Picture Hits	0.73 (0.13)
New FAs	0.09 (0.12)
Picture Test	
Both Hits	0.76 (0.13)
Red Word FAs	0.13 (0.10)
Picture Hits	0.72 (0.14)
New FAs	0.07 (0.09)
Red Word Test	
Both Hits	0.58 (0.16)
Red Word Hits	0.64 (0.20)
Picture FAs	0.37 (0.20)
New FAs	0.35 (0.34)

Note. Means are presented with standard deviations in parentheses. Refer to Glossary for a full explanation of each term.

The first set of Day 1 analyses, conducted on data from the Standard Recognition Test, investigated whether items studied as *both* pictures and red words were recognized better than items studied as *either* pictures or red words. Therefore, three separate dependent-samples *t*-tests were conducted on the data from the Standard Recognition Test. As shown in Figure 8, the number of hits (correct responses) for items studied as both pictures and red words (i.e., Both Hits) was statistically significantly greater than the number of hits for (a) items studied only as pictures (i.e., Picture Hits), $t(56) = 9.88$, $p < .001$, $r = .52$, and for (b) items presented only as red words (i.e., Red Word Hits), $t(56) = 17.24$, $p < .001$, $r = .74$. This result is consistent with predictions made by Gallo and colleagues (2004): They stated that items studied as both pictures and red words should be better remembered than items presented as either red words or pictures due to the fact that the former were the only items presented twice during the study phase, and should therefore be more familiar. The result replicates data reported by Gallo et al. (2004).

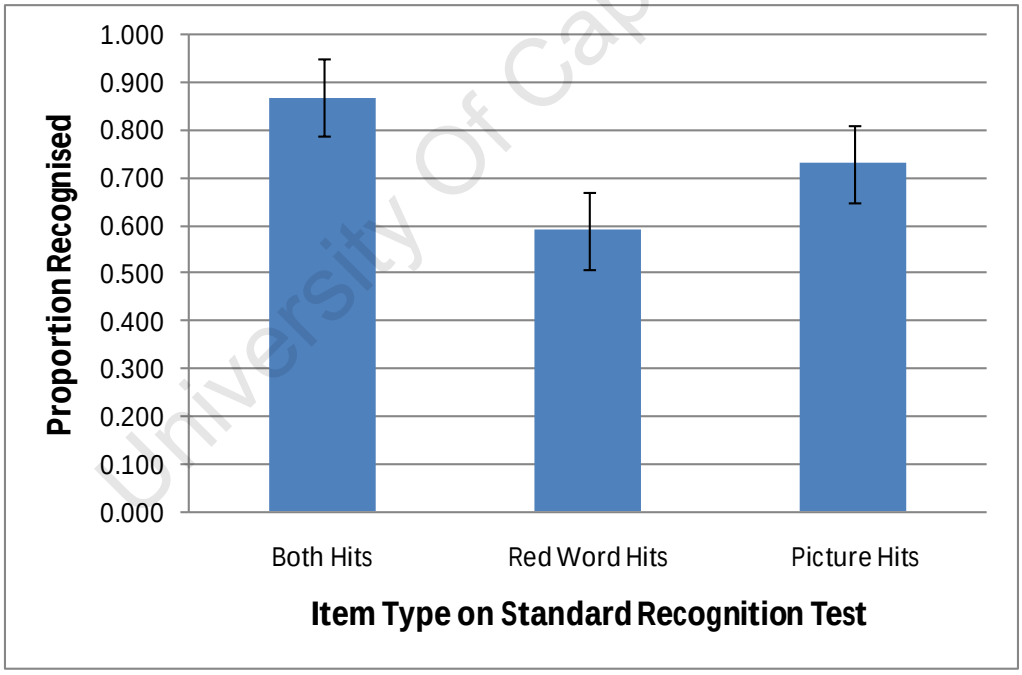


Figure 8. Comparison of correct responses for Day 1 on the standard recognition test. Vertical bars denote standard error of the means.

The second set of Day 1 analyses, conducted on data from the Criterial Recollection tests, sought to confirm that items studied twice (i.e., as both pictures and as red words) were

recognized better throughout the Day 1 recognition tests. Therefore, separate dependent-samples *t*-tests were conducted on data from the Picture Test and from the Red Word Test. On the Picture Test, the number of hits for items presented as both pictures and words was statistically significantly greater than the number of hits for items presented as pictures only, $t(56) = -2.60$, $p = .006$, $r = .15$ (see Figure 9). This result is consistent with Gallo et al.'s (2004) predictions, which state that items presented as both pictures and words are more likely to be familiar than items presented as pictures only due to the fact that they were presented twice during the study phase. The data also replicate those obtained by Gallo et al. (2004).

On the Red Word Test, however, the number of hits for items presented as both pictures and words was not statistically significantly different from the number of hits for items presented as words only, $t(56) = -1.42$, $p = .080$, $r = .16$ (see Figure 10). This result, obviously, is not consistent with Gallo et al.'s (2004) predictions (as stated above), and does not replicate data presented in that study. However, the effect size was almost identical to that found on the Picture Test; therefore increasing the sample size should allow the replication of Gallo's results for the Red Word Test.

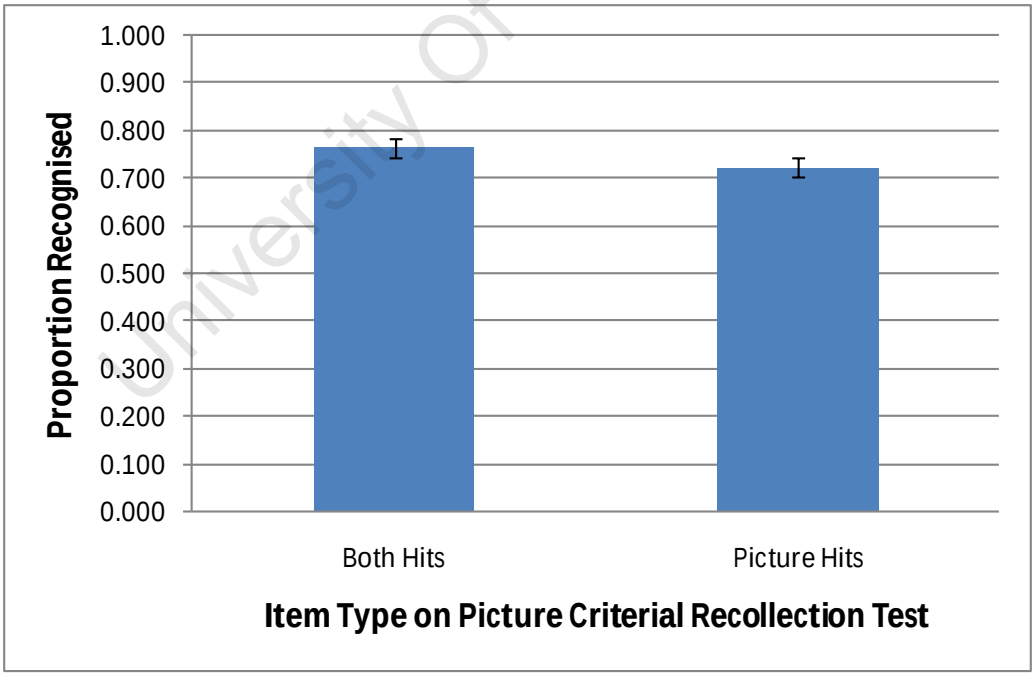


Figure 9. Comparison of correct responses for Day 1 on the picture criterial recollection test. Vertical bars denote standard error of the means.

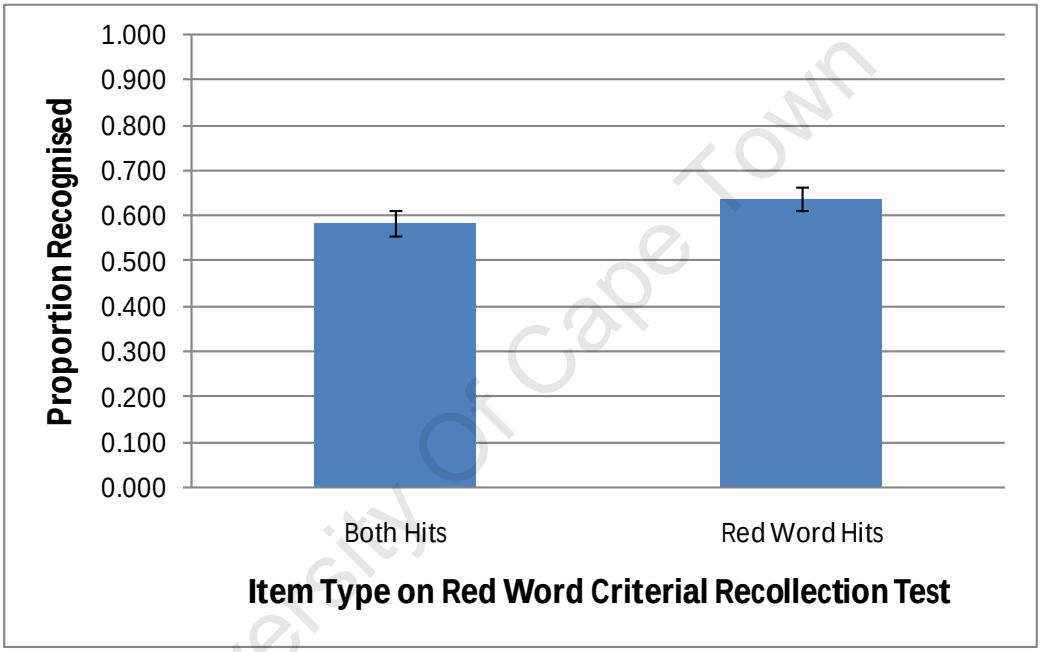


Figure 10. Comparison of correct responses for Day 1 on the red word criterial recollection test. Vertical bars denote standard error of the means.

The third set of Day 1 analyses, conducted on data from both the Standard Recognition test and the Criterial Recollection tests, investigated whether picture superiority effect predictions, derived from distinctiveness heuristic theories, were confirmed by the current data. More specifically, data from the Standard Recognition test were analyzed to examine whether items studied as pictures only were recognized better than items studied as red words only. As predicted by Gallo and colleagues, and again consistent with the data they reported, the current data showed a picture superiority effect: The number of Picture Hits achieved by

participants on the Standard Recognition test was statistically significantly greater than the number of Red Word Hits achieved on that test, $t(56) = 7.42$, $p < .001$, $r = .45$.

Next, data from the Criterial Recollection tests were analyzed to compare the number of Picture Hits on the Picture test against the number of Red Word Hits on the Red Word test. The number of hits for items studied as pictures on the Picture test was statistically significantly greater than the number of hits for items studied as red words on the Red Word test, $t(56) = 2.89$, $p = .003$, $r = .23$. Once again, then, the picture superiority effect was obtained, and Gallo et al.'s (2004) results in this respect were replicated.

In summary, then, this third set of analyses confirmed predictions derived from distinctiveness heuristic theories: pictures are more likely to be remembered than words, due to their more distinctive perceptual qualities.

The fourth set of Day 1 analyses, conducted on data from the Criterial Recollection tests, sought to investigate the occurrence of false memory errors by participants during the Day 1 procedures. Therefore, two separate sets of dependent-samples *t*-tests were conducted to compare the average number of different sources of false alarms (FAs) in the Red Word Test and in the Picture Test. On the Red Word Test, Picture FAs can be classified as a false memory because participants are incorrectly identifying an item originally presented as a picture during the study phase as having been presented as a red word. Similarly, on the Picture Test, Red Word FAs can be classified as a false memory because participants are incorrectly identifying an item originally presented as a red word during the study phase as having been presented as a picture.

Following distinctiveness heuristic predictions, pictures should be less likely to be falsely remembered than words due to their more distinctive perceptual qualities which make them more familiar and therefore more likely to be recognised. Therefore Picture FAs on the Red Word Test were compared against Red Word FAs on the Picture Test to explore the above mentioned prediction. The number of Red Word FAs on the Picture Test was statistically significantly lower than the number of Picture FAs on the Red Word test, $t(56) = -9.73$, $p < .001$, $r = .60$. This result, although consistent with Gallo et al.'s data, contradicts the picture superiority effect, which states that pictures are less likely to be falsely remembered than words.

Consistent with Gallo et al.'s (2004) work and a prediction deriving from the picture superiority effect, on the Picture Test the number of New FAs was statistically significantly lower than that on the Red Word test, $t(56) = -6.37$, $p < .001$, $r = .49$. The smaller amount of false alarms on the Picture Test suggests that studying and recalling pictorial materials, which are more distinctive than words, leads to fewer false memory errors.

Based on predictions made by Gallo et al.'s (2004) work: New FAs are false alarms for items that were not presented to participants during the study phase; they should therefore have been less familiar to the participants and thus less likely to be falsely remembered compared to previously presented items. Firstly, to investigate this, New FAs were compared to Picture FAs on the Red Word Test. The analysis revealed that the number of Picture FAs was not statistically significantly different from the number of New FAs, $t(56) = .56$, $p = .287$, $r = .04$. This result does not confirm predictions made on the basis of Gallo et al.'s (2004) work. The second analysis compared New FAs to Red Word FAs on the Picture Test. The analysis revealed that the number of Red Word FAs was statistically significantly greater than the number of New FAs, $t(56) = 4.49$, $p < .001$, $r = .30$. This result does confirm predictions made on the basis of Gallo et al.'s (2004) work, whereby New FAs are less likely to occur since these items were never originally studied, and are therefore less familiar and thus less likely to be falsely remembered.

In summary, the first set of Day 1 analyses confirmed that items presented twice during the study phase (i.e., as both red words and pictures) were more likely to be remembered than items presented as pictures or red words only. This result was expected, as items presented twice should be more familiar, and therefore more likely to be remembered. The second set of Day 1 analyses confirmed this effect on the Picture Test, however not on the Red Word Test. The third set of Day 1 analyses confirmed the picture superiority effect, which states that pictures are more likely to be remembered than words due to their more distinctive perceptual qualities. This effect was confirmed on the Standard Recognition Test, and between the two Criterial Recollection Tests where Picture Hits on the Picture Test were compared against Red Word Hits on the Red Word Test. The fourth set of Day 1 analyses confirmed the prediction that the occurrence of false memory recognition errors would be lower on the Picture Test compared to the Red Word Test. It also confirmed that New FAs were less likely to occur than Red Word FAs on the Picture Test because the former refers to items that were

never studied, thus making them less familiar and less likely to be falsely remembered. However, this effect was not found when comparing New FAs to Picture FAs on the Red Word Test. For the most part, then, analyses from the Day 1 results confirm predictions made by Gallo et al. (2004), and replicate the data presented in that paper.

The current study replicated Gallo et al.'s (2004) study, therefore participants in the current study were behaving in a similar manner to those in Gallo's study. Since this has been established, the new variables of stress, biological sex, and time retention were added to determine their effect on the material specificity of false memory.

All analyses of Day 2 and Day1 versus Day 2 were designed to test the 4 main hypotheses of the current study.

Analyses: Day 2 memory performance. For all further analyses, participants were split into their respective groups (Stress or Relax) as each group received a different experimental manipulation on Day 2. Participants' scores for each of the three recognition tests (the Standard Test as well as the two Criterial Recollection Tests) are presented in Tables 6, 7, and 8. Unless otherwise specified, all statistical tests of significance were one-tailed, as most relied on directional hypotheses.

Hypothesis 1: The first set of Day 2 analyses, conducted on data from both the Standard Recognition Test and the two Criterial Recollection Tests, was designed to further confirm the presence of the picture superiority effect in the current study. More specifically, two separate repeated-measures factorial ANOVAs were run to compare (a) the number of Picture Hits with the number of Red Word Hits within the Standard Recognition Test, and (b) the number of Picture Hits on the Picture Criterial Recollection Test with the number of Red Word Hits on the Red Word Criterial Recollection Test. Repeated-measures analyses were used as comparisons were of the same participants' performance on two different occasions. The independent variables were experimental condition (Stress versus Relax) and sex (Male versus Female).

On the Standard Recognition Test, the analysis showed there was a statistically significant main effect of item type, $F(1, 53) = 68.27$, $p < .001$, $\eta^2 = .56$, and a statistically significant Sex x Item Type interaction, $F(1, 53) = 7.99$, $p = .007$, $\eta^2 = .13$. There was no statistically significant main effect of experimental condition, $F(1, 53) = 0.02$, $p = .889$, or sex, $F(1, 53) = 0.22$, $p = .643$, and no statistically significant Experimental Condition x Sex

interaction, $F(1, 53) = 0.01$, $p = .754$, Experimental Condition x Item Type interaction, $F(1, 53) = 1.34$, $p = .252$, or Sex x Experimental Condition x Item Type interaction, $F(1, 53) < 0.01$, $p = .966$. The statistically significant main effect of item type indicates that the number of Picture and Red Word Hits differed significantly between participants. The pattern of interaction effects suggests that the number of Picture and Red Word Hits differs significantly by sex, but not by experimental condition, or by an interaction between sex and experimental condition.

Within-groups planned comparisons conducted on the same data, and designed to explore whether a picture superiority effect was found within all participants, revealed that participants in the Stress group had a statistically significantly larger number of Picture Hits than Red Word Hits ($p < .001$), as did participants in the Relax group ($p < .001$). Furthermore, both female and male participants in the Stress group had a statistically significantly larger number of Picture Hits than Red Word Hits (both *p's* < .001; see Table 6). Similarly, both female and male participants in the Relax group had a statistically significantly larger number of Picture Hits than Red Word Hits ($p < .001$ and $p = .017$, respectively; see Table 7).

Overall, then, the results reported above provide support for predictions derived from distinctiveness heuristic theories which state that pictures are more likely to be remembered than words because of their more distinctive perceptual qualities. Furthermore, it appears that neither stress nor biological sex distorts the picture superiority effect (i.e., the effect appears equally in males and females, and is robust in the face of an acute psychosocial stressor, regardless of whether that stressor is applied to males or females).

Analysis between the two Criterial Recollection Tests (that of Picture Hits on the Picture Test compared to Red Word Hits on the Red Word Test) revealed no statistically significant main effect of item type, $F(1,53) = 1.22$, $p = .275$, experimental condition, $F(1,53) = 0.66$, $p = .421$, or sex, $F(1,53) = 0.22$, $p = .642$. Furthermore, the analysis revealed no statistically significant Sex x Experimental Condition interaction, $F(1,53) = 0.05$, $p = .821$, Sex x Item Type interaction, $F(1,53) < 0.01$, $p = .990$, Experimental Condition x Item Type interaction, $F(1,53) = .30$, $p = .584$, or Sex x Experimental Condition x Item Type interaction, $F(1,53) = 2.79$, $p = .101$.

Even though no significant main effects or interactions were found, within-groups planned comparisons were run to further explore whether a picture superiority effect was

found within all participants. The analyses revealed that participants in the Stress group showed no statistically significant difference between the number of Picture Hits and Red Word Hits made (p = .126), nor did participants in the Relax group (p = .347; see Table 7). Furthermore, female participants in the Stress group showed no statistically significant difference between the number of Picture Hits and Red Word Hits made (p = .499), nor did male and female participants in the Relax group (p = .282 and p = .136, respectively). In contrast, male participants in the Stress group had a statistically significantly larger number of Picture hits than Red Word hits (p = .047), supporting predictions made by the picture superiority effect.

Overall, then, the majority of results reported above between the two Criterial Recllection Tests do not provide support for predictions derived from distinctiveness heuristic theories which state that pictures are more likely to be remembered than words because of their more distinctive perceptual qualities.

Table 6

Recognition of Each Item Type as a Function of Test Type in the Stress Group

	STRESS

	n = 28			
	Female Day 1 *n* = 13	Female Day 2 *n* = 13	Male Day 1 *n* = 15	Male Day 2 *n* = 15
Standard Test				
Both Hits	0.88 (0.10)	0.86 (0.14)	0.87 (0.10)	0.85 (0.10)
Red word Hits	0.62 (0.13)	0.52 (0.15)	0.59 (0.19)	0.61 (0.19)
Picture Hits	0.71 (0.15)	0.76 (0.15)	0.71 (0.11)	0.74 (0.12)
New FAs	0.06 (0.06)	0.30 (0.20)	0.07 (0.11)	0.33 (0.23)
Picture Test				
Both Hits	0.75 (0.15)	0.71 (0.18)	0.80 (0.11)	0.76 (0.12)
Red word FAs	0.14 (0.11)	0.22 (0.14)	0.12 (0.09)	0.18 (0.11)
Picture Hits	0.73 (0.14)	0.64 (0.18)	0.71 (0.14)	0.71 (0.12)
New FAs	0.04 (0.05)	0.12 (0.10)	0.05 (0.07)	0.15 (0.12)
Red Word Test				
Both Hits	0.55 (0.17)	0.56 (0.15)	0.66 (0.12)	0.56 (0.16)
Red word Hits	0.67 (0.15)	0.64 (0.19)	0.55 (0.18)	0.60 (0.15)
Picture FAs	0.39 (0.21)	0.55 (0.20)	0.32 (0.20)	0.50 (0.15)
New FAs	0.32 (0.34)	0.49 (0.29)	0.13 (0.20)	0.44 (0.25)

Note. Means are presented with standard deviations in parentheses.
Refer to Glossary for a full explanation of each term.

Table 7

Recognition of Each Item Type as a Function of Test Type in the Relax Group

	RELAX

n = 29

	Female Day 1 *n* = 14	Female Day 2 *n* = 14	Male Day 1 *n* = 15	Male Day 2 *n* = 15
Standard Test				
Both Hits	0.87 (0.11)	0.79 (0.17)	0.86 (0.10)	0.78 (0.15)
Red word Hits	0.60 (0.14)	0.56 (0.19)	0.55 (0.15)	0.63 (0.20)
Picture Hits	0.80 (0.13)	0.76 (0.17)	0.71 (0.13)	0.71 (0.13)
New FAs	0.12 (0.17)	0.35 (0.27)	0.10 (0.11)	0.38 (0.17)
Picture Test				
Both Hits	0.76 (0.11)	0.66 (0.19)	0.75 (0.14)	0.69 (0.17)
Red word FAs	0.14 (0.11)	0.17 (0.13)	0.13 (0.10)	0.21 (0.14)
Picture Hits	0.74 (0.12)	0.64 (0.13)	0.71 (0.15)	0.61 (0.19)
New FAs	0.06 (0.07)	0.15 (0.13)	0.14 (0.12)	0.21 (0.15)
Red Word Test				
Both Hits	0.56 (0.20)	0.53 (0.22)	0.57 (0.13)	0.57 (0.16)
Red word Hits	0.65 (0.26)	0.57 (0.25)	0.69 (0.18)	0.65 (0.20)
Picture FAs	0.35 (0.18)	0.42 (0.17)	0.42 (0.20)	0.50 (0.17)
New FAs	0.44 (0.39)	0.46 (0.30)	0.51 (0.31)	0.58 (0.18)

Note. Means are presented with standard deviations in parentheses.
Refer to Glossary for a full explanation of each term.

Table 8.

Recognition of Each Item Type as a Function of Test Type in the Stress and Relax Group (irrespective of sex)

	GROUP			
	Stress		Relax	
	n = 28		*n* = 29	
	Day 1	Day 2	Day 1	Day 2
Standard Test				
Both Hits	0.88 (0.09)	0.85 (0.12)	0.86 (0.11)	0.79 (0.16)
Red word Hits	0.60 (0.16)	0.57 (0.17)	0.57 (0.15)	0.59 (0.19)
Picture Hits	0.71 (0.13)	0.75 (0.13)	0.75 (0.13)	0.73 (0.16)
New FAs	0.06 (0.09)	0.32 (0.21)	0.11 (0.14)	0.36 (0.22)
Picture Test				
Both Hits	0.77 (0.13)	0.74 (0.15)	0.76 (0.13)	0.68 (0.17)
Red word FAs	0.13 (0.09)	0.20 (0.13)	0.13 (0.10)	0.19 (0.13)
Picture Hits	0.72 (0.14)	0.68 (0.15)	0.72 (0.14)	0.63 (0.16)
New FAs	0.04 (0.06)	0.14 (0.11)	0.10 (0.11)	0.18 (0.14)
Red Word Test				
Both Hits	0.61 (0.15)	0.56 (0.15)	0.56 (0.16)	0.55 (0.19)
Red word Hits	0.60 (0.17)	0.62 (0.17)	0.67 (0.22)	0.61 (0.22)
Picture FAs	0.35 (0.21)	0.52 (0.17)	0.39 (0.19)	0.46 (0.17)
New FAs	0.22 (0.29)	0.46 (0.26)	0.48 (0.34)	0.52 (0.25)

Note. Means are presented with standard deviations in parentheses.
Refer to Glossary for a full explanation of each term.

Hypothesis 1: The second set of Day 2 analyses was designed to test the prediction that, across all groups, false memory for words would be greater than false memory for pictures. This prediction was derived from the picture superiority effect, whereby pictures are less likely to be falsely remembered due to their more distinctive perceptual qualities.

Hence, a repeated-measures factorial ANOVA was conducted to compare number of Picture False Alarms on the Red Word Test to number of Red Word False Alarms on the Picture Test. Again, experimental condition (Stress versus Relax) and sex (Male versus Female) were used as the independent variables. The analysis detected a statistically significant main effect of item type, $F(1, 53) = 150.43$, $p < .001$, $\eta^2 = .74$, in the absence of a statistically significant main effect of experimental condition, $F(1, 53) = 1.42$, $p = .239$, or sex, $F(1, 53) = 0.06$, $p = .808$. There was no statistically significant Sex x Experimental Condition interaction, $F(1, 53) = 2.79$, $p = .101$, Sex x Item Type interaction, $F(1, 53) = 0.12$, $p = .729$, Experimental Condition x Item Type interaction, $F(1, 53) = 1.17$, $p = .285$, or Sex x Experimental Condition x Item Type interaction, $F(1, 53) = 0.32$, $p = .574$.

Planned comparisons examining within-subjects effects, and designed to explore whether a picture superiority effect was found with regard to false memory errors within all participants, showed that participants in both the Stress and Relax groups had a statistically significantly larger number of Picture False Alarms than Red Word False Alarms (both p's $<$ .001). Both female and male participants, in both the Stress and Relax groups, had a statistically significantly larger number of Picture False Alarms than Red Word False Alarms (all p's $< .001$).

Overall, the results of this second set of Day 2 analyses do not support the prediction that false memory for words would be greater than false memory for pictures. In fact, the extant data showed the opposite effect: participants committed more false memory errors when dealing with pictorial stimuli than when dealing with verbal stimuli. Possible reasons for this state of affairs are examined in the Discussion.

Hypothesis 2: The third set of Day 2 analyses, conducted on data from all three recognition tests, sought to test predictions about the occurrence of false memory errors in participants exposed to the psychosocial stressor. Recall, the specific prediction was that (due to greater cortisol increases) participants in the Stress group would commit more false memory errors than participants in the Relax group, and that (again due to greater cortisol increases) male participants in the Stress group would commit more false memory errors than female participants in the Stress group. Three separate sets of factorial ANOVAs (with number of New FAs as the dependent variable) were run on data from the Standard Recognition Test, Picture Criterial Recollection Test, and Red Word Criterial Recollection

Test, respectively, to detect whether participants performed statistically significantly differently after their respective experimental manipulations and based on sex. Experimental condition (Stress versus Relax) and sex (Male versus Female) were used as the independent variables.

On the Standard Recognition Test, when comparing the number of New False Alarms across biological sex and experimental condition, the analysis detected no statistically significant main effect of sex, $F(1, 53) = 0.31$, $p = .582$, or experimental condition, $F(1, 53) = 0.57$, $p = .453$, and no statistically significant Sex x Experimental Condition interaction, $F(1,53) < 0.01$, $p = .962$. Between-groups planned comparisons revealed no statistically significant difference between participants in the Stress and Relax groups ($p = .227$), or between male and female participants in the Stress group ($p = .338$).

On the Picture Criterial Recollection Test, conducting a similar ANOVA as detailed in the previous paragraph, the analysis detected no statistically significant main effect of sex, $F(1, 53) = 1.81$, $p = .184$, or experimental condition, $F(1, 53) = 1.71$, $p = .196$, and no statistically significant Sex x Experimental Condition interaction, $F(1, 53) = 0.36$, $p = .550$. Between-groups planned comparisons again revealed no statistically significant difference between participants in the Stress and Relax groups ($p = .098$), or between male and female participants in the Stress group ($p = .302$).

On the Red Word Criterial Recollection Test, a similar analysis as the two above detected no statistically significant main effect of sex, $F(1, 53) = 0.32$, $p = .574$, or experimental condition, $F(1, 53) = 0.71$, $p = .403$, and no statistically significant Sex x Experimental Condition interaction, $F(1, 53) = 1.72$, $p = .195$. Between-groups planned comparisons once again revealed no statistically significant difference between participants in the Stress and Relax groups ($p = 201$), or between male and female participants in the Stress group ($p = .302$).

Overall, then, the results reported above do not provide support for predictions that stressed participants and male participants in the Stress group would commit more false memory errors. It appears that neither exposure to a psychosocial stressor nor biological sex distorts the amount of false memory errors made (i.e., false memory errors occur equally in exposed and unexposed participants, and in male and females in the Stress group).

To further investigate whether (a) stressed participants made more false memory errors than non-stressed participants, and (b) male participants in the Stress group made more false memory errors than female participants in the Stress group, two separate factorial ANOVAs using experimental condition (Stress versus Relax) and sex (Male versus Female) as the independent variables were run on data from the two Criterial Recollection Tests. The first used number of Red Word False Alarms on the Picture Test as the dependent variable. This analysis detected no statistically significant main effect of sex, $F(1, 53) < 0.01$, $p = .984$, or experimental condition, $F(1, 53) = 0.11$, $p = .736$, and no statistically significant Sex x Experimental Condition interaction, $F(1,53) = 1.31$, $p = .258$. Between-groups planned comparisons revealed no statistically significant difference between participants in the Stress and Relax groups ($p = .368$), or between male and female participants in the Stress group ($p = .209$).

The second factorial ANOVA used number of Picture False Alarms on the Red Word Test as the dependent variable. This analysis also detected no statistically significant main effect of sex, $F(1, 53) = 0.13$, $p = .720$, or experimental condition, $F(1, 53) = 2.04$, $p = .159$, and no statistically significant Sex x Experimental Condition interaction, $F(1, 53) = 2.22$, $p = .142$. Between-groups planned comparisons once again revealed no statistically significant difference between participants in the Stress and Relax groups ($p = .079$), or between male and female participants in the Stress group ($p = .216$).

The results from second set of Day 2 analyses therefore all disconfirm the *a priori* predictions made with respect to false memory, psychosocial stress, and biological sex. Given the current data, it appears that neither biological sex, nor exposure to a psychosocial stressor, nor any interaction between the two, provides a circumstance under which false memory recognition errors are potentiated.

Analyses: Comparison of Day 1 and Day 2 scores: False memory rates. Based on D. G. Payne et al.'s (1996) work, a first major prediction tested when comparing Day 1 and Day 2 scores was that rates of false memory recognition errors would remain stable over a 24-hour retention period in all participants. To test this hypothesis, only data from the Standard Recognition Test was used. This recognition test is the most pure reflection of false memory, as it simply asks participants if they remember an item or not. The two Criterial Recollection Tests are confounded by material specificity and may not truly reflect false memory

performance. To test the prediction, a repeated-measures factorial ANOVA was run to compare the within-groups performance on the Standard Recognition Test, using New FAs as the dependent variable. Experimental condition (Stress versus Relax), sex (Male versus Female) and time of testing (Day 1 (immediately after the study phase) versus Day 2 (24-hours after the study phase)) were used as the independent variables. The above mentioned analysis was two-tailed.

The comparison of New FAs on the Standard Recognition Test revealed a statistically significant main effect of time, $F(1, 53) = 113.79$, $p < .001$, $\eta^2 = .68$, in the absence of a statistically significant main effect of experimental condition, $F(1, 53) = 1.19$, $p = .280$, or sex, $F(1, 53) = 0.11$, $p = .737$. There was no statistically significant Sex x Experimental Condition interaction, $F(1, 53) = 0.04$, $p = .837$, Sex x Time interaction, $F(1, 53) = 0.63$, $p = .433$, Experimental condition x Time interaction, $F(1, 53) < 0.01$, $p = .999$, or Sex x Experimental Condition x Time interaction, $F(1, 53) = 0.05$, $p = .817$. The significant main effect of time indicates that number of New FAs differed significantly between Day 1 and 2 of testing. Planned comparisons further examining the within-subject effects, and designed to further determine whether false memory remained stable over a 24-hour retention period, revealed that participants in both the Stress and Relax groups made statistically significantly more New FAs on Day 2 of testing compared to Day 1 ($p < .001$ in both cases). Female and male participants in both the Stress and Relax group all made statistically significantly more New FAs on Day 2 of testing compared to Day 1 (all p's $< .001$). The above results disconfirm the a priori prediction: False memory rates did not remain stable over a 24-hour retention period, but instead increased. The non-significant interactions described by the above analyses suggest that neither experimental condition nor biological sex, nor an interaction of the two, provides a circumstance under which false memory recognition errors are affected over a 24-hour retention period.

Analyses: Comparison of Day 1 and Day 2 scores: True memory rates. Based on predictions from previous work (e.g., Brainerd & Reyna, 1990; J. D. Payne et al., 2006), a second major prediction made when comparing Day 1 and Day 2 scores was that rates of true memory recognition success would decrease over a 24-hour retention period in all participants. Again, to test this hypothesis, only data from the Standard Recognition Test was used for the same reasons as those stated in the previous analysis. To test this prediction, three

separate sets of repeated-measures ANOVAs to compare within-group performances on the two days of testing with regard to true memory (i.e., item hits) on the Standard Recognition Test . All analyses described here were one-tailed.

The first analysis (that of number of Both Hits on the Standard Recognition Test compared across Day 1 and Day 2) revealed a statistically significant main effect of time, $F(1, 53) = 10.58$, $p = .002$, $\eta^2 = .17$, in the absence of a statistically significant main effect of experimental condition, $F(1, 53) = 1.60$, $p = .212$, or sex, $F(1, 53) = 0.10$, $p = .753$. The analysis revealed no statistically significant Sex x Experimental Condition interaction, $F(1, 53) < 0.01$, $p = .990$, Experimental Condition x Time interaction, $F(1, 53) = 3.22$, $p = .078$, Sex x Time interaction, $F(1, 53) = 0.02$, $p = .882$, or Sex x Experimental Condition x Time interaction, $F(1, 53) < 0.01$, $p = .966$. The significant main effect of time indicates that number of Both Hits differed significantly between Day 1 and 2 of testing. Planned comparisons examining within-subject effects, and designed to further investigate whether true memory decreased over a 24-hour retention period, revealed that participants in the Stress group did not show a statistically significant difference in true memory success rates from Day 1 to Day 2 ($p = .156$), whereas participants in the Relax group showed a statistically significant decrease in that performance measure ($p < .001$). Neither male nor female participants in the Stress group showed a statistically significant difference in true memory success rates from Day 1 to Day 2 ($p = .200$ and $p = .274$, respectively). In contrast, both male and female participants in the Relax group showed a statistically significant decrease in true memory success rates from Day 1 to Day 2 ($p = .005$ and $p = .009$, respectively). These results indicate that experimental condition is a circumstance under which true memory rates are affected over a 24-hour retention period, as is the interaction between experimental condition and biological sex.

The results reported above show contradictory evidence, with some pointing to the decay of true memory over a 24-hour retention period (i.e., confirming the *a priori* prediction), and others pointing to the stability of true memory over a 24-hour retention period (i.e., disconfirming the *a priori* prediction).

The second analysis (that of number of Picture Hits on the Standard Recognition Test compared across Day 1 and Day 2) revealed a statistically significant Experimental Condition x Time interaction, $F(1, 53) = 4.16$, $p = .046$, $\eta^2 = .05$, in the absence of a statistically

significant main effect of time, $F(1, 53) = 0.51$, $p = .479$, experimental condition, $F(1, 53) = 0.19$, $p = .667$, or sex, $F(1, 53) = 1.34$, $p = .253$, and no statistically significant Sex x Experimental Condition interaction, $F(1, 53) = 0.79$, $p = .378$, Sex x Time interaction, $F(1, 53) = 0.01$, $p = .920$, or Sex x Experimental Condition x Time interaction, $F(1, 53) = 1.12$, $p = .296$. The significant Experimental Condition x Time interaction indicates that experimental condition (i.e., being in the Stress group as opposed to the Relax group) is a circumstance under which true memory success is affected over a 24-hour retention period. Planned comparisons examining within-subject effects, and designed to further investigate whether true memory decreased over a 24-hour retention period, revealed that participants in the Stress group did not show a decrease in true memory success rates from Day 1 to Day2, and in fact showed a statistically significant increase from Day 1 to Day 2 ($p = .030$). In contrast, participants in the Relax group showed no statistically significant difference in true memory from Day1 to Day2 ($p = .174$). Female participants in the Stress group did not show a decrease in true memory from Day 1 to Day 2, and in fact showed a statistically significant increase from Day 1 to Day 2 ($p = .041$). Neither male participants in the Stress group ($p = .180$), nor male and female participants in the Relax group ($p = .465$ and $p = .111$, respectively), showed a statistically significant difference in true memory success rates from Day 1 to Day 2.

The above results do not confirm the priori hypothesis that true memory success rates would decrease over a 24-hour retention period; in fact, some results show the opposite effect (i.e., an increase in true memory success over the same retention period).

The third analysis (that of number of Red Word Hits on the Standard Recognition Test compared across Day 1 and Day 2) revealed a statistically significant Sex x Time interaction, $F(1, 53) = 6.26$, $p = .015$, $\eta^2 = .11$, in the absence of a statistically significant main effect of time, $F(1, 53) = 0.26$, $p = .615$, experimental condition, $F(1, 53) < 0.01$, $p = .996$, or sex, $F(1, 53) = 0.19$, $p = .667$, and no statistically significant Sex x Experimental Condition interaction, $F(1, 53) = 0.11$, $p = .745$, Experimental Condition x Time interaction, $F(1, 53) = 1.51$, $p = .224$, or Sex x Experimental Condition x Time interaction, $F(1,53) < 0.01$, $p = .966$. The significant Sex x Time interaction indicates that sex is a condition under which true memory success is affected over a 24-hour retention period. Planned comparisons examining within-subject effects, and designed to further investigate whether true memory decreased over a 24-hour retention period, revealed that neither participants in the Stress or Relax group showed a

statistically significant difference in true memory success rates from Day 1 to Day 2 (p = .115 and p = .303, respectively). Neither male participants in the Stress group nor female participants in the Relax group showed a statistically significant difference in true memory success rates from Day 1 to Day 2 (p = .356 and p = .185, respectively). However, female participants in the Stress group showed a statistically significant decrease in true memory success rates from Day 1 to Day 2 (p = .025), whereas male participants in the Relax group showed a statistically significant increase (p = .049).

The above results do not confirm the a priori hypothesis that true memory success rates would decrease over a 24-hour retention period; in fact, some results show the opposite effect (i.e., an increase in true memory success over the same retention period).

Analyses: Difference scores. To calculate difference scores, participants' Day 2 score on each item type in the recognition tests was subtracted from their Day 1 score (see Tables 9 and 10 for the outcomes of these calculations). Recall that all scores are proportions, with a minimum of 0, and a maximum of 1. A positive difference score indicates that the participant's Day 1 score was higher than his/her Day 2 score (i.e., he/she remembered less on Day 2 than on Day 1). A negative difference score, in contrast, indicates that the participant's Day 1 score was lower than his/her Day 2 score (i.e., he/she remembered more on Day 2 compared to Day 1). All analyses described in this section were one-tailed, as all statistical tests explored directional hypotheses.

Table 9

Difference Scores for True Memory Performance in Male and Female Stressed Participants

	Stress	
	Male	Female
	n = 15	*n* = 13
Standard Test		
Both Hits	0.02 (0.10)	0.02 (0.11)
Red Word Hits	-0.02 (0.16)	0.10 (0.16)
Picture Hits	-0.03 (0.13)	-0.06 (0.14)

Note. Means are presented with standard deviations in parentheses.
Refer to Glossary for a full explanation of each term.

Table 10

Difference Scores for True Memory Performance in the Stress and Relax Group (irrespective of sex)

	Group	
	Stress	Relax
	n = 28	*n* = 29
Standard Test		
Both Hits	0.02 (0.10)	0.08 (0.12)
Red word Hits	0.04 (0.17)	-0.02 (0.19)
Picture Hits	-0.04 (0.13)	0.02 (0.10)

Note. Means are presented with standard deviations in parentheses.
Refer to Glossary for a full explanation of each term.

Based on the fact that true memories in a recognition test decline with increasing time delay (e.g., D. G. Payne et al., 1996), the major prediction here was that true memory success rates would decrease over the 24-hour retention period, and that, furthermore, this decrease would be greater in participants in the Stress group, and in male participants in that group in particular (due to predicted higher cortisol increases in the Stress group in general and in male participants exposed to the stressor). To test this prediction, three separate sets of factorial ANOVAs were run to directly compare participants' difference scores on hits outcome measures (Both Hits, Picture Hits, and Red Word Hits) on the Standard Recognition Test. Again, only data from the Standard Recognition Test was used for reasons mentioned earlier.

All of the analyses used experimental condition and sex as the independent variables, and all analyses were one-tailed.

The first analysis began by analysing Both Hits difference scores on the Standard Recognition Test. A factorial ANOVA revealed no statistically significant main effect of experimental condition, $F(1, 53) = 3.22$, $p = .078$, or sex, $F(1, 53) = 0.02$, $p = .882$, and no statistically significant Sex x Experimental Condition interaction, $F(1, 53) < 0.01$, $p = .966$. Even though no significant main effects or interaction were found, between-group planned comparisons were run to further investigate whether stressed participants and male participants in the stress group showed a greater decay of true memory (i.e., larger difference scores between Day 1 and Day 2). Analyses revealed no statistically significant difference between male and female participants in the Stress group ($p = .447$), which does not support the *a priori* prediction that male participants in the Stress group would show a greater decay of true memory compared to the female participants. There was, however, a statistically significant difference on this measure between the Stress and Relax groups ($p = .039$). As shown in Table 10, participants in the Relax group showed a larger decrease in Both Hits scores from Day 1 to Day 2 than did participants in the Stress group. This result disconfirms the a priori hypothesis, and in fact demonstrates the opposite effect.

The second analysis proceeded by analysing Picture Hits difference scores on the Standard Recognition Test. A factorial ANOVA revealed a statistically significant main effect of experimental condition, $F(1, 53) = 4.16$, $p = .046$, $\eta^2 = .07$, in the absence of a statistically significant main effect of sex, $F(1, 53) = 0.01$, $p = .920$, or a Sex x Experimental Condition interaction, $F(1, 53) = 1.12$, $p = .296$. The significant main effect of experimental condition indicates that the difference between Day 1 and Day 2 number of Picture Hits made by the Stress and Relax groups differed significantly, with the Relax group showing a decrease in true memory success rates from Day1 to Day 2, whereas the Stress group showed an increase.

Between-groups planned comparisons were run on the same data to further investigate whether stressed participants and male participants in the Stress group showed a greater decrease in true memory success rates. The analyses revealed no statistically significant difference between Stress group male and female participants' difference scores ($p = .253$); this result disconfirms the prediction that stressed males would show a greater decrease in true

memory success rates compared to stressed females. In fact, both male and female participants in the Stress group showed an increase in Picture Hits over a 24-hour retention period.

The between-groups planned comparison analysing difference scores in Picture Hits from the Stress and Relax groups revealed a statistically significant difference ($p = .023$), however. As shown in Table 10, participants in the Relax group showed a decrease in true memory success rates from Day 1 to Day 2, whereas those in the Stress group showed an increase. Again, this result disconfirms the hypothesis that participants in the Stress group would show a greater decrease in true memory success rates.

The final stage of the analyses in this section featured an analysis of Red Word Hits difference scores on the Standard Recognition Test. The factorial ANOVA revealed a statistically significant main effect of sex, $F(1, 53) = 6.26$, $p = .015$, $\eta^2 = .11$, in the absence of a statistically significant main effect of experimental condition, $F(1, 53) = 1.51$, $p = .224$, or a Sex x Experimental Condition interaction, $F(1, 53) < 0.01$, $p = .966$.

Between-groups planned comparisons were run on the same data to further investigate whether stressed participants and male participants in the Stress group showed a greater decrease in true memory success rates. The analyses revealed a statistically significant difference between male and female Stress group participants' difference scores ($p = .045$), with females showing a large decrease in true memory success rates, and males showing a small increase (see Table 9). The above result disconfirms the prediction that male participants in the Stress group would show a greater decrease in true memory success rates over the 24-hour retention period.

The between-groups planned comparison analysing difference scores in Red Word Hits from the Stress and Relax groups showed no statistically significant difference ($p = .112$). However, as shown in Table 10, the Relax group showed an increase in true memory from Day 1 to Day 2, whereas the Stress group showed a decrease.

Discussion

Replication of Gallo et al.'s (2004) Work

As mentioned in the results section, the analyses of Day 1's results were to confirm that this study replicated the results found by Gallo et al. (2004).

Picture superiority effect. Firstly, Gallo and colleagues (2004) found that the number of Picture Hits was significantly greater than the number of Red Word Hits on the Standard Recognition Test and between the two Criterial Recollection Tests (comparing Picture Hits on the Picture Test against Red Word Hits on the Red Word Test). This effect can be explained by the distinctiveness heuristic, which states that pictures will always be better remembered than words due to their more distinctive perceptual qualities. A familiarity model could also explain this effect, as pictures should be more familiar that words due to their distinctive features, therefore, the more familiar pictures should be better remembered than words. The current study replicated those results, as number of Picture Hits was statistically significantly greater than number of Red Word Hits on the Standard Recognition Test and between the two Criterial Recollection Tests.

Items studied twice compared with items studied only once. Secondly, Gallo and colleagues (2004) found that on the Standard Recognition Test, items presented twice during the study phase (i.e., Both Hits) were statistically significantly greater than items presented only once during the study phase (i.e., Picture Hits and Red Word Hits). A familiarity model can account for this, as items presented twice are more familiar than items presented only once, and are therefore more likely to be remembered. The current study replicated the above mentioned result, as Both Hits were statistically significantly greater than either Picture Hits or Red Word Hits.

Furthermore, Gallo et al. (2004) found this effect on the Picture Criterial Recollection Test (comparing Both Hits with Picture Hits) and on the Red Word Criterial Recollection Test (comparing Both Hits with Red Word Hits). Again, a familiarity model can account for this, as items presented twice during the study phase are more familiar, and therefore more likely to be remembered. The current study replicated this result on the Picture Test, as the number of Both Hits was significantly greater than the number of Picture Hits. Unexpectedly, however, analyses of Red Word Test data showed there was no significant difference between the number of Both Hits and the number of Red Word Hits. This result cannot be explained by a

familiarity model, as items presented twice during the study phase should be more familiar, and should therefore more likely to be remembered.

Additionally, Gallo et al. found that on the Standard Recognition Test, the number of Both Hits was significantly greater than the number of Red Word Hits but not significantly greater than the number of Picture Hits. The first part of this pattern of data is easily explained by a familiarity model: Items presented twice (as both pictures and words during the study phase) were more familiar to participants than those presented only once, and should therefore be better remembered than items presented as red words only. The second part of this pattern of data requires a slightly more complex explanation: With regard to items presented as pictures only, one might speculate that, given their distinctive qualities, they might be just as well remembered as items presented twice during the study phase. In other words, here the effects of the familiarity model and the distinctiveness heuristic might cancel one another out, leading to a situation where, as Gallo et al. found, there are no significant differences between hits for items presented as both pictures and words and hits for items presented as only pictures

Data from the current study did not replicate the latter finding on the Standard Recognition Test, as number of Both Hits was statistically significantly greater than number of Picture Hits. In contrast, data from the Standard Recognition Test did replicate the finding that number of Both Hits was statistically significantly greater than number of Red Word Hits. On the Picture Test, the current data replicated Gallo's results, as number of Both Hits was not statistically significantly greater than number of Picture Hits. In contrast, data from the Red Word Test did not replicate Gallo et al.'s findings, as number of Both Hits was not statistically significantly different from number of Red Word Hits.

Retrieval strategies. On the Criterial Recollection Tests, participants had to search for the to-be-remembered information, as they had to remember not only whether an item was studied, but whether it was studied as a picture or red word. Therefore a more conservative criterial recollection shift occurred, whereby individuals were more cautious about their decisions. On the Standard Recognition Test, however, individuals can use a more familiarity-based strategy for remembering because all they need to determine is whether an item was studied or not, irrespective of the format it was studied in. Therefore on the Standard

Recognition Test individuals are more likely to say an item was studied as they are relying on the feeling that the item is familiar and not whether it is specific to the experimental context.

Gallo et al. confirmed this pattern of strategic differences, showing that hits for all items were lower on the Criterial Recollection Tests than on the Standard Recognition Test, indicating a more conservative approach. The current study did not replicate this finding, however: Hits for all items were not different between the Standard Recognition Tests and the two Criterial Recollection Tests. One interpretation of the current data, then, is that participants, across all of the recognition tests, participants may not have been using a conservative criterial recollection approach, and may have been relying more on familiarity.

Evidence that participants were relying on familiarity in the Criterial Recollection tests comes from the number of false alarm errors made. On the Criterial Recollection Tests, participants had to search not only for the to-be-remembered information, but also the study format of this information (studied as a picture or red word). However, on the Standard Recognition Test, successful remembering could be accomplished by familiarity alone, where individuals merely had to remember if an item was *ever* presented during the study phase and not the *format* it was presented in. Therefore, false alarms on the Criterial Recollection tests should be lower than on the Standard Recognition Test, as individuals are making more conservative/cautious decisions on the Criterial Recollection Tests.

This pattern of data was not observed in the current study, as New FAs were much higher on the Red Word Test than on the Standard Recognition Test. In contrast, this pattern of data was observed when comparing New FAs between the Picture Test and Standard Recognition Test, with the former having a lower amount of New FAs than the latter. A possible explanation for this is that on the Picture Test individuals expected more distinctive recollections, therefore items that were never presented during the study phase failed to confirm their expectations, and therefore less likely to be falsely remembered.

False memory within the criterial recollection tests. On the Picture Test, false alarms for to-be-excluded items (i.e., word false alarms) were significantly greater that false alarms for new items (i.e., items never presented during the study phase). However, the same result was not found on the Red Word Test; there, the number of Picture false alarms was not significantly different from the number of New FAs. This latter result cannot be explained by a familiarity model, as to-be-excluded items should still be more familiar than new items that

were never been presented during study phase. Participants should be affected by the prior presentation of the to-be-excluded items, and should therefore be more likely to remember them.

Interestingly, Gallo et al. (2004) also found this result; on both Criterial Recollection Tests in their study, as the number of false alarms for to-be-excluded items was greater than the number of false alarms for new items. These results cannot be explained by a familiarity model, as items that were never presented during the study phase are less familiar and therefore more likely to be falsely remembered.

Amount of false memory errors made. Most importantly, Gallo et al. found that all false alarms were lower on the Picture Test than on the Red Word Test: Red Word FAs on the Picture Test were significantly lower than Picture FAs on the Red Word Test. Similarly, and New FAs on the Picture Test were significantly lower than New FAs on the Red Word Test. These recollections are consistent with the distinctiveness heuristic as participants should expect more distinct recollections on the Picture test, thereby lowering all false alarms. A familiarity-based model could also explain these results. Seen as pictures were 'stronger' in memory than words, we could predict a more conservative criterion recollection response on the Picture test, thereby lowering the number of false alarms relative to the Red Word test. The current study replicated these findings, as Red Word FAs on the Picture Test were statistically significantly lower than Picture FAs on the Red Word Test, and the amount of New FAs made were statistically significantly lower on the Picture Test compared to the Red Word Test.

Overall, the current study for the most part replicated Gallo et al.'s (2004) work. One can assume, then, that participants in the current study behaved in a similar manner to those in the Gallo study, and that the memory processes under consideration were similar here as in that study. The current study, however, was not only concerned with replication; it added biological sex, time retention, and the presence of a stressor to determine their effect on the material specificity of false memory, and to investigate the decay of both true and false memory over a 24-hour retention period.

Summary of Hypotheses Tested in the Current Study

The first hypothesis made predictions based on the picture superiority effect: Firstly, that pictures would be better remembered than words in all participants, and secondly, that false recognition errors would be higher for words compared to pictures in all participants.

With regard to the first point, all participants had a statistically significantly larger number of Picture Hits compared to Red Word Hits on the Standard Recognition Test. These results support the a *priori* hypothesis that pictures would be better remembered than words. It appears that the picture superiority effect is neither distorted by the presence of a stressor, biological sex, or an interaction of the two on the Standard Recognition Test.

Male participants in the Stress group had a statistically significantly larger number of Picture Hits on the Picture Test compared to Red Word Hits on the Red Word Test. In contrast, female participants in the Stress group, and both male and female participants in the Relax group showed no statistically significant difference between number of Picture Hits on the Picture Test compared to Red Word Hits on the Red Word Test. These results disconfirm the a *priori* hypothesis that pictures would be better remembered than words. It appears that the picture superiority effect is distorted by the presence of a stressor and biological sex on the Criterial Recollection Tests. A possible explanation for this is that on the Criterial Recollection Tests participants are using a more conservative recollection shift which may be more susceptible to the effects of stress than their approach on the Standard Recognition Test (a familiarity based strategy).

With regard to the second point, all participants made statistically significantly more Picture FAs on the Red Word Test compared to Red Word FAs on the Picture Test. This result disconfirms the a priori hypothesis that pictures are less likely to be falsely remembered than words due to their more distinctive perceptual qualities. On the Picture Test participants expected more detailed recollections (as they had to remember whether an item was studied as a picture or not), therefore they may have been less likely to make Red Word FAs which failed to confirm their expectations. This more conservative approach on the Picture Test could explain why Picture FAs on the Red Word Test were greater than Red Word FAs on the Picture Test.

The second hypothesis made predictions based on previous literature regarding stress and false memory: Specifically, that false memory recognition errors would be greater in

Stressed participants and male participants in the Stress group due to predicted higher cortisol increases. All analyses testing this hypothesis revealed no statistically significant difference between the number of false memory recognition errors made by the Stress and Relax group, or by male and female participants in the Stress group. All of the above mentioned analyses testing the second hypothesis disconfirm the a *priori* hypothesis, and possible explanations for this are discussed later.

The third hypothesis made predictions regarding the stability of false memory over a 24-hour retention period: Specifically, that false memory would remain stable over a 24-hour retention period in all participants. The analysis of New FAs on the Standard Recognition Test revealed that all participants showed a statistically significant increase in the amount of false memory errors over a 24-hour retention period (i.e., they made more false memories on Day 2 of testing compared to Day 1). This analysis disconfirms the a *priori* hypothesis regarding the stability of false memory, and in fact point to the decay of false memory over a 24-hour retention period.

A possible reason for false memory recognition errors increasing over a 24-hour retention period is the following: Reder et al. (2000) proposed for every item in the study phase, two kinds of information are coded. Firstly, an increase in familiarity, and secondly, encoding of situation-specific information. High frequency word (common, everyday words) are encountered on a frequent basis, leading to higher baseline familiarity, but furthermore, a decrease in distinctiveness for the most recent context in which the item is encountered (i.e., the study phase). Low frequency words, which are encountered on a rarer basis, have lower baseline levels of familiarity; and the situation-specific information from the study phase will stand out. Therefore, low frequency words tend to be better recollected, whereas recollection of high frequency words rely heavily on familiarity, increasing false recognition rates. In the current study, the pictures and words used in the study phase were common nouns (making them high frequency words), which could explain the high rate of false memory errors on Day 2 of testing.

The fourth hypothesis made predictions regarding the decay of true memory over a 24-hour retention period: Firstly, that true memory would decrease over a 24-hour retention period (based on previous literature), and secondly that this decrease would be greater in stressed participants' and male participants in the Stress group (due to predicted higher

cortisol increases). With regard to the first point: All participants in the Stress group made equal amount of true memory successes rates on Day 1 and Day 2 of testing for Both Hits on the Standard Recognition Test. This result disconfirms the a *priori* hypothesis regarding the decay of true memory, and rather points to the stability of true memory over a 24-hour retention period. In contrast, all participants in the Relax group made statistically significantly fewer amounts of true memory successes rates on Day 2 of testing for Both Hits on the Standard Recognition Test. This result confirms the a *priori* hypothesis regarding the decay of true memory.

The majority of participants made equal amount of true memory successes rates on Day 1 and Day 2 of testing for Picture Hits on the Standard Recognition Test. This result disconfirms the a *priori* hypothesis regarding the decay of true memory, and rather points to the stability of true memory over a 24-hour retention period. This result also suggests that pictorial material is less susceptible to decay over time, possibly due to their more distinctive perceptual qualities which make them easier to remember. In fact, the Stress group, and female participants in the Stress group made statistically significantly more true memory success rates on Day 2 of testing.

All participants made equal amount of true memory successes rates on Day 1 and Day 2 of testing for Red Word Hits on the Standard Recognition Test, except for female participants in the Stress group, who made statistically significantly fewer amounts of true memory successes rates on Day 2 of testing, and male participants in the Relax group, who made statistically significantly greater amounts of true memory successes rates on Day 2 of testing. The majority of results for Red Word Hits again disconfirm the a *priori* hypothesis regarding the decay of true memory, and rather point to the stability of true memory over a 24-hour retention period.

With regard to the second point: When comparing the decay of Both Hits on the Standard Recognition Test, there was no significant difference between male and female participants in the Stress group. Furthermore, the Relax group showed a greater decrease in true memory success rates compared to the Stress group. These results disconfirm the a *priori* hypothesis that stressed participants and male participants in the Stress group would show a greater decrease in true memory over a 24-hour retention period.

When comparing the decay of Picture Hits on the Standard Recognition Test, there was no significant difference between male and female participants in the Stress group. Furthermore, the Relax group showed a greater decrease in true memory success rates compared to the Stress group, who actually showed an increase. These results disconfirm the a *priori* hypothesis that stressed participants and male participants in the Stress group would show a greater decrease in true memory over a 24-hour retention period.

When comparing the decay of Red Word Hits on the Standard Recognition Test, there was a significant difference between male and female participants in the Stress group, with females showing a statistically significant decrease, whereas males showed an increase. Furthermore there was no significant difference between the Stress and Relax group. These results disconfirm the a *priori* hypothesis that stressed participants and male participants in the Stress group would show a greater decrease in true memory over a 24-hour retention period.

Possible reasons for results found regarding the decay of true memory will be discussed later.

Memory Performance under Stress Depends on the Stage at which the Stressor is Applied and the Type of Memory being Tested

The impact of glucocorticoids on memory function seems to depend on the stage at which the stressor is applied. Cortisol (and, by implication, stressors that raise cortisol levels) have been shown to have differing effects on encoding, retrieval, and consolidation processes (Roozendaal, 2000). Het, Ramlow, and Wolf's (2005) meta-analysis revealed that cortisol elevations applied before encoding had no effect on memory performance, whereas when cortisol elevations were applied after encoding, memory performance was significantly impaired. It appears that recall of neurtral material learned under normal cortisol levels are impaired by elevated cortisol, however materials learned under elevated cortisol levels are not affected.

Studies have found that when cortisol elevations occur before encoding memory retrieval is not impaired (Wolf, Convit, et al., 2001). For example, de Quervain, Roozendaal, Nitsch, McGaugh, and Hock (2000) found cortisol administration one hour before encoding or immediately after , encoding had no effect on retrieval (either immediate or delayed recall). In

contrast, de Quervain, Roozendaal, and McGaugh (1998) illustrated that when a stressor was applied before encoding it impaired retrieval 24 hours later.

On the other hand, studies have shown that retrieval is impaired when a stressor is applied *after* encoding (Kuhlmann et al., 2005; Wolf, Convit, et al., 2001). In contrast, de Quervain et al. (1998) showed that when cortisol elevations occur after encoding, memory retrieval was not impaired, possibly due to the fact that cortisol concentrations had returned to baseline levels at the time of recall. This result is similar to those found in the current study, where participants in the Stress and Relax group often showed no difference in memory impairment. One study even found that when a stressor is applied after encoding, memory retrieval is enhanced (Roozendaal, 2000). In the current study, the stressor was applied after encoding, and if memory retrieval is enhanced (as was found by Roozendaal) this would explain why true memory success rates did not significantly decay over a 24-hour retention period, and in some instances actually increased over the 24-hour retention period.

The impact of glucocorticoids on memory function also seems to depend on the type of memory being tested. In a study by de Quervain et al. (2000), glucocorticoid administration one hour before delayed recall (i.e., 23 hours after encoding and consolidation) impaired recall but not recognition. Furthermore, de Quervain et al. (2003) found that although cortisol administration affected cued recall of words learnt 24hours earlier, it had no effect on recognition memory for that material. Buchanan and Tranel (2008) found a similar result, with cortisol responders and non-responders not differing in recognition performance, while responders showed a lower recall compared to non-responders. .

The fact that recognition memory does not seem to be impaired by stress could explain why, in this study, false memory was not modulated by experimental condition or biological sex. Since recognition memory does not seem to be impaired by stress, the presence of a stressor should not impair this type of memory. This could explain why the Stress and Relax group and stress-exposed male and female participants performed equally with regard to false recognition memory errors.

Stress Response within the Current Study

Based on evidence from numerous previous studies, the current study set out to test the prediction that, in participants exposed to acute psychosocial stress, there would be an

increased likelihood of false recognition memories (due to, as the literature shows, temporarily disrupted hippocampal and PFC functioning in those exposed to the stressor).

Results pertaining to a check of the experimental manipulation indicated that the administration of the TSST was successful in significantly raising cortisol levels, heart rate levels, and self-reported anxiety in Stress group participants. Furthermore, participants in the Relax group showed significantly lowered cortisol levels, heart rate levels, and self-reported levels of anxiety following a period of relaxation. Therefore, as the participants entered the cognitive testing phase of the experiment, participants in the Relax group were in a different psychological and physiological state to those in the Stress group, with the latter more likely to have temporarily impaired hippocampal and PFC function.

Although the current study induced a significant cortisol response in the Stress group, the magnitude of this response was lower than that of numerous previously published studies. This may have had important implication for memory performance, as many studies have shown that the magnitude of cortisol response is negatively correlated with memory performance (i.e., higher cortisol responders show more severe memory impairments; Andreano et al., 2008; Lupien et al., 1994; Wolf, Schommer, et al., 2001). Participants in the Stress group (irrespective of gender) showed an increase in salivary cortisol levels from baseline (1.62 nmol/l ± 1.57) to post-TSST (6.53 nmol/l ± 4.11), indicating an increase in salivary cortisol levels of an average of 4.91 nmol/l in response to the TSST. Some previous studies using the same stress induction procedure, and both male and female participants, have reported increases much lower than this. For instance, Jackson, Payne, Nadel, and Jacobs (2006) reported a 1.75 noml/l increase; Kirschbaum and Hellhammer (1992) reported a 2.13 nmol/l increase; Schwabe et al. (2007) reported a 2.7 nmol/l increase; and Elzinga and Roelofs (2005) reported a 4.39 nmol/l increase. However, numerous other studies using the same stress induction procedure, and both male and female participants, have found slightly higher post-TSST cortisol increases than those reported in the current study. For instance, Lupien et al. (1997) reported a 6.1 nmol/l increase, Kirschbaum and Hellhammer (1992) a 6.15 nmol/l increase, and Kudielka, Buske-Kirschbaum, Hellhammer, and Kirschbaum (2004b) a 6.5 nmol/l increase. A few previous studies, again also using the same stress induction procedure and both male and female participants, have reported *much* larger cortisol increases than those found in the current study. For instance, Kirschbaum and Hellhammer (1992) reported an

increase of 7.5 nmol/l and 8 nmol/l in two independent studies, Kirschbaum, Wolf, et al. (1996) reported an increase of 9.19 nmol/l, and Wolf, Schommer, et al. (2001) reported an increase of 10.5 nmol/l. It seems, therefore, that the current study produced TSST-provoked cortisol increases that are at the lower end of the range established by previous studies. Therefore, cognitive effects are likely to be seen as previous literature has shown higher cortisol responses are associated with poorer memory performance (Andreano et al., 2008; Lupien et al., 1994; Wolf, Schommer, et al., 2001), possibly due to greater disruption of hippocampal and PFC functioning

With regard to female participants, those in this study's Stress group showed an increase in salivary cortisol levels from baseline (1.34 nmol/l ± 1.23) to post-TSST (4.99 nmol/l ± 2.82), indicating an average increase of 3.65 nmol/l in response to the TSST. Also with regard to female participants, the majority of previously published studies in this research area report increases in salivary cortisol levels in a similar range to that found here (i.e., less than 5 nmol/l; see, e.g., Domes, Heinrichs, Reichwald, & Hautzinger, 2002; Elzinga & Roelofs, 2005; Jackson et al., 2006). It should be noted, however, that most of these studies did not exclude female participants who were taking oral contraceptives, which have been shown to decrease the magnitude cortisol responses to a stressor (Kirschbaum et al., 1995, 1999). In addition, many of these studies did not control for phase of menstrual cycle, which as discussed earlier can play an important role in cortisol response due to varying estrogen and progesterone levels at different times of the cycle. A couple of studies have used similar menstrual-cycle controls to those employed in this study, and have reported starkly contrasting results: Wolf, Schommer, et al. (2001) and Elzinga and Roelofs (2005) both used female participants in the late luteal phase of their menstrual cycle (as did the current study), but whereas the former study reported cortisol increases of 10.3 nmol/l in response to the TSST, the latter reported increases of only 0.9 nmol/l. It appears, then, that the procedures employed in the current study did not induce as large a cortisol response in female participants as did those of previously published studies in this research area. Again, cognitive effects are likely to be seen for the same reasons stated in the previous paragraph.

With regard to male participants, those in this study's Stress group showed an increase in salivary cortisol levels from baseline (1.85 nmol/l ± 1.82) to post-TSST (7.86 nmol/l ± 4.66), indicating an increase in average salivary cortisol levels of 6.01 nmol/l in response to

the TSST. Also with regard to male participants, only a few previously published studies in this area report an increase in salivary cortisol levels less than that found in the current study. Jackson et al. (2006) reported an increase of only 2.9 nmol/l, Kirschbaum and Hellhammer (1992) an increase of 4 nmol/l, and both Kirschbaum, Wüst, et al. (1993), and Scoofs, Preuβ, and Wolf (2008) an increase of 6 nmol/l. In contrast, the majority of studies in this area report increase greater than 7 nmol/l (see, e.g., Elzinga & Roelofs, 2005; Kulhman et al., 2005; Wolf, Schommer, et al., 2001), with many reporting increases greater than 12 nmol/l (see, e.g., Nater et al., 2007; Oei, Everaerd, Elzinga, Van Well, & Bermond, 2006). It appears, then, that the procedures employed in the current study did not induce as large a cortisol response in male participants as did those in the majority of previously published studies in this research area.

Overall, and for both female and male participants, it appears that the stress induction procedure used in the current study did not induce as large a cortisol response in participants exposed to it as did previous studies that used the TSST in a stress-cognition experimental paradigm. The lower cortisol response found in the current study could explain why stressed participants, and male participants in the Stress group did not show a greater decrease in true memory over a 24-hour retention period. It would also explain why stressed participants and male participants in the Stress group did not show a greater amount of false memories.

Possible reasons for this discrepancy between previous studies and this one are discussed in the next section.

Reasons for a Lower Cortisol Response Compared to Previously Published Studies

There are several reasons why the current study did not induce as large a cortisol response compared to previous studies. These include: a) timing of cortisol samples taken, b) chronic nicotine consumption, and c) method of cortisol sampling. Each of these contributing factors is discussed in further detail below.

Perhaps the lower peak cortisol levels reached by participants in the current study were due to the time of sampling. Some studies have found that peak cortisol levels are only reached as much as 50 minutes after the administration of an acute psychosocial stressor (Kirschbaum, Pirke, et al., 1993). This delay in reaching peak cortisol increases after the onset of stress occurs because it takes time to activate the HPA axis (Dickerson & Kemeny, 2004). Therefore, Kudielka and Kirschbaum (2005) recommend that several cortisol samples should

be taken throughout a study to accurately measure baseline functioning, the initial stress response, and the recovery phase. In their own study, Kudielka and Kirschbaum (2005) found that the initial stress response could be measured 5-20 minutes after the cessation of the stress induction procedure, whereas peak cortisol levels were only detected 10-30 minutes later after the cessation of that procedure. Similarly, Kirschbaum and Hellhammer (1992) reported that peak cortisol levels were only reached 30 minutes after the cessation of the stress induction procedure. In the current study, the post-TSST cortisol samples were collected only 5 minutes after cessation of the stress induction procedure; clearly, then, our procedures might not have allowed enough time to elapse for peak cortisol levels to be reached.

Psychoneuroendocrine studies have shown large inter-individual differences in cortisol responses (Kirschbaum, Pirke, et al., 1993), with multiple factors influencing these responses. For example, chronic nicotine consumption is a strong activator of the HPA axis system (Matta, Fu, Valentine, & Sharp, 1998), causing elevated basal cortisol levels, which are in turn associated with smaller magnitude of cortisol responses to stress (Kirschbaum & Hellhammer, 1994). Although we did ask participants in the current study to refrain from smoking for 1 hour before their Day 2 appointment, we did not control for the fact that some participants may have been regular smokers. It should be noted that many previous studies did not control for chronic nicotine consumption, and it is not to say that the current studies population contained more people who smoke than previous studies samples. Even with this is mind, participants that were chronic smokers may have contributed to the lower cortisol responses found in the current study.

The use of salivettes in the current study could be another possible explanation for the lower magnitude of cortisol responses compared to previous studies. Although cotton-based devices are an accepted and frequently used method for the assessment of cortisol, some have been shown to affect the assay results. For instance, Strazdins et al. (2005) reported that cotton salivettes (such as those used in the current study) reduced the concentration of cortisol in the assay, whereas cellulose-cotton eyespears did not.

Furthermore, while salivary cortisol levels strongly agree with the amount of free cortisol in blood, they only show a moderate correlation with total cortisol levels (Kirschbaum & Hellhammer, 1994; Kudielka & Kirschbaum, 2005). Therefore, while assessment of cortisol

levels in saliva is non-invasive and cost effective, it may not be a true reflection of our body's response to stressful stimuli.

The Relationship between Memory and Cortisol Response

The relationship between memory and circulating glucocorticoids typically follows an inverted-U shaped pattern, indicating that acute stress can have both enhancing and impairing effects on memory, depending on how intensely the stressor is experienced by the individual (Conrad, Lupien, & McEwen, 1999; McEwen, 1997). More specifically, a certain level of cortisol is needed to enhance memory functioning, and increases beyond the threshold of optimal functioning impair memory.

Even more specifically with regard to how different types of memorized material might be affected by stress, cortisol at very low levels can enhance memory for neutral words (see, e.g, Buchanan & Lovallo, 2001), whereas cortisol responses of greater magnitude are associated with impaired declarative memory (see, e.g., Andreano et al., 2008; Kirschbaum, Wolf, et al., 1996; Lupien et al., 1994; Wolf, Schommer, et al., 2001).On the other hand, studies have found that cortisol response has a more enhancing effect on memory for emotional material (Buchanan & Tranel, 2008). The results for emotional materials need not concern us here, given that the current study's materials were all neutral (i.e., emotionally non-provocative) in nature.

Newcomer et al. (1994, 1999) suggest that *prolonged* glucocorticoid increases are necessary to impair learning and memory. They found that after 4 days of oral cortisol administration, the group who received a higher cortisol dosage performed more poorly on a declarative memory task. Prolonged glucocorticoid exposure has also been shown to impair learning of declarative material in animals (Conrad, Galea, Kuroda, & McEwen, 1996; Luine et al., 1994). The fact the current study only induced acute glucocorticoid increases could be a possible explanation why in many instances, memory performance was not modulated by the presence of a stressor, biological sex, or an interaction of the two.

The impact of stress on memory, whether acute or prolonged, seems to depend on the differential activation of glucocorticoid receptors in the brain. Only when cortisol levels are elevated (as might happen following exposure to a stressor), and both MR and GR receptors are activated, is memory consolidation and learning impaired (Alderson & Novack, 2002).

The activation of MR receptors through basal cortisol levels increases long-term potentiation (LTP) and hippocampal plasticity, thereby enhancing memory processing. However, when both MRs and GRs are activated by stress-related cortisol elevations, LTP decreases and plasticity is inhibited, thereby impairing memory processing (de Kloet et al., 1999; Kim & Yoon, 1998). The fact that the current study induced cortisol increases of a lower magnitude than that in previous studies may have meant that both MR and GR receptors were not activated, explaining why participants in the Stress group did not show memory impairments relative to those in the Relax group.

Since the current study induced lower cortisol increases compared to previous studies, the increase may have only raised cortisol levels to below the threshold of the inverted-U, resulting in equal performances by the Stress and Relax groups'. Furthermore, with regard to the prediction that true memory would decrease over a 24-hour retention period, if cortisol was only increased below a particular threshold of the inverted-U curve, that rise in the hormone may have served to enhance memory processing, thereby explaining why, in many instances true memory was not impaired over the retention period. Furthermore, true memory decay did not seem to be modulated by experimental condition, which could be explained by the low cortisol responses induced in the Stress group. Although cortisol levels were significantly higher in Stress group participants compared to Relax group participants after the experimental manipulation, cortisol levels in all participants could have been below the threshold mentioned above, thereby not causing significantly more memory impairment in the Stress group.

Furthermore, with regard to sex differences in cortisol response, if participants of one sex showed a higher cortisol response than those of the other, it is predicted that the former would also show poorer memory performance. In the current study, male participants in the Stress group showed a significantly higher cortisol response compared to females, but both sexes showed lower cortisol elevations compared to previous studies. This fact could explain why there was no significant difference between stress-exposed male and females false and true memory performances.

The relationship between cortisol elevation and memory is made even more complex by the fact that modulation of memory by cortisol is dependent on the time of day at which the stressor is applied. Activity in the HPA axis follows a circadian rhythm, with cortisol levels

highest in the morning and then decreasing over the course of the day. Higher basal cortisol levels (such as those seen in the morning) are associated with smaller magnitudes of stress-related increases in cortisol (Kudielka et al., 2004). Specifically, the ceiling values in baseline cortisol levels in the morning are assumed to flatten the extent of the superimposed stress response.

With regard to psychological stress and HPA axis response, most studies have found higher cortisol responses in the afternoon and evening (Maheu, Collicutt, Kornik, Moszkowski, & Lupien, 2005), however some found no differences according to time of day (Kudielka et al., 2004). The current study, which was conducted in the afternoon/evening produced lower cortisol responses compared to previous studies. This does not support the literature that under psychological stress, HPA axis responses are higher in the afternoon and evening.

The circadian rhythm of the HPA axis and cortisol levels leads to differential activation of MR and GR receptors. In the morning, when basal cortisol levels are at their peak, MR receptors are saturated, whereas GR receptors only have a 67-74% occupation. In the evening, when basal cortisol levels are lower, MR receptors have a 90% occupation, whereas GR receptors only have a 10% occupation (de Kloet et al., 1999). If a stressor is applied in the morning, increased cortisol levels will act by saturating GR receptors, whereas the same stressor applied in the evening will only occupy half of the GR receptors it did in the morning (Lupien et al., 2002). Recall that stress-induced elevations in cortisol modulate declarative memory according to an inverted-U shaped curve, with moderate levels of cortisol needed for optimal memory functioning, whereas higher or lower levels impair memory (de Kloet et al., 1999). Lupien et al. (2002) suggest that if a stressor is applied in the morning it will impair memory processing (because cortisol levels will be higher and occupy the right hand side of the inverted-U curve), whereas a stressor applied in the afternoon or evening will have no impairing effect on memory (because cortisol levels will occupy the left hand side or top of the inverted-U curve). A meta-analysis by Het et al. (2005) confirmed these predictions: stress-related cortisol elevations in the morning significantly impaired memory, whereas elevations in the afternoon enhanced memory. In sum, then, perhaps studies conducted in the afternoon are less likely to detect the negative effects of psychosocial stress on memory. Because the current study was conducted in the late afternoon, stress-related cortisol increases

(which were lower than previous studies) may not have been great enough to impair memory processing.

Furthermore, the time of day of testing could explain why not all true memory decreased over a 24-hour retention period as expected, and why false memory was not modulated by the presence of a stressor. The small magnitude of cortisol responses would also explain why true memory declines did not differ between male and female participants in the Stress group, but cannot explain why, in many instances, participants in the Relax group showed a greater decline than the Stress group. In some instances, true memory increased over a 24-hour retention period, which again could be a result of the time of day at which testing occurred, with cortisol elevations in the afternoon enhancing memory.

False Memory Recognition Errors over a 24-hour Retention Period

Although the current study tested the prediction that false memory recognition errors would remain stable over a 24-hour period, the obtained data showed that false memory rates increased over a 24-hour retention period in all participants (a possible explanation for this is discussed in the next section). Although some studies have shown that false memories remain relatively stable over a 24-hour delay (Bartlett, 1932; D. G. Payne et al., 1996; J. D. Payne et al., 2006), others have found that false memories increase over a delayed retention period (McDermott, 1996; Spiro, 1980). The current study found that false memory increased over a 24-hour retention period in all participants, which is in support of findings by McDermott (1996) and Spiro (1980). It is possible that false memories remain relatively stable over a 24-hour retention period under normal circumstances, but increase over a 24-hour retention period under the influence of a stressor. The current study was one of the first to investigate the decay of false memories over a 24-hour retention period under the influence of stress, and further exploration is needed.

Race and Cortisol Response

Although the relationship between race and cortisol response was not examined in the current study, some recent studies have found race-based differences in HPA axis response to psychological stress (see, e.g., Chong, Uhart, McCaul, Johnson, & Wand, 2008; Wilcox, Bopp, Wilson, Fulk, & Hand, 2005). The Chong et al. (2008) study used 98 healthy

participants (aged 18-30 years), with both white and black participants in their sample. They found that white participants displayed statistically significantly higher cortisol and ACTH responses after administration of the TSST compared to blacks, while subjective anxiety did not differ between races. In contrast, however, Wilcox et al. (2005) conducted a study using 16 white and 12 African-American participants (all post-menopausal women). They found that their African-American participants displayed a statistically significantly higher cortisol response to psychological stress (an interpersonal challenge) than did their white participants. In the current study, there were 19 white and 25 black (defined as both African and Coloured) participants in the Stress group (including cortisol non-responders). White participants showed an increase in cortisol levels from baseline to post-TSST of 4.89 nmol/l, whereas black participants showed only an increase of 3.18 nmol/l. An independent samples t-test revealed that there was no statistically significant difference between the current studies black and white participants cortisol increases in response to the TSST, $t(42) = 0.82$, $p = .419$ (two-tailed). Although no significant difference was found, this finding is consistent with the work of Chong and colleagues (2008), with whites displaying a larger cortisol increase compared to blacks.

Several of the factors that affect the magnitude of the stress response on their own seem to interact with race to produce interesting effects on cortisol levels. Three of these factors are type of stressor employed, diurnal variation in cortisol, and socio-economic status (SES).

With regard to the type of stressor employed, studies have found an association between race and magnitude of cortisol response to psychological stressors (e.g., Wilcox et al., 2005), but no such association in the case of physical stressors, such as exercise (Giannopoulou, Carhart, Sauro, & Kanaley, 2003; Yanovski et al., 2000). Perhaps a physical reaction on their own is not enough to induce racial differences in stress response, and an additional psychological reaction is needed.

With regard to diurnal variation in cortisol, studies have demonstrated that black participants show a less steep decline in cortisol levels throughout the day (Cohen et al., 2006), resulting in higher evening cortisol levels compared to white participants. This does not seem to be the case in the current study, as white participants had an average baseline cortisol

level of 3.80nmol/l, whereas black participants average baseline cortisol level was 1.40nmol/l, which is not consistent with the finding that blacks have higher cortisol levels in the evening.

SES is another mediating factor that has been linked to cortisol responsiveness (Cohen et al., 2006). Increasing SES has been associated with higher morning cortisol levels in both males and females (Brandtstädter, Baltes-Götz, Kirschbaum, & Hellhammer, 1991). However, results are not consistent, as (Decker, 2000) found no association between SES and morning cortisol levels in both men and women. Furthermore, higher SES has been associated with lower average cortisol levels throughout the day in men, but not in women (Steptoe et al., 2003). The above results suggest that race; in conjunction with SES seem to play a role in cortisol levels.

Although some studies reviewed above have demonstrated a link between race and cortisol levels or cortisol responsiveness, the mechanisms underlying these effects are not well understood (Richman & Jonassaint, 2008). One possible explanation is the physiological variations in the stress hormone cortisol (Chong et al., 2008). Variations in human glucocorticoid receptor genes have been associated with race, pointing to the possibility that cortisol response is partly heritable (Wüst et al., 2004). However, there is not much evidence supporting this, and further investigation needs to be conducted to determine the underlying biological and genetic influences contributing to racial differences in cortisol levels and responsiveness to stressful situations.

Limitations and Direction for Future Research

The primary aims of the current study were to investigate the impact of stress, biological sex, and time retention on the material specificity of false memory, and to investigate the decay of both true and false memory over a 24-hour retention period. Although not all hypotheses were confirmed, some results tended towards the predicted direction, which indicates that there is continued promise in the study of the impairing effects of stress, and the moderating effects of sex, on the occurrence and nature of false recognition memory.

Several limitations of the current study need to be addressed by future researchers who wish to clearly outline the relationship between stress, sex, and false memory. First, although the sample size used here was larger than those used in previously published studies in

this field, the effects being studied may require an even larger group of participants. A larger sample size should yield promising results, by adding more power to statistical analyses. In addition, given the large number of participants who had to be dropped due to the fact they were cortisol non responders), recruiting larger numbers of participants is imperative.

Second, cortisol increases in response to the TSST were lower than those reported in other studies (e.g., Kirschbaum & Hellhammer, 1992; Kirschbaum, Wolf, et al., 1996; Wolf, Schommer, et al., 2001). This difference in magnitude cannot easily be explained, as the current study adhered to the original TSST procedure strictly. One possible explanation is that the interview panel consisted of postgraduate students, at least some of whom the participants may have known. Therefore, future studies should use an interview panel consisting of older people, and/or of people whom participants would never have encountered before.

Third, meal intake has been shown to affect HPA axis response depending on the time of day, with higher increases in the afternoon, but attenuated or even absent cortisol responses in the evening (Quigley & Yen, 1979). While the current study did ask participants not to eat one hour prior to their Day 2 appointment, perhaps more stringent control over meal intake should be used in future studies.

Fourth, the nature of the HPA axis activation and duration of the activation are important considerations. Investigations into the effect of time of day on HPA axis response by applying pharmacological provocation yields varied results. Most evidence points to larger cortisol responses to pharmacological stimulation in the afternoon and evening, however other studies have found no effect of time of day on cortisol response (Kudielka et al., 2004). Results are inconsistent, and seem dependent on the type of stimulation used. Future studies should include both physical, pharmacological, and psychological HPA axis stimulation to evaluate a wider spectrum of effects.

Furthermore, using healthy, young participants limits the study's ability to generalise results to the general population, as HPA axis responses may differ in clinical populations. Furthermore, the use of laboratory stress induction procedures may not truly reflect real-life stressors, as they may misinterpret the extent to which naturally occurring stressors elicit cortisol responses. Therefore a number of different types of stressors, plus a more diverse sample, should be used in order to generalise results.

Fifth, while cortisol increases are affected by time of day, stress related heart rate increases don't seem to be affected (Kudielka et al., 2004). Studies have demonstrated that the effects of stress on memory are dependent on both autonomic nervous system (ANS; heart rate and skin conductance) and HPA axis activation. Elzinga and Roelofs (2005) showed impairments in working memory after stress only when both cortisol and heart rate were elevated. Similarly, Buchanan and Tranel (2008) found that only participants who displayed increased heart rate and cortisol levels in response to a stressor showed reduced memory retrieval. Furthermore, Kuhlmann et al. (2005) found that moderate increase in cortisol, in combination with activation of the ANS to a psychosocial stressor led to impaired memory retrieval. True and false memory performance in the current study did not seem to be modulated by sex, which could be due the fact that while males showed a greater increase in cortisol response to the TSST, females showed a greater heart rate response (see Appendix E). Variations in cardiac control are complex and finer methods of detection may be necessary. This was a limitation in the current study, as a fairly crude cardiovascular measure was employed, and many participants heart rate could not be measured due to machine malfunctions.

Sixth, many studies use confidence ratings to determine not only whether people a remember event, but the accuracy with which they remember it (D. G. Payne et al., 1996; Roediger & McDermott, 1995; Tulving, 1985). Such ratings were not used in the current study, primarily due to the fact that the study phase was already lengthy. The inclusion of such confidence ratings might be important for future studies, however: If people frequently say, with confidence, that they can mentally recollect an event that has never occurred, this could have important implications for how much emphasis can be placed on the accuracy of those memories. Previous studies have shown that 'remember' responses (being able to mentally relieve the experience of when an event occurred) decline quite steeply over a 24-hour retention period, whereas 'know' responses (confidence an event occurred but not being able to mentally relive it) decrease more gradually over time (Knowlton & Squire, 1995). Furthermore, Johnson and Raye (1981) found that memories for actually occurring events provided more spatial and temporal details than those for imagined events. This resulted in more 'remember' responses for true memories, and more 'know' responses for false memories. To my knowledge, there have been no studies investigating the effects of stress on

false memory that include remember/know ratings; such inclusion might be a promising direction for future research.

Finally, most human studies investigating the relationship between memory performance and stress response use sample sizes too small to detect gender differences (Kirschbaum, Wolf, et al., 1996; Lupien et al., 1997, 1999). Furthermore, many studies using female participants do not control for phase of menstrual cycle or use of oral contraceptives (de Quervain et al., 2000; Newcomer et al., 1999). The current study used a relatively large sample size and did control for phase of menstrual cycle and use of oral contraceptives. Even with this in mind, this was one of the first studies to investigate the effect of stress, biological sex, and time retention on the material specificity of false memory; therefore questions remain open for future research

References

Alderson, A. L., & Novack, T. A. (2002). Neurophysiological and clinical aspects of glucocorticoids and memory: A review. *Journal of Clinical and Experimental Neuropsychology, 24*, 335-355.

Andreano, J. M., Arjomandi, H., & Cahill, L. (2008). Menstrual cycle modulation of the relationship between cortisol and long-term memory. *Psychoneuroendocrinology, 33*, 874–882.

Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge, England: Cambridge University Press.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio, TX: Psychological Corporation.

Beck, A. T., Steer, R. A., & Garbin, G. M. (1988). Psychometric properties of the Beck Depression Inventory: Twenty-five years of evaluation. *Clinical Psychology Review, 8*, 77-100.

Bebbington, P. E. (1996). The origins of sex differences in depressive disorder: Bridging the gap. *International Review of Psychiatry, 8*, 295–332.

Bodnoff, S. R., Humphreys, A. G., Lehman, J. C., Diamond, D. M., Rose, G. M., & Meaney, M. J. (1995). Enduring effects of chronic corticosterone treatment on spatial memory learning, synaptic plasticity and hippocampal neuropathology in young and mid-aged rats. *Journal of Neuroscience, 15*, 61-69.

Bonito Attwood, C. (2008). *The impact of acute psychological stress on spatial cognition.* Unpublished master's thesis. University of Cape Town, Cape Town, South Africa.

Boyer, P., Phillips, J. L., Rousseau, F. L., & Ilivitsky, S. (2007). Hippocampal abnormalities and memory deficits: New evidence of a strong pathophysiological link in schizophrenia. *Brain Research Reviews, 54*, 92-112.

Brainerd, C. J., & Reyna, V. F. (1990). Gist is the gist: The fuzzy-trace theory and new intuitionism. *Developmental Review, 10*, 3–47.

Brandtstädter, J., Baltes-Götz, B., Kirschbaum, C., & Hellhammer, D. (1991). Developmental and personality correlates of adrenocortical activity as indexed by salivary cortisol: Observations in the age range of 35-65 years. *Journal of Psychosomatic Research, 35*, 173-185.

Buchanan, T. W., & Lovallo, W. R. (2001). Enhanced memory for emotional material following stress-level cortisol treatment in humans. *Psychoneuroendocrinology, 26*, 307-317.

Buchanan, T. W., & Tranel, D. (2008). Stress and emotional memory retrieval: Effects of sex and cortisol response. *Neurobiology of Learning and Memory, 89*, 134-141.

Budson, A. E., Dodson C. S., Vatner, J. M., Daffner, K. R., Black, P.M., & Schacter, D. L. (2005). Metacognition and false recognition in patients with frontal lobe lesions: The distinctiveness heuristic. *Neuropsychologia*, *43*, 860-871.

Budson, A. E., Droller, D. B. J., Dodson C. S., Schacter, D. L., Rugg, M. D., Holcomb, P. J., & Daffner, K. R. (2005). Electrophysiological dissociation of picture versus word encoding: The distinctiveness heuristic as a retrieval orientation. *Journal of Cognitive Neuroscience, 17*, 1181-1193.

Budson, A. E., Sitarski, J., Daffner, K. R., & Schacter, D. L. (2002). False recognition of pictures versus words in Alzheimer's disease: The distinctiveness heuristic. *Neuropsychology, 16*, 163-173.

Burgess, L. H., & Handa, R. J. (1992). Chronic estrogen-induced alterations in adrenocorticotropin and corticosterone secretion, and glucocorticoid receptor-mediated functions in female rats. *Endocrinology, 131*, 1261–1269.

Burgess, P. W., & Shallice, T. (1996). Confabulation and the control of recollection. *Memory, 4*, 359–411.

Carlson, L. E., & Sherwin, B. B. (1999). Relationships among cortisol (CRT), dehydroepiandrosterone-sulfate (DHEAS), and memory in a longitudinal study of healthy elderly men and women. *Neurobiology of Aging, 20*, 315–324.

Chong, R. Y., Uhart, M., McCaul, M. E., Johnson, E., & Wand, G. S. (2008). Whites have a more robust hypothalamic-pituitary-adrenal axis response to a psychological stressor than blacks. *Psychoneuroendocrinology, 33,* 246-254.

Cohen, S., Schwartz, J. E., Epel, E., Kirschbaum, C., Sidney, S., & Seeman, T. (2006). Socioeconomic status, race, and diurnal cortisol decline in the coronary artery risk development in young adults (CARDIA) study. *Psychomatic Medicine, 68*, 41-50.

Conrad, C. D., Galea, L. A., Kuroda, Y., & McEwen, B. S. (1996). Chronic stress impairs rat spatial memory on the Y maze, and this effect is blocked by tianeptine pretreatment. *Behavioral Neuroscience, 110,* 1321-1334.

Conrad, C. D., Lupien, S. J., & McEwen, B.S. (1999). Support for a bimodal role for type II adrenal steroid receptors in spatial memory. *Neurobiology of Learning & Memory, 72*, 39–46.

Curran, T., & Cleary, A. M. (2003). Using ERPs to dissociate recollection from familiarity in picture recognition. *Cognitive Brain Research, 15*, 191-205.

Dab, S., Claes, T., Morais, J., & Shallice, T. (1999). Confabulation with a selective descriptor process impairment. *Cognitive Neuropsychology, 16*, 215-242

Decker, S. (2000). Salivary cortisol and social status among Dominican men. *Hormones & Behavior, 38*, 29-38.

de Kloet, E. R., Oitzl, M. S., & Joëls, M. (1993). Functional implications of brain corticosteroid receptor diversity. *Cellular & Molecular Neurobiology, 13*, 433- 455.

de Kloet, E. R., Oitzl, M. S., & Joëls, M. (1999). Cognition: Are corticosteroids good or bad guys. *Trends in Neurosciences, 10,* 422-426.

de Leon, M. J., McRae, T., Rusinek, H., Convit, A., De Santi, S., Tarshish, C., ... McEwen, B. (1997). Cortisol reduces hippocampal glucose metabolism in normal elderly, but not in Alzheimer's disease. *Journal of Clinical Endocrinology and Metabolism, 82*, 3251–3259.

de Quervain, D. J. F., Henke, K., Aerni, A., Treyer, V., McGaugh, J. L., Berthold, T., ... Hock, C. (2003). Glucocorticoid-induced impairment of declarative memory retrieval is associated with reduced blood flow in the medial temporal lobe. *European Journal of Neuroscience, 17*, 1296-1302.

de Quervain, D. J. F., Roozendaal, B., & McGaugh, J. L. (1998). Stress and glucocorticoids impair retrieval of long-term spatial memory. *Nature, 394*, 787–790.

de Quervain, D. J. F., Roozendaal, B., Nitsch, R. M., McGaugh, J. L., & Hock, C. (2000). Acute cortisone administration impairs retrieval of long-term declarative memory in humans. *Nature Neuroscience, 3*, 313–314.

Diamond, D. M., Bennett, M. C., Fleshner, M. & Rose, G. M. (1992). Inverted-U relationship between the level of peripheral corticosterone and the magnitude of hippocampal primed burst potentiation. *Hippocampus, 2*, 421–430.

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130,* 355-391.

Domes, G., Heinrichs, M., Reichwald, U., & Hautzinger, M. (2002). Hypothalamic–pituitary–adrenal axis reactivity to psychological stress and memory in middle-aged women: High responders exhibit enhanced declarative memory performance. *Psychoneuroendocrinology, 27,* 843-853.

Elzinga. B. M., & Roelofs, K. (2005). Cortisol-induced impairments of working memory require acute sympathetic activation. *Behavioral Neuroscience,* 119, 98–103.

Filip, V., Alda, M., David, I,, Topinka, J., Kristofikova, Z., Dvorakova, J., ... Albrecht, V. (1989). Neuroendocrine response to clomipramine and desipramine: The evidence of partial determination by heredity and sex. *Neuropsychobiology, 21,* 111-116.

Galea, L. A. M., McEwen, B. S., Tanapat, P., Deak, T., Spencer, R. L., & Dhabhar, F. S. (1997). Sex differences in dendritic atrophy of CA3 pyramidal neurons in response to chronic restraint stress. *Neuroscience, 81,* 689-697.

Gallo, D. A., Kensinger, E. A., & Schacter, D. L. (2006). Prefrontal activity and diagnostic monitoring of memory retrieval: fMRI of the critical recollection task. *Journal of Cognitive Neuroscience*, 18, 135-148.

Gallo, D. A., & Roediger, H. L. (2002). Variability among word lists in eliciting memory illusions: Evidence for associative activation and monitoring. *Journal of Memory & Language, 47,* 469-497.

Gallo, D. A., Weiss, J. A., & Schacter, D. L. (2004). Reducing false recognition with critical recollection tests: Distinctiveness heuristic versus criterion shifts. *Journal of Memory & Language, 51,* 473-493.

Giannopoulou, I., Carhart, R., Sauro, L. M., & Kanaley, J. A. (2003). Adrenocortical responses to submaximal exercise in postmenopausal black and white women. *Metabolism, 52*, 1643-1647.

Grady, C. L., McIntosh, A. R., Rajah, M. N., & Craik, F. I. M. (1998). Neural correlates of the episodic encoding of pictures and words. *Proceedings of the National Academy of Sciences, 95*, 2703-2708.

Griffin, A. C., & Whitacre, C. C. (1991). Sex and strain differences in the circadian rhythm fluctuation of endocrine and immune function in the rat: Implications for rodent models of autoimmune disease. *Journal of Neuroimmunology, 35*, 53-64.

Haleem, D. J., Kennett, G., & Curzon, G. (1988). Adaptation of female rats to stress: shift to male pattern by inhibition of corticosterone synthesis. *Brain Research, 458***,** 339–347.

Hampson, E. (1990a). Estrogen-related variations in human spatial and articulatory-motor skills. *Psychoneuroendocrinology, 15*, 97–111.

Hampson, E. (1990b). Variations in sex-related cognitive abilities across the menstrual cycle. *Brain & Cognition, 14*, 26-43.

Hampson, E., Finestone, J. M., & Levy, N. (2005). Menstrual cycle effects on perceptual closure mediate changes in performance on a fragmented objects test of implicit memory. *Brain and Cognition, 57*, 107–110.

Handa, R. J., Burgess, L. H., Kerr, J. E., & O'Keefe, J. A. (1994). Gonadal steroid hormone receptors and sex differences in the hypothalamic–pituitary–adrenal axis. *Hormones & Behavior, 28*, 464–476.

Herman, B. H., Arthur-Smith, A., Hammock, M. K., & Josephs, S. (1988). Ontogeny of beta-endorphin and cortisol in the plasma of children and adolescents. *Journal of Clinical Endocrinology & Metabolism, 67,* 186-190.

Het, S., Ramlow, G., & Wolf, O. T. (2005). A meta-analytic review of the effects of acute cortisol administration on human memory. *Psychoneuroendocrinology, 30,* 771-784.

Het, S., & Wolf, O. T. (2007). Mood changes in response to psychosocial stress in healthy young women: Effects of pretreatment with cortisol. *Behavioral Neuroscience, 121*, 11-20.

Hyde, J. S., Fennema, E., & Lamon, S. J. (1990). Gender differences in mathematics performance: A meta-analysis. *Psychological Bulletin, 107*, 139-155.

Israel, L., & Schacter, D. L. (1997). Pictorial encoding reduces false recognition of semantic associates. *Psychonomic Bulletin & Review, 4*, 577-581.

Jackson, E. D., Payne, J. D., Nadel, L., & Jacobs, W. J. (2006). Stress differentially modulates fear conditioning in healthy men and women. *Biological Psychiatry, 59*, 516-522.

Jacoby, L. L., Kelley, C. M., & Dywan, J. (1989). Memory attributions. In H. L. Roediger III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 391-422). Hillsdale, NJ: Erlbaum.

Joëls, M. (2003). Corticosteroid actions in the hippocampus. *Journal of Neuroendocrinology, 13*, 657–669.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin, 114*, 3-28.

Johnson, M. K., & Raye, C. L. (1981). Reality monitoring. *Psychological Review, 88*, 67-85.

Johnson, M. K., & Raye, C. L. (1998). False memories and confabulation. *Trends in Cognitive Sciences, 2*, 137-145.

Kahn, J. P., Rubinow, D. R., Davis, C. L., Kling, M., & Post, R. M. (1988). Salivary cortisol: A practical method for evaluation of adrenal function. *Biological Psychiatry, 23*, 335-349.

Kelly, M. M., Tyrka, A. R., Anderson, G. M., Price, L. H., & Carpenter, L. L. (2007). Sex differences in emotional and physiological responses to the trier social stress test. *Journal of Behavior Therapy and Experimental Psychiatry, 39*, 87–98.

Kessler, R. C., Brown, R. L., & Broman, C. L. (1981). Sex differences in psychiatric help-seeking: evidence from four large-scale surveys. *Journal of Health & Social Behaviour, 22*, 49–64.

Kim, J. J., & Diamond, D. M. (2002). The stressed hippocampus, synaptic plasticity and lost memories. *Nature Reviews Neuroscience, 3*, 453-462.

Kim, J. J., & Yoon, K. S. (1998). Stress: Metaplastic effects in the hippocampus. *Trends in Neuroscience, 21*, 505-509.

Kirschbaum, C., & Hellhammer, D. H. (1992). Methodological aspects of salivary cortisol measurement. In C. Kirschbaum, G. F. Reeds, & D. H. Hellhammer (Eds.), *Assessment of hormones and drugs in saliva in biobehavioural research* (pp. 19-32*)*. Seattle, WA: Hogrefe & Huber.

Kirschbaum, C., & Hellhammer, D. H. (1994). Salivary cortisol in psychoneuroendocrine research: Recent developments and applications. *Psychoneuroendocrinology, 19*, 313-333.

Kirschbaum, C., Kudielka, B. M., Gaab, J., Schommer, N. C., & Hellhammer, D. H. (1999). Impact of gender, menstrual cycle phase, and oral contraceptives on the activity of the hypothalamus-pituitary-adrenal axis. *Psychosomatic Medicine, 61,* 154-162.

Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1993). The Trier Social Stress Test - A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28,* 76-81

Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1995). Preliminary evidence for reduced cortisol responsivity to psychological stress in women using oral contraceptives. *Psychoneuroendocrinology, 20,* 509-514.

Kirschbaum, C., Schommer, N., Federenko, I., Gaab, J., Neumann, O., Oellers, M., ... Hellhammer, D. H. (1996). Short-term estradiol treatment enhances pituitary-adrenal axis and sympathetic responses to psychosocial stress in healthy young men. *Journal of Clinical Endocrinology & Metabolism, 81,* 3639-3643.

Kirschbaum, C., Wolf, O. T., May, M., Wippich, W., & Hellhammer, D. H. (1996). Stress and treatment-induced elevation of cortisol levels associated with impaired declarative memory in healthy adults. *Life Science, 58,* 1475-1483.

Kirschbaum, C., Wüst, S., & Hellhammer, D. (1993). Consistent sex differences in cortisol responses to psychological stress. *Psychosomatic Medicine, 54,* 648-657.

Kitay, J. I. (1961). Sex differences in adrenal cortical secretion in the rat. *Endocrinology, 68,* 818–24.

Kitay, J. I. (1963). Pituitary-adrenal function in the rat after gonadectomy and gonadal hormone replacement. *Endocrinology, 73,* 253–60.

Knowlton, B. J., & Squire, L. R. (1995). Remembering and knowing: Two different expressions of declarative memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 21,* 699–710.

Kroenke, K., & Spitzer, R. L. (1998). Gender differences in the reporting of physical and somatoform symptoms. *Psychosomatic Medicine, 60,* 150–155.

Kudielka, B. M., Buske-Kirschbaum, A., Hellhammer, D. H., & Kirschbaum, C. (2004a). Differential heart rate reactivity and recovery after psychosocial stress (TSST) in healthy children, younger adults, and elderly adults: The impact of age and gender. *International Journal of Behavioral Medicine, 11,* 116-121.

Kudielka, B. M., Buske-Kirschbaum, A., Hellhammer, D. H., & Kirschbaum, C. (2004b). HPA axis responses to laboratory psychosocial stress in healthy elderly adults, younger adults, and children: Impact of age and gender. *Psychoneuroendocrinology, 29,* 83–98.

Kudielka, B. M., Hellhammer, D. H., & Wüst, S. (2009). Why do we respond so differently? Reviewing determinants of human salivary cortisol responses to challenge. *Psychoneuroendocrinology, 34,* 2-18.

Kudielka, B. M., & Kirschbaum, C. (2005). Sex differences in HPA axis response to stress: A review. *Biological Psychology, 69,* 113-132.

Kudielka, B. M., Schommer, N. C., Hellhammer, D. H., & Kirschbaum, C. (2004). Acute HPA axis responses, heart rate, and mood changes to psychosocial stress (TSST) in humans at different times of day. *Psychoneuroendocrinology, 29,* 983-992.

Kuhlmann, S., Piel, M., & Wolf, O.T. (2005). Impaired memory retrieval after psychosocial stress in healthy young men. *Journal of Neuroscience, 25,* 2977-2982.

Lovallo, W. R. (1997). *Stress and health: Biological and psychological interactions*. Thousand Oaks, CA: Sage.

Luine, V., Villages, M., Martinex, C., & McEwen, B. S. (1994). Repeated stress causes reversible impairments of spatial memory performance. *Brain Research, 639*, 167-170.

Lupien, S. J., Gaudreau, S., Tchiteya, B. M., Maheu, F., Sharma, S., Nair, N.P.V., ... Meaney, M. J. (1997). Stress-induced declarative memory impairment in healthy elderly subjects: Relationship to cortisol reactivity. *Journal of Clinical Endocrinology and Metabolism, 82*, 2070-2075.

Lupien, S. J., Gillin, C. J., & Hauger, R. L. (1999) Working memory is more sensitive than declarative memory to the acute effects of corticosteroids: A dose-response study in humans. *Behavioural Neuroscience, 113*, 420-430.

Lupien, S. J., Lecours, A. R., Lussier, I., Schwartz, G., Nair, N. P. V., & Meaney, M. J. (1994). Basal cortisol levels and cognitive deficits in human aging. *The Journal of Neuroscience, 74*, 2893-2903.

Lupien, S. J., Wilkinson, C. W., Brie`re, S., Me´nard, C., Yin Kin, N. M. K., & Nair, N. P. V. (2002). The modulatory effects of corticosteroids on cognition: Studies in young human populations. *Psychoneuroendocrinology, 27*, 401–416.

Maheu, F. S., Collicutt, P., Kornik, R., Moszkowski, R., & Lupien, S. J. (2005). The perfect time to be stressed: A differential modulation of human memory by stress applied in the morning or in the afternoon. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 29*, 1281-1288.

Maki, P. M., Rich, J. B., & Rosenbaum, R. S. (2002). Implicit memory varies across the menstrual cycle: Estrogen effects in young women. *Neuropsychologia, 40*, 518–529.

Marsh, E. J., McDermott, K. B., & Roediger, H. L. (2004). Does test-induced priming play a role in the creation of false memories? *Memory, 12*, 44-55.

Matta, S. G., Fu, Y., Valentine, J. D., & Sharp, B. M. (1998). Response of the hypothalamo-pituitary-adrenal axis to nicotine. *Psychoneuroendocrinology, 23,* 103-113.

McDermott, K. B. (1996). The persistence of false memories in list recall. *Journal of Memory & Language, 35*, 212-230.

McDermott, K. B., & Watson, J. M. (2001). The rise and fall of false recall: The impact of presentation duration. *Journal of Memory & Language*, 45, 160-176.

McEwen, B. S. (1997). The brain is an important target of adrenal steroid actions: A comparison of synthetic and natural steroids. *Annals of the New York Academy of Sciences, 823*, 201-213.

McEwen, B. S., & Magarinos, A. M. (1997). Stress effects on morphology and function of the hippocampus. *Annals of the New York Academy of Sciences, 821*, 271–284.

McGonagle, K. A., & Kessler, R. C. (1990). Chronic stress, acute stress, and depressive symptoms. *American Journal of Community Psychology, 18*, 681–706.

Mendl, M. (1999). Performing under pressure: Stress and cognitive function. *Applied Animal Behaviour Science, 65*, 221-244.

Mitchell, K. J., Johnson, M. K., Raye, C. L., & D'Esposito, M. (2000). fMRI evidence of age-related hippocampal dysfunction in feature binding in working memory. *Cognitive Brain Research, 10*, 197-206.

Moghaddam, B. (2002). Stress activation of glutamate neurotransmission in the prefrontal cortex: Implications for dopamine-associated psychiatric disorders. *Biological Psychiatry, 51*, 775–787.

Morris, R. G. M. (1984). Developments of a water-maze procedure for studying spatial learning in the rat. *Journal of Neuroscience Methods, 11*, 47-60.

Multhaup, K. S., & Conner, C. A. (2002). The effects of considering nonlist sources on the Deese-Roediger-McDermott memory illusion. *Journal of Memory & Language, 47*, 214-228.

Nater, U. M., Moor, C., Okere, U., Stallkamp, R., Martin, M., Ehlert, U., & Kliegel, M. (2007). Performance on a declarative memory task is better in high than low cortisol responders to psychosocial stress. *Psychoneuroendocrinology, 32*, 758-763.

Newcomer, J. W., Craft, S., Hershey, T., Askins, K., & Bardgett, M. E. (1994). Glucocorticoid-induced impairment in declarative memory performance in adult humans. *The Journal of Neuroscience, 14*, 2047-2053.

Newcomer, J. W., Selke, G., Melson, A. K., Hershey, T., Craft, S., Richards, K., & Alderson, A. L. (1999). Decreased memory performance in healthy humans induced by stress-level cortisol treatment. *Archives of General Psychiatry, 56*, 527-533.

Norman, R. L., Smith, C. J., Pappas, J. D., & Hall, J. (1992). Exposure to ovarian steroids elicits a female pattern of cortisol levels in castrated male macaques. *Steroids, 57*, 37–43.

Oei, N. Y. L., Everaerd, W. T. A. M., Elzinga, B. M., Van Well, S., & Bermond, B. (2006). Psychosocial stress impairs working memory at high loads: An association with cortisol levels and memory retrieval. *Stress, 9*, 133-141.

Pavlides, C., Ogawa, S., Kimura, A., & McEwen, B. S. (1996). Role of adrenal steroid mineralocorticoid and glucocorticoid receptors in long-term potentiation in the CA1 field of hippocampal slices. *Brain Research, 738*, 229–235.

Payne, D. G., Elie, C. J., Blackwell, J. M., & Neuschatz, J. S. (1996). Memory illusions: Recalling, recognizing and recollecting events that never occurred. *Journal of Memory & Language, 35*, 261-285.

Payne, J. D., Jackson, E. D., Ryan, L., Hoscheidt, S., Jacobs, W. J., & Nadel, L. (2006). The impact of stress on neutral and emotional aspects of episodic memory. *Memory, 14*, 1-16.

Payne, J. D., Nadel, L., Allen, J. J. B., Thomas, K. G. F., & Jacobs, W. J. (2002). The effects of experimentally induced stress on false recognition. *Memory, 10*, 1-6.

Postma, A., Winkel, J., Tuiten, A., & van Honk, J. (1999). Sex differences and menstrual cycle effects in human spatial memory. *Psychoneoroendocrinology*, 24, 175-192.

Quigley, M. E., & Yen, S. S. (1979). A mid-day surge in cortisol levels. *Journal of Clinical Endocrinology & Metabolism, 49*, 945–947.

Rajaram, S., & Roediger, H.L. (1993). Direct comparison of four implicit memory tests. *Journal of Experimental Psychology: Learning, Memory & Cognition, 19*, 765-776.

Reder, L. M., Nhouyvanisvong, A., Schunn, C. D., Ayers, M. S., Angstadt, P., & Hiraki, K. (2000). A mechanistic account of the mirror effect for word frequency: A computational model of remember-know judgements in a continuous recognition paradigm. *Journal of Experimental Psychology: Learning, Memory & Cognition, 26*, 294-320.

Richman, L. S., & Jonassaint, C. (2008). The effects of race-related stress on cortisol reactivity in the laboratory: Implications of the Duke Lacrosse Scandal. *Annals of Behavioural Medicine, 35*, 105-110.

Roca, C. A., Schmidt, P. J., Altemus, M., Deuster, P., Danaceau, M. A., Putnam, K., & Rubinow, D. R. (2003). Differential menstrual cycle regulation of hypothalamic–pituitary–adrenal axis in women with premenstrual syndrome and controls. *Journal of Clinical Endocrinology & Metabolism, 88*, 3057–3063.

Roediger, H. L. (1996). Memory illusions. *Journal of Memory & Language, 35*, 76-100.

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented on lists. *Journal of Experimental Psychology: Learning, Memory & Cognition, 21*, 803-814.

Roozendaal, B. (2000). Glucocorticoids and the regulation of memory consolidation. *Psychoneuroendocrinology, 25*, 213–238.

Rosenberg, L., & Park, S. (2002). Verbal and spatial functions across the menstrual cycle in healthy young women. *Psychoneuroendocrinology, 27*, 835-841.

Rudolph, K. D. (2002). Gender differences in emotional responses to interpersonal stress during adolescence. *Journal of Adolescent Health, 30*, 3–13.

Sapolsky, R. M., Krey, L. C., & McEwen, B. S. (1986). The neuroendocrinology of stress and aging: The glucocorticoid cascade hypothesis. *Endocrinology Reviews, 7*, 284-301.

Schacter, D. L., Israel, L., & Racine, C. (1999). Suppressing false recognition in younger and older adults: The distinctiveness heuristic. *Journal of Memory & Language, 40*, 1-27.

Schacter, D. L., & Wagner, A. D. (1999). Medial temporal lobe activations in fMRI and PET studies of episodic encoding and retrieval. *Hippocampus, 9,* 7-24.

Schoofs, D., Preuβ, D., & Wolf, O. T. (2008). Psychosocial stress induces working memory impairments in an n-back paradigm. *Psychoneuroendocrinology, 33,* 643-653.

Schwabe, L., Oitzl, M. S., Philippsen, C., Richter, S., Bohringer, A., Wippich, W., & Schachinger, H. (2007). Stress modulates the use of spatial versus stimulus-response learning strategies in humans. *Learning & Memory, 14*, 109-116.

Seeman, T. E., McEwen, B. S., Singer, B. H., Albert, M. S., & Rowe, J. W. (1997). Increase in urinary cortisol excretion and memory declines: MacArthur studies of successful aging. *Journal of Clinical Endocrinology & Metabolism, 82*, 2458–2465.

Seeman, T. E, Singer, B., & Charpentier, P. (1995). Gender differences in patterns of HPA axis response to challenge: Macarthur studies of successful aging. *Psychoneuroendocrinology, 20*, 711–725.

Sherwin, B. B., & Tulandi, T. (1996). ‘‘Add-back’’ estrogen reverses cognitive deficits induced by a gonadotropin-releasing hormone agonist in women with leiomyomata uteri. *Journal of Clinical Endocrinology and Metabolism, 81*, 2545–2549.

Shors, T. J., Chua, C., & Falduto, J. (2001). Sex differences and opposite effects of stress on dendritic spine density in the male versus female hippocampus. *Journal of Neuroscience, 21*, 6292–6297.

Smeets, T., Dziobek, I., & Wolf, O. T. (2009). Social cognition under stress: Differential effects of stress-induced cortisol elevations in healthy young men and women. *Hormones and Behaviour, 55*, 507–513.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Memory and Learning, 6*, 174-215.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State–Trait Anxiety Inventory*. Palo Alto, TX: Consulting Psychologists Press.

Spielberger, C. D., & Vagg, P. (1984). Psychometric properties of the STAI: A reply to Ramanaiah, Franzen, and Schill. *Journal of Personality Assessment, 48*, 95-97.

Spiro, R. J. (1980). Accomodative reconstruction in prose recall. *Journal of Verbal Learning and Verbal Behavior, 19***,** 84–95.

Starkman, M. N., Gebarski, S. S., Berent, S., & Schteingart, D. E. (1992). Hippocampal formation volume, memory dysfunction, and cortisol levels in patients with Cushing's syndrome. *Biological Psychiatry, 32*, 756–765.

Steptoe, A., Kunz-Ebrecht, S., Owen, N., Feldman, P. J., Willemsen, G., Kirschbaum, C., & Marmot, M. (2003). Socioeconomic status and stress-related biological responses over the working day. *Psychomatic Medicine, 65*, 461-470.

Strazdins, L., Meyerkort, S., Brent, V., D'Souza, R. M., Broom, D. H., & Kyd, J. M. (2005). Impact of saliva collection methods on sIgA and cortisol assays and acceptability to participants. *Journal of Immunological Methods, 307*, 167-171.

Stroud, L. R., Salovey, P., & Epel, E. S. (2002). Sex differences in stress responses: Social rejection versus achievement stress. *Biological Psychiatry, 52*, 318–327.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychologist, 26*, 1-12.

Uhart, M., Chong, R. Y., Oswald, L., Lin, P., & Wand, G. S. (2006). Gender differences in hypothalamic–pituitary–adrenal (HPA) axis reactivity. *Psychoneuroendocrinology, 31*, 642-652.

Underwood, B. J. (1965). False recognition produced by implicit verbal responses. *Journal of Experimental Psychology, 70*, 122-129.

van Stegeren, A. H., Wolf, O. T., & Kindt, M. (2008). Salivary alpha amylase and cortisol responses to different stress tasks: Impact of sex. *International Journal of Psychophysiology, 69*, 33–40.

Ward, C. L., Flisher, A. J., Zissis, C., Muller, M., & Lombard, C. (2001). Exposure to violence and its relationship to psychopathology in adolescents. *Injury Prevention, 7,* 297-301.

Weeks, J. W., & Heimberg, R. G. (2005). Evaluation of the psychometric properties of the Beck Depression Inventory in a non-elderly adult sample of patients with generalized anxiety disorder. *Depression & Anxiety, 22*, 41-44.

Weissman, M. M., Bland, R. C., Canino, G. J., Faravelli, C., Greenwald, S., Hwu, H. G., ... Yeh, E. K. (1996). Crossnational epidemiology of major depression and bipolar disorder. *Journal of the American Medical Association, 276*, 293–299.

Wilcox, S., Bopp, M., Wilson, D. K., Fulk, L. J., & Hand, G. A. (2005). Race differences in cardiovascular and cortisol responses to an interpersonal challenge in women who are family caregivers. *Ethnicity & Disease, 15*, 17-24.

Wolf, O. T. (2003). HPA axis and memory. *Best Practice and Research Clinical Endocrinology and Metabolism, 17,* 287–299.

Wolf, O. T., Convit, A., McHugh, P. F., Kandil, E., Thorn, E. L., De Santi, S., ... de Leon, M. J. (2001). Cortisol differentially affects memory in young and elderly men. *Behavioral Neuroscience, 115*, 1002-1011.

Wolf, O. T., Kudielka, B. M., Hellhammer, D. H., Hellhammer, J., & Kirschbaum, C. (1999). Opposing effects of DHEA replacement in elderly subjects on declarative memory and attention after exposure to a laboratory stressor. *Psychoneuroendocrinology, 23*, 617–629.

Wolf, O. T., Schommer, N. C., Hellhammer, D. H., McEwen, B. S., & Kirschbaum,C. (2001). The relationship between stress induced cortisol levels and memory differs between men and women. *Psychoneuroendocrinology, 26*, 711-720.

Wolkowitz, O. M., Reus, V. I., Weingartner, H., Thompson, K., Breier, A., Doron, A., ... Pickar, D. (1990). Cognitive effects of corticosteroids. *American Journal of Psychiatry, 147*, 1297-1303.

Wüst, S., Van Rossum, E. F., Federenko, I. S., Koper, J. W., Kumsta, R., & Hellhammer, D. H. (2004). Common polymorphisms in the glucocorticoid receptor gene are associated with adrenocortical responses to psychosocial stress. *Journal of Clinical Endocrinology & Metabolism, 89*, 565–73.

Yanovski, J. A., Yanovski, S. Z., Boyle, A. J., Gold, P. W., Sovik, K. N., & Drinkard, B. (2000). Hypothalmic-pituitary-adrenal axis activity during exercise in African American and Caucasian women. *Journal of Clinical Endocrinology & Metabolism, 85*, 2660-2663.

Young, E. A. (1995). Glucocorticoid cascade hypothesis revisited: Role of gonadal steroids. *Depression, 3*, 20–27.

Appendix A
DRM Explanation

The Deese-Roediger-McDermott (DRM) paradigm provides a means of creating false memories and has successfully been used in numerous studies (e.g., Marsh, McDermott & Roediger, 2004). Subjects are tested on a list of semantically associated words, all related to a non-presented critical lure. When later tested, subjects recall and recognise the non-presented critical word with unusually high probabilities, often as high or greater than studied items (Gallo & Roediger, 2002; Roediger & McDermott, 1995). An example of a word list given is the DRM is as follows: bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, and drowsy (Roediger & McDermott, 1995). All these words are semantically related to the critical lure (which is sleep). Although the word sleep (the critical lure) was never presented during the study phase, it was presented in the recognition test. Subjects recall the critical lure with a probability comparable to recall of items presented in the middle of a list, thought to represent recall from long term memory (McDermott, 1996). Numerous experiments replicating the DRM paradigm have reported similar results (e.g., Multhaup & Conner, 2002; D. G. Payne et al., 1996).

Appendix B

Words used in the False Memory Test

recordplayer	butterfly	suitcase	heart
mortarboard	saddle	plant	yoyo
toaster	rainbow	goat	duck
powerstrip	hockeystick	mug	cow
pig	sneakers	flamingo	dresser
spatula	penguin	tissues	nest
teddybear	skateboard	wheelchair	horse
cigar	television	apron	thumbtack
fishingrod	carrot	joystick	dollars
pelican	pear	table	corn
bandana	mushroom	cookie	wrench
wolf	snake	candle	clarinet
clock	necklace	overalls	bull
football	rabbit	beetle	snail
speakers	slide	pliers	screwdriver
backpack	sandals	battery	golfbag
saturn	pot	rooster	america
maracas	bulldozer	accordion	bow
octopus	peas	clothespin	banana
files	brain	staplegun	dna
scale	turkey	elephant	pogostick
hat	bandaid	cloud	tank
canon	refrigerator	strawberry	tree
house	tent	flower	guitar
zebra	hourglass	lizard	donut
hanger	sandwich	ladder	watch
icecream	microscope	vacuum	doorknob
whistle	deer	calculator	giraffe
stapler	dartboard	computer	roller
bat	clipboard	tuba	tie
kettle	dumptruck	glasses	socks
bench	vase	meter	trophy
whisk	net	racket	package
hammer	bottle	mirror	pretzel
lantern	bucket	candycane	turtle
	jackolantern	matches	caterpillar
	stroller		harp

tape	telephone	blimp	car
headphones	peanuts	owl	fish
bicycle	doll	bread	binoculars
hotairballoon	grill	crab	broom
pen	toilet	pipe	corkscrew
mouse	gavel	tiger	briefcase
knife	blinds	camel	spider
fan	shorts	drill	sofa
cat	pepper	screen	notebook
paintbrush	rollerskate	rhinoceros	cherries
airpump	hook	scrubbrush	pan
walrus	iron	pants	racecar
buggy	dragon	camcorder	alligator
leaf	windmill	scissors	register
hydrant	towel	microwave	safetypin
spraybottle	jacket	jar	trombone
sewingmachine	lightbulb	cake	medal
shelves	axe	carousel	rocket
footprints	pitchfork	stethoscope	wagon
train	shoppingbag	fireplace	bell
pumpkin	ring	violin	shovel
comb	gear	rope	crown
coconut	lemon	skis	sweater
lifevest	hairdryer	helmet	extinguisher
dinosaur	compass	acorns	lion
scoop	lighthouse	lamp	marble
thermos	fork	palette	skull
tire	peacock	handtruck	mixer
tomato	ovenmitts	babycarriage	chest
belt	flag	frog	flippers
lighter	buffalo	bus	camera
pancakes	ostrich	scarf	lobster
kite	airplane	pie	desk
pillow	bathtub	iceskate	orange
astronaut	helicopter	monkey	clip
satellitedish	pineapple	pacifier	sled
moviereel	brazier	watermelon	fryingpan
barrel	dice	mask	tincan
seahorse	compactdisc	balloons	panda
armadillo	policecar	lock	rocker
drum	bed	mailbox	shirt
trashcan	cactus	projector	handcuffs
grapes	squirrel	needle	seal
fox	sharpener	photocopier	microphone
book	hamburger	gumballs	rake
moose	horn	sink	worm
roledex	cheese	magnifier	plate
globe	submarine	wastebasket	flashlight
nail	boat	piano	

umbrella satellite razor colander eggs apple crutches ballhoop shuttlecock giftbox highchair chesspiece gun seashell dumbbell pencil scooter parrot cassette hotdog			

Appendix C

Consent Form

Informed Consent to Participate in Research and Authorization for Collection, Use, and Disclosure of Protected Health Information

This form provides you with information about the study and seeks your authorization for the collection, use and disclosure of your protected health information necessary for the study. The Principal Investigator (the person in charge of this research) or a representative of the Principal Investigator will also describe this study to you and answer all of your questions. Your participation is entirely voluntary. Before you decide whether or not to take part, read the information below and ask questions about anything you do not understand. By participating in this study you will not be penalized or lose any benefits to which you would otherwise be entitled.

1. Name of Participant ("Study Subject")

_____

2. Title of Research Study

The impact of acute psychological stress on cognitive functioning

3. Principal Investigator and Telephone Number(s)

Kevin G. F. Thomas, Ph.D.
Department of Psychology
University of Cape Town
021-650-4608

Robyn Human, B.Soc.Sc.
Masters Candidate
Department of Psychology
University of Cape Town
021-788-5536

Michelle Henry, B.Sc.
Masters Candidate
Department of Psychology
University of Cape Town
021-551-6534

Health Sciences Faculty
Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Tel: 021-406-6338

Fax: 021-406-6411
Email: lamees.emjedi@uct.ac.za

4. What is the purpose of this research study?

The purpose of this research study is to better understand how exposure to acute psychological stress affects cognitive functioning. More specifically, we are interested in individual differences in cognitive responses to acute psychological stress.

5. What will be done if you take part in this research study?

This study requires you to be take part in two research sessions on two consecutive days. On the first day you will be required to complete a number of memory-based tasks. On the second day you may be required to complete a 20-minute presentation which will be followed by another series of memory based tasks. Throughout the study your levels of stress will be assessed through the collection of heart rate measurements and saliva samples with the aid of a cotton swab. These saliva samples will be used to analyse levels of salivary cortisol.

6. What are the possible discomforts and risks?

If you are one of the participants selected to complete the 20-minute presentation, you may be placed in a mildly stressful situation involving public speaking. There are no other discomforts and risks associated with participation in the study.

7. What are the possible benefits of this study?

One major benefit of this study is that scientists, and society in general, will have better understanding of the effects of acute psychological stress on cognitive functioning. This knowledge can then be applied to many different individuals and situations, including students who are taking exams, business managers who have to present to their boards, and so on.

8. Can you withdraw from this research study and if you withdraw, can information about you still be used and/or collected?

You may withdraw your consent and stop participation in this study at any time. Information already collected may be used.

9. Once personal information is collected, how will it be kept confidential in order to protect your privacy and what protected health information about you may be collected, used and shared with others?

Information collected will be stored in locked filing cabinets or in computers with security passwords. Only certain people - the researchers for this study and certain University of Cape Town officials - have the legal right to review these research records. Your research records will not be released without your permission unless required by law or a court order.

If you agree to be in this research study, it is possible that some of the information collected might be copied into a "limited data set" to be used for other research purposes. If so, the limited data set may only include information that does not directly identify you.

10. Signatures

As a representative of this study, I have explained to the participant the purpose, the procedures, the possible benefits, and the risks of this research study; the alternatives to being in the study; and how the participant's protected health information will be collected, used, and shared with others:

_____ _____
Signature of Person Obtaining Consent and Authorization Date

You have been informed about this study's purpose, procedures, and risks; how your protected health information will be collected, used and shared with others. You have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time.

You voluntarily agree to participate in this study. You hereby authorize the collection, use and sharing of your protected health information. By signing this form, you are not waiving any of your legal rights.

_____ _____
Signature of Person Consenting and Authorizing Date

Please indicate below if you would like to be notified of future research projects conducted by our research group:

_____ (initial) Yes, I would like to be added to your research participation pool and be notified of research projects in which I might participate in the future.

Method of contact:
Phone number: _____
E-mail address: _____
Mailing address: _____
_____
_____

Appendix D

Magnitude of STAI State Anxiety Response within the Stress Group

Participants in the Stress group (irrespective of gender) showed an increase in STAI State levels from baseline (35.00 ± 7.35) to post-TSST (45.25 ± 11.52), indicating an increase of 9.56 points in response to the TSST. A previous study using the same stress induction procedure and both male and female participants reported an increase of 21 points in response to the TSST (Jackson et al., 2006). The Jackson et al. (2006) study reported similar baseline STAI State scores; however the resultant increase due the stress induction procedure was much higher than that found in the current study.

Studies have shown that females report more distress/anxiety to stressful experiences (Kelly et al., 2007; Kudielka et al., 2004b), indicating that females experience negative emotions at a greater intensity compared to males. In response to the TSST, previous studies have found that females report greater fear and irritability, thereby showing a greater negative affect in response to interpersonal social stressors (Kelly et al., 2007; Rudolph, 2002). Furthermore, females tend to report more stressful life events than men, and are more likely to become depressed in response to life stressors (McGonagle & Kessler, 1990). Even though females report more life stressors compared to males, they are not more likely to be exposed to them (Bebbington, 1996), indicating that females show a tendency to perceive events as more stressful. However, in the current study there was no significant difference between the magnitude of male and females STAI responses to the TSST ($t(26) = 1.48$, $p = .076$, $d = .56$) (one-tailed). While there was no significant difference, female participants did show a higher increase compared to males (12.92 versus 7.93 respectively; see Table 3), consistent with previous studies findings that females subjectively experience events as more stressful compared to males.

Appendix E

Magnitude of Heart Rate Response within the Stress Group

Participants in the Stress group (irrespective of gender) showed an increase in heart rate levels from baseline (74.92 bpm ± 11.34) to post-TSST (104.13 bmp ± 18.45), indicating an increase in heart rate levels of 29.21 bpm in response to the TSST. Previous studies using the same stress induction procedure and both male and female participants have reported increases lower than this. In response to the TSST, Schwabe et al. (2007) reported a 17.7 bpm increase; Kirschbaum, Pirke, et al. (1993) reported a 26 bpm increase; and Buchanan and Tranel (2008) reported a 27 bpm increase. Is seems therefore, that the current study produced heart rate increases in response to the TSST at a greater level compared to previous studies.

Female participants in the Stress group showed an increase in heart rate levels from baseline (81.26 bpm ± 4.71) to post-TSST (118.44 bpm ± 13.24), indicating an increase in heart rate levels of 37.18 bpm in response to the TSST. With regard to female participants, the majority of studies report an increase in heart rate levels much lower than that reported here. In response to the TSST, Kelly et al. (2007), and Kudielka et al. (2004) both reported an increase of only 6 bmp, whereas Buchanan and Tranel (2008) reported an increase of 9 bmp.

Male participants in the Stress group showed an increase in heart rate levels from baseline (71.23 bpm ± 12.57) to post-TSST (95.78 bpm ± 15.95), indicating an increase in heart rate levels of 24.55 bpm in response to the TSST. With regard to male participants, again, the majority of studies report an increase in heart rate levels much lower than that reported here. Buchanan and Tranel (2008) reported an increase of only 9 bpm, Kelly et al. (2007) reported an increase of 13 bpm, whereas Kudielka et al. (2004) reported no increase in male participant's heart rate post-TSST. It should be noted that in this study, heart rate did increase in response to the TSST in both males and females during the TSST, however male participant's heart rate returned to baseline shortly after the cessation of the TSST procedure.

Buchanan and Tranel (2008) reported no gender difference in heart rate response to a stressor, Kudielka et al. (2004) reported that females show a higher increase in heart rate levels, whereas Kelly et al. (2007) reported that males show a higher increase in heart rate levels in response to the TSST. In the current study there was a significant difference between the magnitude of male and females heart rate responses to the TSST ($t(17) = -2.20$, $p = .042$, d

= .98), with females showing a higher heart rate response compared to males (see Table 3). This result is in line with the findings of Kudielka and colleagues (2004).

Glossary

Both Hits (on the Standard Recognition Test): Correctly identifying an item originally presented as both a picture and a red word as having been presented during the study phase (i.e., a true memory).

Red Word Hits (on the Standard Recognition Test): Correctly identifying an item originally presented as a red word only as having been presented during the study phase (i.e., a true memory).

Picture Hits (on the Standard Recognition Test): Correctly identifying an item originally presented as a picture only as having been presented during the study phase (i.e., a true memory).

New False Alarms (on the Standard Recognition Test): Incorrectly identifying an item that had never been presented as having been presented during the study phase (i.e., a false memory).

Both Hits (on the Picture Criterial Recollection Test): Correctly identifying an item originally presented as both a picture and a red word as having been presented as a picture during the study phase (i.e., a true memory).

Red Word False Alarms (on the Picture Criterial Recollection Test): Incorrectly identifying an item originally presented as a red word only during the study phase as having been presented as a picture (i.e., a false memory).

Picture Hits (on the Picture Criterial Recollection Test): Correctly identifying an item originally presented as a picture only as having been presented as a picture during the study phase (i.e., a true memory).

New False Alarms (on the Picture Criterial Recollection Test): Incorrectly identifying an item that had never been presented as having been presented as a picture during the study phase (i.e., a false memory).

Both Hits (on the Red Word Criterial Recollection Test): Correctly identifying an item originally presented as both a picture and a red word as having been presented as a red word during the study phase (i.e., a true memory).

Red Word Hits (on the Red Word Criterial Recollection Test): Correctly identifying an item originally presented as a red word only as having been presented as a red word during the study phase (i.e., a true memory).

Picture False Alarms (on the Red Word Criterial Recollection Test): Incorrectly identifying an item originally presented as a picture only during the study phase as having been presented as a red word (i.e., a false memory).

New False Alarms (on the Red Word Criterial Recollection Test): Incorrectly identifying an item that had never been presented as having been presented as a red word during the study phase (i.e., a false memory).

Student: Michelle Henry Supervisor: Dr Kevin Thomas

Corrections made to Minor Dissertation

1) In response to the examiners comment that there was no reference to ethical considerations the following correction was made on page 27: Under the methods section it was noted that ethical consideration for the study was approved by the Health Sciences Faculty Committee of the University of Cape Town.

2) In response to the examiners comment that exclusion criteria were not specific enough the following correction was made on page 26: Certain medical conditions (which were an exclusion criteria) were elaborated on to clarify what was meant.

3) The examiner commented that it was unclear how the 4 female participants not in the correct phase of their menstrual cycle were distributed amongst the stress and relax group, nor to which side of the first day of the menstrual cycle they were on. To correct this a caption was added below Figure 1 on page 28 indicating the above mentioned information.

4) In response to the examiners comment that the certain aspects regarding the administration of the BDI was no clear, the following correction was made on pages 27 and 36: Under the procedure section it is now stated whether administration was done in groups or individually, and what intervention and support was given to participants who were excluded on the basis that they were severely depressed.

5) In response to the examiners comment that semantic and non-declarative memory were not elaborated on enough in the literature review the following correction was made on page 19: It is clearly stated that the current study only deals with episodic memory, and that semantic and non-declarative memory are not relevant to the current thesis and will therefore not be elaborated on.