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Stress and selective attention: The impact of a stressful challenge on mood, cortisol, and the processing of emotional information

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ABSTRACT

Stress and selective attention: The impact of a stressful challenge on mood, cortisol, and the processing of emotional information

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The studies presented in this thesis were designed to examine the unfolding of events when an individual is faced with a stressful challenge, by monitoring subjective mood, attention to emotional stimuli, and the hypothalamic-pituitary-adrenal (HPA) response to stress. It was hypothesized that participants would selectively attend to negative words (study 1) and pictures (study 2) following an aversive stressful experience, and that the attentional response to stress would mediate mood and HPA reactivity. Stress induction was achieved by means of a competitive Stroop task with monetary rewards where participants either repeatedly lost (negative stressor) or won (positive stressor) against a confederate. Participants then performed a spatial cueing task assessing attentional shifts towards and away from emotional and neutral stimuli. The results of these studies can be summarized by three major findings. Contrary to predictions, participants selectively *avoided* negatively-valenced pictures and words. This attentional avoidance response was associated with effective emotional and HPA regulation, suggesting that avoidance in this context may be adaptive as a coping response to stress. Second, stress-induced changes in processing efficiency or alertness, resulting in a wide-scope and flexible attentional style, were also observed, and this too may facilitate adaptive coping. Finally, participants with mild symptoms of depression and anxiety exhibited different patterns of response to stress than euthymic subjects, several

characteristics of which may indicate a vulnerability to psychopathology. In effect, the results of these studies provide a possible model of how healthy participants cope with mild stress, and point to an attentional mechanism of emotion regulation that facilitates the maintenance of goal-directed behaviour.

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I dedicate this thesis to the memory of Kathleen Ellenbogen.

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INTRODUCTION

1. STRESS, ATTENTION AND ORIENTING

There is considerable evidence linking stress with physical illness and psychopathology (Holsboer, 1995; Gold et al., 1988b; Gold et al., 1988a; Post, 1992; Steptoe, 1991; Wiedenfeld et al., 1990). Research has shown that one of the key signs of impending psychological disturbance is a diminishing capacity to cope with normative life stresses (Thoits, 1983). Studies have also documented differences in stress-related response patterns between normally functioning adults, those who commit major criminal offenses (Virkkunen, 1985; Woodman et al., 1978), and those clinically depressed or anxious (Mogg & Bradley, 1998; Mathews & MacLeod, 1994; Kagan et al., 1988; Holsboer, 1995). In children and neonates, variations in stress reactivity have important implications for normative development and psychopathology (Nachmias et al., 1996; Gunnar, 1994; Hart et al., 1995; Moss et al., 1995; Gunnar et al., 1995; Granger et al., 1994). Work of this kind has stimulated interest in the mechanisms underlying the stress response and the long-term consequences of repeated stress over time (McEwen, 1999; Koolhaas et al., 1997). However, the factors and processes that mediate the relationship between stress and psychopathology are not fully understood. Although the individual's subjective appraisal of an event is paramount in defining the impact of a stressor (Lazarus, 1993), factors leading to this later stage of cognitive processing remain relatively unexplored. The orienting and allocation of attention to salient stimuli in the environment may be critical here. These attentional functions represent the first step in processing information

about the environment, and, as such, can have profound effects on all other cognitive functions. For these reasons, it is proposed that the individual's response to stress is mediated in part by attentional brain circuits that influence the efficiency in which environmental information is selectively attended to and processed. The studies presented here were designed to examine the unfolding of events when an individual is faced with a stressful challenge, by monitoring subjective mood, attention and the hypothalamic-pituitary-adrenal (HPA) response to stress. It is hypothesized that allocating attention to negative sources of information will mediate the impact of stressful events on mood and HPA response. Before describing the current model in more detail, the construct of selective attention and its associated brain circuits will be introduced below. This literature review will provide a framework for understanding how stress may influence attentional processes.

Selective attention and the operations underlying visual orienting

Although attention encompasses numerous phenomena, a basic function of attention is that it facilitates cognitive and behavioral functioning by amplifying the signal of interest at which attention is directed towards, and by inhibiting other sources of non-relevant information (Hillyard et al., 1999; Posner & Dehaene, 1994; Heinze et al., 1994; Corbetta et al., 1990; Spitzer et al., 1988; Luck, 1995). This is termed selective attention, indicating that some stimuli are given priority or emphasis over others. Once a focal point is selected, attention functions to highlight the information that is most relevant to present functioning, often referred to as the 'spotlight' metaphor (Klein & Hansen, 1990; Posner, 1980; Posner et al., 1980). Attention amplifies information processing of the stimulus or stimulus characteristics to which we are attending to (Hillyard et al.,

1999; Heinze et al., 1994; Spitzer et al., 1988). For example, visual attention to colour, shape or size of a stimulus array augments neuronal activity, as assessed by positron emission tomography (PET), in the extrastriate region specialized for processing of that attribute (Corbetta et al., 1990). Thus, attentional mechanisms serve to select information for further processing, and thus represent the first step between environmental input and behavioral response.

Orienting of attention plays an integral role in selecting stimuli for further processing. Through studies of mental chronometry, brain lesions and neuroimaging, pioneering work by Posner and colleagues (1994; 1987; 1987; 1978) has begun to delineate the different mental components and brain networks that subserve visual spatial attention. A shift of attention can be broken down into three elementary operations: (1) the disengagement or release of attention from its current location, (2) the "moving" of attention to a new location, and (3) finally its re-engagement at the new location. There is empirical support for the decomposition of visual orienting into these different components. From a cognitive (Posner, 1978), neuroanatomical (Corbetta et al., 1993; Posner et al., 1987), electrophysiological (Luck, 1995), or neurobiological (Johnson et al., 1995; Clark et al., 1989) perspective, attentional disengagement can be differentiated and disassociated from shifting and allocating attention. For example, acute administration of a noradrenergic agonist affects disengagement but not attentional engagement (Clark et al., 1989). In patients with lesions of the right parietal lobe, disengaging attention from a cued location in the right (unimpaired) visual field to the left (impaired) visual field is severely impeded. Yet, these patients are relatively unimpaired when disengaging attention from the left to right visual field, or in performing simple attentional shifts without cues (Posner et al., 1987; Posner et al., 1984). In patients with progressive

deterioration of the superior colliculus and surrounding areas of the midbrain, all shifts of attention are slowed down regardless of whether attention was previously cued elsewhere (Posner & Petersen, 1990). These findings suggest that there are distinct differences between disengaging and moving attention, supporting the view that there are separate operations underlying visual orienting.

Spatial cueing

The components of covert orienting can be differentiated through the use of spatial cueing tasks (Danckert & Maruff, 1997; Johnson & Yantis, 1995; Posner et al., 1980; Posner et al.,. 1978; Posner et al., 1987; Hillyard et al., 1990). In these types of experiments, a cue is used to direct attention to the probable location of a subsequent target stimulus. On most trials (60-80%), the target appears at the cued location (valid trials), but occasionally will appear at an uncued location (invalid trials). Valid and invalid trials are often compared with "neutral" trials, where the cue provides no information about the probable location of the target. Reaction time is faster for valid trials than neutral trials, indicating that the cue intensified attentional processing at the validly-cued location. Reaction time is slower for invalid trials than neutral trials, indicating the cost of allocating attention to an incorrect spatial location. These effects are achieved even when all stimuli appear within foveal vision, and eye movement are controlled for. The rapid detection of a stimulus following valid cueing is believed to reflect the operation of attentional engagement, and the delay following invalid cueing the cost of disengaging and re-engaging attention at a new location. Spatial cueing effects have been replicated using other measures of attention besides reaction time, such as perception threshold (Luck et al., 1994;

Hillyard et al., 1990), discrimination accuracy (Henderson, 1996), and event-related potentials (Luck et al., 1994; Rugg et al., 1987).

Spatial cueing tasks are designed to elicit either exogenous or endogenous shifts of attention. Exogenous shifts occur when attention is drawn in an automatic fashion to the location of an abrupt change in the environment. Exogenous cueing studies typically use a sudden change in brightness to cue attention to the probable target location. Endogenous orienting refers to shifts of attention that require volition or intention. It is most commonly achieved in cueing tasks by presenting an arrow at fixation that points to the most probable target location. The major distinctions between these two types of cueing are as follows: exogenous shifts are fast (within 50 ms), stimulus-driven, automatic and independent of subjective awareness, while endogenous shifts are slow (200 ms), goal-directed, and under cognitive control (McCormick, 1997; Yantis & Johnson, 1990; Sheppard & Müller, 1989). The spatial cueing task used in the present studies was designed to elicit primarily exogenous orienting. However, exogenous and endogenous influences in cueing studies are not easily separable: task instructions, for example, exert some cognitive control over exogenous shifts of attention.

Attention systems of the brain

The neural structures underlying the orienting system, called the posterior attentional network, include portions of the parietal cortex, the superior colliculus of the midbrain, and a region of the thalamus called the pulvinar (Posner & Dehaene, 1994; Posner & Petersen, 1990). The superior colliculus, one of the earliest stages of visual processing and essential for visual saccades, is important for the execution of attentional shifts (Posner & Petersen, 1990). The pulvinar

has been described as a critical structure in engaging attention at a selected location, and for increasing the saliency of the attended stimulus (for reviews, see LaBerge, 1995; Robinson & Petersen, 1992). The pulvinar receives input from the superior colliculus and is a critical pathway in the transmission of sensory information to the cortex. It projects to, and receives input from, many extrastriate and parietal areas involved in visual processing. Thus, it is located in a strategic position for modulating the transmission of visual information to the cortex. In a PET study, Laberge and Buchsbaum (1990) found increased glucose uptake in the pulvinar during the processing of a target stimulus surrounded by similar distractors than during the processing of the target alone. This result suggests that the pulvinar plays an important role in amplifying attended information, and/or in the filtering out of non-relevant distracting information, features that are important for attentional engagement. As described in the previous section, the parietal lobe is critical in releasing attentional focus from a region of space. The importance of the parietal cortex in shifting attention has been supported in a PET study measuring shifts of attention to spatial cues (Corbetta et al., 1993), as well as studies of non-human primates (Steinmetz, 1998).

In addition to the posterior attentional system, Posner (1994; 1990) has described two other attentional networks. The anterior attention network is involved in executive functions and in the detection of events in a wide variety of situations. This network is located in areas around the mid-frontal cortex and anterior cingulate. In PET studies, increased activation of the anterior attention network occurs when subjects are required to attend to multiple stimulus features or the semantic meaning of words (Corbetta et al., 1991; Petersen et al., 1993), but not for the selection of location or the orienting of attention (Corbetta et al.,

1993). These results support the notion that the anterior attention network is distinct from the posterior one, and that this system functions at a level beyond the processing of physical attributes of the stimulus. Another important aspect of the anterior attention system is that it appears to be active in tasks where there are competing inputs. Activation of the anterior cingulate was observed during conflict trials of a Stroop task, where the word spelled out a colour inconsistent with the ink colour, but not during non-conflict trials (Pardo et al., 1990). Similar activation was observed during a divided attention task where subjects attended to three different stimulus attributes at the same time, but not when monitoring a single attribute (Corbetta et al., 1991). Thus, the anterior system appears to be important in executive attentional selection and may be particularly relevant in the coordination of conscious goals with appropriate response selection.

The third attentional system described by Posner and Petersen (1990), and by others (Aston-Jones et al., 1999; Robbins, 1997; Robertson & Manly, 1999; Parasuraman et al., 1998), is the vigilance network, which refers to ascending locus coeruleus-noradrenergic innervation of wide areas of the cortex, but particularly of the right parietal cortex. Functionally, this system exerts its effects on alertness and sustained attention over time. Activation of this system allows for high priority information to be selected and processed more efficiently over extended time periods. In sum, the process of orienting to and selecting visual information in the environment is well delineated, with a distributed network of neural structures implicated in the shifting, engaging and disengaging of attention from spatial locations. It is hypothesized that other systems interact with the orienting or posterior network, such as an executive system for more goal-oriented influences (anterior network) and a vigilance system for increased alertness during arousing conditions. The interaction between orienting systems

and these other influences will be further illustrated below, where motivational influences on attention are considered.

2. ATTENTION AND MOTIVATION

The direction and intensity of attentional engagement may be influenced by internal (goal-directed) and external (stimulus-driven) factors. Stimulus factors that influence attention include abrupt onset (Jonides & Yantis, 1988), saliency (Fiske & Taylor, 1991; von Grünau & Iordanova, 1997), novelty, (Johnston et al., 1990), and affective valence (Pratto, 1994; Hansen & Hansen, 1994). These stimulus factors are thought to automatically capture attentional resources. Motivational factors refer to goal-directed and intentional influences on behaviour. From a theoretical perspective, motivational states have important implications for what Laberge (1995b) has termed preparatory attention. This form of attention refers to the fact that the expectation (or anticipation) of an event or stimulus can engage attention at a particular location in space. Waiting for a streetlight to change from red to green is an example of this phenomenon, as attention is likely to be re-allocated from the red light to the spatial location of the green light prior to its occurrence. Endogenous cueing provides a good example of this process, where a valid cue facilitates reaction time and an invalid cue delays it (Johnson & Yantis, 1995; Posner et al., 1980). The effects of cueing attention have been interpreted as a form of preparatory attention, where the cue elicits an attentional readiness for the presentation of the target stimulus (LaBerge, 1995b). Preparatory attention represents one theoretical explanation of how motivational states can influence attention. That is, motivational states may elicit a type of attentional expectancy that biases subsequent attention and

information processing.

Empirical research in normal populations

Traditionally, the study of basic attentional phenomena has neglected emotional and motivational factors, but there has been renewed interest in this area over the last decade (Mogg & Bradley, 1998; Derryberry & Tucker, 1994). In a series of studies by Derryberry and colleagues (1994; 1993; 1991; 1989; 1988; 1987), motivational states were manipulated in various reaction time tasks by using positive and negative feedback after each trial, and by allotting positive and negative values (win/lose points) to pretarget stimuli or the target itself. These types of manipulations were capable of influencing measures of attention (for review, see Derryberry and Tucker, 1994). For example, negative feedback about performance on a previous trial elicited faster reaction time to high valued negative targets on subsequent trials. Similarly, a faster response to high valued positive targets was observed following positive feedback. Individual differences in trait measures of neuroticism and extraversion also influence the attentional response to motivationally-significant stimuli. Attention to a pretarget cue with negative incentive value increased attentional engagement or "holding power" at that location in neurotic introverts, while extraverts demonstrated the same attentional bias for stimuli with a positive incentive value (Reed & Derryberry, 1995; Derryberry & Reed, 1994; Derryberry, 1987).

A recent study has demonstrated how manipulating a basic drive state can influence selective attention to motivationally-significant cues on a dot probe task (Mogg et al., 1998). This task measures the allocation of attention to motivational-significant words, when faced with two competing words in foveal vision. Following a fixation period, neutral and food-related words are presented

above and below the fixation point. Immediately after the display of the word pair, a dot probe appears in one of the two locations. Subjects respond as quickly as possible with two-choice key press to indicate whether the probe was above or below the fixation point. A fast response to probes at the location of food-related stimuli, relative to neutral stimuli, indicates greater allocation of attention towards the motivationally-significant material. In this study, words were presented for 500 ms (suprathreshold) or for 14 ms followed by a random letter mask (subthreshold). In the latter condition, subjective awareness of the word is blocked. Hungry normal volunteers, after fasting for 16 to 22 hours, were faster to respond to probes replacing suprathreshold food-related words than neutral words. This effect was not observed in the control sample of non-fasting subjects, suggesting that the induction of a hunger state, and not a general bias towards food-related stimuli, facilitated reaction time. No attentional bias was observed with words presented outside of conscious awareness. Other studies have demonstrated that a negative mood induction leads to greater allocation of attention to negative (Bradley et al., 1997a) or emotional information in general (Ingram et al., 1994). Lang and colleagues (1998; 1995; 1990) performed a series of studies demonstrating how the processing of affective information, believed to prime motivational states, can significantly modulate the startle response to an acoustic probe. In these studies, the presentation of aversive pictures potentiated the amplitude of the eye blink startle reflex to a loud noise, while the presentation of positive pictures diminished it. These studies demonstrate how affective-motivational priming can modulate a basic attentional reflex (i.e. to orient to a startling stimulus).

Empirical research in Clinical populations

There is a large body of clinical literature suggesting that selective attention to threatening information supports and sustains maladaptive patterns of information processing characteristic of anxious and depressive states (Mogg & Bradley, 1998; Mathews & MacLeod, 1994; Dalgleish & Watts, 1990). Attentional biases in clinical populations have been observed primarily on the dot probe and emotional Stroop task. In the latter task, negatively-valenced and neutral words are presented on a background patch of colour. Subjects are instructed to ignore the words and name the colour of the background patch as quickly as possible. Each trial begins with a fixation period, which is followed by the presentation of the word on a colour background; words are displayed until subjects makes a vocal response. The time taken to name the background colour is used as an index of the extent to which processing resources are being allocated to the word content, thus causing colour naming "interference". A slow response latency to emotional words relative to neutral words is thought to reflect greater attentional allocation to the emotional content of the word. A "subliminal" variant of this task is sometimes used by presenting words briefly (14 ms) followed immediately by a random letter mask, which blocks subjective awareness of the word but not the background colour patch. Using these tasks, anxious and depressed participants exhibit an attentional bias for dysphoric or threatening information, as if they maintain a state of "vigilance" for negative sources of information in the environment (Mogg & Bradley, 1999; Bradley et al., 1998; Mathews et al., 1996; Mogg et al., 1995; Byrne & Eysenck, 1995; Mogg et al., 1993a; MacLeod & Mathews, 1991; MacLeod et al., 1986; Chen et al., 1996; Lavy et al., 1993; McNally et al., 1992; Foa et al., 1991). Of particular interest, the attentional bias in anxious populations is observed even when negatively

valenced stimuli are presented outside of subjective awareness (Mogg et al., 1993a; MacLeod & Rutherford, 1992; Mogg et al., 1995). These findings suggest that this processing bias in anxious participants occurs during an early evaluative stages of stimulus analysis. Thus, experiments in normal and clinical populations indicate that selective attention may be sensitive to affective-motivational states. From this perspective, it seems plausible that biases in attention may occur in response to stress.

3. STRESS AND THE HYPOTHALAMIC-PITUITARY-ADRENAL AXIS

The indices of stress response commonly used in psychological research are the glucocorticoids, specifically cortisol or corticosterone. Cortisol production is the end-product of a complex series of events involving hypothalamic, pituitary and adrenal actions but also implicating regulatory functions in the hippocampus and cortical structures (Munck et al., 1984; Diorio et al., 1993; Jacobson & Sapolsky, 1991). The HPA-axis is particularly sensitive to stress. Such perturbations are associated with increases in cortisol depending on the nature of the stress. An extensive literature has evolved examining the nature of stimuli which activate the HPA-axis. It has been shown that novelty, uncertainty and lack of control over the stressor are paramount in elevating cortisol levels (Lundberg & Frankenhaeuser, 1980; Kehlet & Binder, 1973; Kral et al., 1968; Czeisler et al., 1976; Johansson et al., 1983; Ursin et al., 1978; Breier, 1989; Hanson et al., 1976; Dess et al., 1983; Schwartzman & Austin, 1998). The perception of control over the stressor may be a particularly salient aspect of HPA regulation, since it appears to distinguish HPA activation from other stress sensitive systems such as the catecholaminergic sympathetic-adrenomedullary

system. Based on both animal (Henry, 1992; de Boer et al., 1990b; de Boer et al., 1990a) and human laboratory studies (Lovallo et al., 1990; Breier et al., 1987; Lundberg & Frankenhaeuser, 1980), norepinephrine (NE) and epinephrine typically increase in response to effort, vigilance and arousal associated with a stressor, whereas the release of glucocorticoids appears more closely linked to the perception of loss of control or a state of despair. That is, the response to a stressful challenge can be depicted as a two-stage process. The first stage is a sympathetic response to challenge, characterized by a "fight-flight" reaction, active coping and effort. Activation of the HPA system, the second stage, is triggered by the perception of coping failure, distress and defeat (Henry, 1992).

According to the above review, appraisal processes and the mood response to stress should be associated with HPA activation when confronted with stress in the environment. Empirical support for this assertion has been mixed. The cortisol response to a social stressor, making a verbal presentation in front of a panel of judges for example, correlates with subjective distress or negative affect in some studies (Buchanan et al., 1999; Al'Absi et al., 1997), but not in others (van Eck et al., 1996). Cortisol reactivity to this speech stressor is typically highest in anticipation of the event (while subjects are preparing for the talk) rather than during the event (Kirschbaum et al., 1993; Kirschbaum & Hellhammer, 1989). Thus, it is difficult to judge whether the activation of the HPA system is due to effort, distress, or the anticipation of a stressful experience. For studies of stress in naturalistic settings (i.e. examination and work stress), appraisal of the stressor and perceived coping ability, but not mood state or distress (Huwe et al., 1998; Gilbert et al., 1996; Allen et al., 1985), are associated with increased cortisol (Malarkey et al., 1995; van Eck & Nicolson, 1994; Nicolson, 1992). However, a recent study found an association between the

mood and cortisol response to naturally-occurring daily stressors (Smyth et al., 1998). In fact, the relationship between daily stressors and cortisol became non-significant when mood ratings were controlled for, suggesting that the mood response was mediating the relationship between stress and cortisol. This study was noteworthy because of its large sample size (n=120) and random assessments of mood, stress and salivary cortisol (6 measures/day) across two days. In sum, stress-induced activation of the HPA axis is achieved through a complex interaction involving the nature of the stressful event, subjective appraisal, and distress. Given that the HPA axis is sensitive to cognitive factors such as the appraisal of events, selective attention may be an important determinant of HPA activation under conditions of stress.

4. COGNITION AND THE HYPOTHALAMIC-PITUITARY-ADRENAL AXIS

The effects of cortisol on attention and memory

There is evidence that corticosteroids alter general sensory processing (Fehm-Wolfsdorf et al., 1993; Fehm-Wolfsdorf et al., 1989; Henkin, 1975), selective attention (Epel et al., 2000; van Honk et al., 1998; van Honk et al., 2000; Skosnik et al., 2000; Kopell et al., 1970; Mölle et al., 1997; Born et al., 1987; Born et al., 1986; Born et al., 1990; Born et al., 1988), and memory (Lupien & Meaney, 2000; Plihal et al., 1999; Schmidt et al., 1999; Kirschbaum et al., 1996; Newcomer et al., 1994; Lupien et al., 1994; Wolkowitz et al., 1990). Unfortunately, there is still much controversy about the exact nature of their influence, and whether their effects are beneficial or detrimental. It has been proposed that corticosteroids affect selective attention and the encoding of information (Wolkowitz, 1994;

Born et al., 1988; Kopell et al., 1970), while others argue that they affect later processes such as the consolidation of memory (Kirschbaum et al., 1996; Newcomer et al., 1994; Schmidt et al., 1999). Lupien and McEwen (1997) propose a model whereby the effect of corticosteroid levels on cognitive function follow an inverted U-shape relationship. They suggest that these different cognitive effects are mediated by differential activation of the Type 1 (mineralocorticoid) and Type 2 (glucocorticoid) corticosteroid receptor systems. Type 1 receptors have a high affinity for corticosteroids (as well as other hormones such as aldosterone) and are highly saturated at basal levels. Type 1 receptors, densely located in the limbic system, are hypothesized to mediate regulatory and tonic functions of the HPA system, particularly those implicated in circadian rhythms. In contrast, Type 2 receptors have a lower affinity for endogenous corticosteroids, are less saturated at basal levels and are widely distributed in the brain. In response to stress, type 1 receptors quickly reach saturation, followed by increasing activation of type 2 receptors. One important function of the type 2 receptor system is to regulate negative feedback of the HPA axis, promoting homeostasis and adaptive recovery from stress (De Kloet et al., 1998; De Kloet, 1995). The implications of these functional characteristics are that different or opposing CNS effects of corticosteroids on behaviour may occur as a result of differential activation of these receptors systems. For cognitive function, type 1 receptors are thought to promote selective attention to relevant sources of information and the adaptive integration of sensory information, both of which are important for memory formation. The function of type 2 receptors, however, is likely related to the consolidation and retrieval of memory, which occurs through glucocorticoid-mediated noradrenergic action in the basolateral nucleus of the amygdala (Ferry et al., 1999; Lupien & McEwen, 1997).

A number of human studies have examined the effects of cortisol on attention and sensory processing. In one study, individuals with an elevated cortisol response to mental stress (consisting of four hours of cognitive tasks) performed a subsequent divided attention task less efficiently than following a control session (Bohnen et al., 1990). In this study, attention is measured before and after the stressor and control conditions, providing an index of stress-induced change. Unfortunately, these results are difficult to interpret because subjects exhibiting a low cortisol response performed poorly following both the stressor and control sessions, relative to cortisol responders. In fact, group differences were most apparent following the control session, where attentional performance improved in cortisol responders, but worsened in non-responders. Although the authors propose that a high cortisol response to stress impedes attention, these results may reflect overall individual differences in cognitive performance between high and low cortisol responders, with the responders generally outperforming non-responders.

According to some studies, the administration of exogenous corticosteroids impedes the ability to filter out distracting information, or discriminate relevant from non-relevant stimuli (Wolkowitz, 1994; Kopell et al., 1970). Unfortunately, it not known whether these effects are specific to attention; the study by Wolkowitz (1994) was based on memory function and the study by Kopell and colleagues (1970) on event-related potentials. The adrenocorticotropin (ACTH) agonist ACTH 4-10 was found to impair selective attention on tasks demanding a sustained focus (Mölle et al., 1997; Born et al., 1987; Born et al., 1986). These authors concluded that stimulation of the HPA axis via ACTH 4-10 results in a more expansive and less focused mode of attention, characterized by a decreased ability to filter out irrelevant stimuli.

Because ACTH 4-10 has no peripheral adrenocorticotropic activity, and therefore does not increase cortisol levels, it is unknown whether these findings extend to stress-induced cortisol release, the focus of the present studies. However, similar changes in sensory processing thresholds have been observed following both a stress induction and the administration of an exogenous corticosteroid. Under conditions of elevated cortisol, increased auditory stimulation was needed to elicit a characteristic auditory or gustatory reflex (Fehm-Wolfsdorf et al., 1993; Fehm-Wolfsdorf et al., 1989). These studies suggest that selective attention is more expansive and less focused during HPA activation. Consistent with this view, it has recently been reported that stress-induced cortisol levels were associated with decreased inhibition of non-relevant information on a negative priming task, a standard measure of the inhibitory attentional processes (Skosnik et al., 2000). Thus, elevations of cortisol and stress may alter information processing by impeding focused modes of attention, a finding that is consistent with a number of arousal and motivational theories of attention (Tucker & Williamson, 1984; Easterbrook, 1959). However, some studies have found no relationship between attention and cortisol (Schmidt et al., 1999; Wolkowitz et al., 1990; Newcomer et al., 1994). Given that the studies reported here use different tasks to measure attention, including neuropsychological tests such as serial addition (Newcomer et al., 1994), distractor tasks (Schmidt et al., 1999), signal detection tasks (Bohnen et al., 1990) and evoked potential response (Mölle et al., 1997; Born et al., 1987; Born et al., 1986), it is not surprising that there are inconsistencies in the literature. Furthermore, most studies of corticosteroids and cognition use different exogenous steroids (i.e. dexamethasone, prednisone, ACTH 4-10) and dosages, which can have paradoxical effects on cognitive function (Lupien & McEwen, 1997). For these reasons, the relationship between

attention and cortisol remains inconclusive, although there is some evidence that HPA activation is associated with a less focused attentional style.

The effects of cortisol on attention to emotional stimuli

The relationship between HPA activation and attention to emotional stimuli has been a neglected area of study in the literature. However, three recent studies report a relationship between selective attention to threatening stimuli on an emotional stroop task and cortisol levels. In the first study (van Honk et al., 1998), facial depictions of emotions were presented with a coloured filter, and subjects were instructed to name the colour of the picture while ignoring its content. Unexpectedly, subjects with high baseline cortisol exhibited less colour naming interference (faster reaction time) on trials with angry faces than trials with neutral faces, but only when stimuli were presented outside of awareness (brief exposure and backward masking). Van Honk and colleagues (1998) interpreted this finding as an automatic avoidance of threatening stimuli in individuals with high baseline cortisol. They speculated that high baseline cortisol underlies fearful or submissive traits (Kalin et al., 1998; Sapolsky, 1990), which perhaps explains this avoidance response to threat. In this study, cortisol was sampled on only one occasion, just prior to the task, and no acclimatization or relaxation phase was included in their design. Thus, high baseline cortisol probably reflected high anticipatory levels of cortisol, suggesting that those participants with the most apprehension prior to the study inhibited processing of threatening stimuli. In the second study (van Honk et al., 2000), cortisol was sampled before and after the emotional stroop task. Cortisol reactivity in response to the task was positively correlated with selective attention to angry faces, for both masked and unmasked stimuli. This finding was recently

replicated. Women with high abdominal fat accumulation[1], relative to a control group of healthy women, produced more cortisol in response to acute stress and selectively attended to threatening words on a subsequent emotional stroop task (Epel et al., 2000). These results suggest that a high cortisol response to stress may facilitate the processing of threatening stimuli.

In sum, cortisol may affect cognitive processes in a number of ways. First, high levels of cortisol, particularly through pharmacological manipulations or robust stress-inductions, can impair memory consolidation. Second, moderate elevations in cortisol seem to affect sensory thresholds and inhibitory attentional processes, leading to a wider scope of attention. This change in attention could facilitate or impair performance on measures of attention, depending on the nature of the task. Finally, elevated cortisol levels appear to be associated with selective attention to threatening information. However, it is unknown whether selective attention to emotional content activates the HPA axis and stimulates cortisol production, or whether those participants with a cortisol response to stress are prone to attentional biases.

5. ATTENTION AS A MEDIATOR OF THE STRESS RESPONSE

As delineated in the two previous sections, the selective processing and interpretation of stress-eliciting stimuli may be of critical importance in determining the organism's physiological and emotional response to stress. Selective attention, in this sense, is fundamental in the assessment of any source of information which challenges the organism's ability to cope. In relation to

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[1] Because chronic stress and exposure to cortisol can increase intra-abdominal fat deposits, a high waist-to-hip ratio was used in this study as a manifestation of chronic stress.

stress, which can be conceived as a threat to the organism's functioning, attentional processes may represent a mediating link between environmental events and indices of the stress response. Furthermore, stress-related biases in attention may represent a putative mechanism whereby stressors, throughout development, can alter patterns of information processing, learning and memory.

A number of studies have assessed whether a stressful experience alters attentional processing. Several studies have found that stress facilitates the processing of threatening information (Chen et al., 1996; Mogg et al., 1990; MacLeod & Mathews, 1988), while others have failed to replicate this effect (Mathews & Sebastien, 1993; Mogg et al., 1993b; McNally et al., 1992; Richards et al., 1992). Inconsistent findings may be due, in part, to the wide variety of stressors used, including anxious mood induction, mathematical anagrams, physical exercise, and approaching a feared object. These studies have used a variety of clinical and non-clinical populations, and have also used different types of negatively-valenced stimuli. The stressors and stimuli used in these studies were not always relevant to the concerns of the individual, or lacked personal significance, and therefore may not have been sufficiently salient to affect attentional processes. A study by Mogg and colleagues (1990) however, is noteworthy. Following performance of a mental stressor task with negative feedback, they assessed selective attention to general and achievement-related threat words on emotional Stroop and dot probe tasks. In both tasks, the stress induction elicited attentional biases for threat-related information, particularly for achievement-related stimuli relevant to the source of stress. Several studies have shown greater selective attention to negative words than neutral words following the induction of a dysphoric mood (Bradley et al., 1997a; Gilboa & Gotlib, 1997; Eckhardt & Cohen, 1997; Ingram et al., 1994). Thus, there is some evidence in

support of the hypothesis that stressful experiences and negative mood may bias attention in a mood-congruent way.

Allocating attention to unpleasant material may represent one facet of poor stress regulation. In contrast, avoidance of negatively-valenced information may conceivably influence stress regulation in a beneficial way. Strategies of emotion regulation, such as shifting attention away from disturbing material (Rothbart et al., 1994), may be particularly important mediators of HPA reactivity. Studies by Rothbart and colleagues (1995; 1994) suggest that attentional processes, particularly the ability to disengage from stimuli, are important in coping with distressing information. Using a longitudinal design, the ability to use attentional disengagement for self-regulation was an important predictor of later adaptive functioning in children. Thus, the tendency to orient and allocate attention to distressing information, as well as the ability to efficiently shift away from negative stimuli, may represent an important dimension in understanding the role of attention in the development of stress-related psychopathology.

To summarize, previous research on clinical populations, stress inductions, and experimental manipulations of mood and motivation suggest that affective-motivational states can influence attention by facilitating the processing of mood-congruent information. Alternatively, there is some evidence that selective avoidance of negatively-valenced information may represent an adaptive means of coping with stress. Attentional biases may develop for distinctive categories of information and become an important feature of information processing in the environment (Bargh & Gollwitzer, 1994; Graham & Hudley, 1994; Bargh & Pratto, 1986). Attending to emotional information may be highly adaptive when faced with a potentially threatening stimulus or interpersonal situation. This type of vigilance is advantageous because it leads to the rapid recruitment of further

cognitive resources for stimulus evaluation and response preparation. It may be less adaptive in situations where there is no "real" threat or when it occurs too frequently. In either case, the role of attentional processes may be paramount in regulating stress reactivity, particularly in terms of HPA response. Because the effects of repeated stressors and stress reactivity are central to current conceptualizations of behavioral adaptation (Schwartzman & Austin, 1998; Gunnar, 1994) and psychopathology (Coplan et al., 1996; Post, 1992), it is important to address the question of whether stress influences attentional processing. This question is of fundamental importance because it suggests that the experience of repeated stressors during development may ultimately bias the way environmental information is processed.

6. CURRENT PROJECT

Overview

The primary objective of the studies described in this thesis was to monitor the impact of a stress-induced motivational state (negative, positive, neutral) on selective attention to emotionally-valenced information. In addition, the role of selective attention in the regulation of the subjective (mood response) and physiological (salivary cortisol) consequences of a stressor was assessed. It was hypothesized that selective attention would mediate the mood and physiological response to stress, and that it would do so by facilitating state-congruent information processing during stressful states. The examination of this type of mechanism may shed light on both the origins of, and the means by which to prevent maladaptive stress-related coping behaviours.

To examine these hypotheses, two experiments were conducted. In study

1, healthy university students were subject to a competitive stressor challenge designed to elicit a positive or negative affective-motivational state, or a "neutral" control condition (described in the next section). Following the stressor, subjects performed a modified spatial cueing task, where negative, positive and neutral words are used as attentional cues (described below). A recognition memory test of words used in the attention task was administered at the end of the experiment. Salivary cortisol and mood state were measured prior to, and throughout the experiment and recovery period. The goal of this study was to assess the effects of stress on mood, cortisol, and attentional shifts towards and away from emotional stimuli. Furthermore, the relationship between attention, mood, and cortisol in recovering from a stressful experience was examined.

The second study assessed the effects of pictorial depictions of emotion on attention using a stressor that temporally overlapped with the attention task. The goals of this study were to re-examine the previous questions using salient, ecologically-valid stimuli (Bradley et al., 1996; Lang et al., 1993) and a more robust stress paradigm. In this study, participants engaged in the same stressor and control tasks as in study 1, except that these tasks were divided into two parts. Following completion of the first part of the stressor or neutral task, subjects performed a pictorial spatial cueing task, where neutral, negative and positive pictures were used as attentional cues. Following the attention task, subjects immediately continued with the second part of the stressor or neutral task. The goal of this alteration was to create a prolonged and robust stressor, where subjects anticipate further stress during the attentional task. All other facets of this study were the same as study 1.

Stress induction

The stress induction was achieved by having subjects either lose (negative stressor) or win (positive stressor) repeatedly while competing against a confederate on a computerized Stroop task with monetary reward. The control condition consisted of performing the same task without competition or incentive. The interpersonal nature of the stress induction was thought to be more naturalistic than traditional stressors such as mental arithmetic or loud noise. In this way, it was similar to other social stressors which draw on evaluative situations to induce stress. The "Trier Social Stress Test", a commonly used stressor, requires subjects to prepare and give a speech in front of a panel of judges (Kirschbaum et al., 1993). These social-evaluative stressors effectively increase negative affect and cortisol production (Al'Absi et al., 1997; van Eck et al., 1996; Kirschbaum et al., 1995; Kirschbaum et al., 1993). The current design differed from other studies of social-evaluative stress by inducing both a positive and negative stressful experience. It was designed to create opposite affective-motivational states through the experience of repeated success and failure during competition with a peer. There is evidence that this type of stressor challenge induces negative affect and increases cortisol output (Croes et al., 1993; Lovallo et al., 1990) .

The "social-competitive" stressor used in the present studies was well-suited to the study of motivational influences on attention. With some exceptions (e.g. Mogg et al., 1998), past research in this area has used very mild experimental manipulations of motivational state, such as assigning attentional cues with incentive value or by giving performance-related feedback following each trial (see Derryberry and Tucker, 1994). Here, motivational states were elicited through monetary reward and the experience of uncontrollable failure

and success. For these reasons, the present paradigm was believed to be a more potent and authentic test of the hypothesis that motivational states can influence information processing of motivationally-significant information.

Modified spatial cueing task

The attention task used in the current studies differs from previous ones in the literature on attention and emotion. The emotional stroop task, the most commonly used test, assesses the allocation of attention to the emotional content of a stimulus through its competing or disruptive effects on task performance (Williams et al., 1996). Attentional effects in this paradigm are difficult to separate from other non-attentional response factors. It is possible that emotional stimuli interfere with the execution of a vocal or motor response in this task, independent of attention. Another frequently used measure of attention is the dot probe task, which measures the allocation of attention to an emotional stimulus when presented with two competing stimuli (Mogg & Bradley, 1998). While this type of task is able to identify attentional biases for emotional information, it provides little understanding of the actual attentional mechanism involved and is not based on any conceptual model of attention. For the present studies, a model of attentional orienting, as postulated by Posner and colleagues (1994; 1987; 1978), was adopted. The attention task used in these studies was developed by Stormark and colleagues (1997; 1995), who modified Posner's (1978) original cueing design to incorporate emotional words. This task was further adapted by incorporating pictorial depictions of emotion for study 2, an aspect that has not been previously examined in the literature.

In this task, covert shifts of attention are assessed by measuring reaction time to a target that is either validly or invalidly cued. For valid trials, the

pretarget cue draws attention to the spatial location where the target will appear, the effect of which is to speed up reaction time. For invalid trials, the pretarget cue draws attention to an incorrect spatial location, the effect of which is to delay reaction time. This delay is hypothesized to result from the disengagement of attention from the incorrectly cued spatial location, and its realignment and allocation at the correct location where the target appears. Negatively-valenced, positively-valenced, and neutral stimuli are used as cues in this task. The advantage of this attention task is that it is devoid of response competition or competing foveal stimuli, and it assesses shifts of attention towards and away from emotional stimuli.

There are several methodological aspects of the modified spatial cueing task that warrant consideration. First, the current task consisted of trials with valid and invalid cues, but did not include "control" trials, where the pretarget cue provides no information about the probable location of the target. In previous studies of spatial cueing (Posner, 1978), non-informative cues were used as comparison trials because they were thought to be equivalent on all processing demands with valid and invalid trials except for their informative value. However, Jonides and Mack (1984) argued that non-informative cues were not fully neutral because they provide information that may affect reaction time and increase alertness in participants. Unless such factors can be controlled for, they advised dropping these trials. In addition, the present task required a large number of trials to establish stable estimates of reaction time for the three types of cues. Additional non-informative trials would have lengthened the task unnecessarily, since there is ample evidence demonstrating differences between valid, invalid, and non-informative control trials (Posner, 1978; Posner, 1988). Because the focus of the current project was to assess affective influences on attention,

neutral words and pictures were used for comparative purposes.

Second, cues were presented at one exposure duration (290 ms for words; 600 ms for pictures) in the modified spatial cueing task. The use of a single stimulus onset asynchrony (SOA), which is the time between the onset of the pretarget cue and the onset of the target, limits the generalizability of these studies. As explained above, multiple SOAs would have lengthened the task, causing other confounding effects such as fatigue. What was important for the present studies was to establish a fixed exposure duration that allowed for sufficient time for the full conscious processing of the stimuli.

7. OBJECTIVES AND HYPOTHESES

Mood and cortisol

There is a large body of evidence showing that subjective distress and increased cortisol are critical features of the stress response (Al'Absi et al., 1997; van Eck et al., 1996; Kirschbaum et al., 1995; Kirschbaum & Hellhammer, 1994; Nicolson, 1992; Breier, 1989; Ursin et al., 1978; Kral et al., 1968). Among the features of an environmental challenge that elicit a stress response, subjective distress (Henry, 1992), aversive contingencies (Lovallo et al., 1990), controllability (Breier et al., 1987), and subjective appraisal of the event (van Eck & Nicolson, 1994) are all deemed important. The current experimental manipulations incorporated several of these features, such as repeated failure or success, competition for monetary gain, and an inability to control the outcome. Therefore, it was hypothesized that the negative stressor would elicit greater mood lowering and higher cortisol levels than the positive stressor and neutral conditions. The positive stressor was predicted to elicit a greater elevation in

mood than the other conditions, and lower cortisol levels than those associated with the negative stressor. The neutral condition was expected to induce no mood change and lower levels of cortisol than those associated with the negative stressor.

Attention

The primary objective of the present studies was to determine whether affective-motivational states induced by repetitive failure and success would influence attentional processing of motivationally significant emotional stimuli. A key feature of the current research was the operational definition of attention as shifts of attention towards and away from salient stimuli, based on a formulation of attentional orienting by Posner and colleagues (1994; 1987). As reviewed earlier, a number of lines of evidence support a relationship between attention and affective-motivational state, including experimental manipulations of incentive (Derryberry & Tucker, 1994), drive state (Mogg et al., 1998), and mood (Bradley et al., 1997a). Research in populations differing in clinical status (Mogg & Bradley, 1998; Mathews & MacLeod, 1994) or personality features (Derryberry & Reed, 1994; Derryberry & Reed, 1994) provide further support of this relationship. Overall, these studies indicate that affective-motivational states bias information processing in a mood-congruent way. Therefore, it was hypothesized that, under conditions of repetitive loss, subjects would selectively attend to negative stimuli, primarily through delays in shifting attention away from these stimuli.

Cortisol and attention

The concurrent measurement of cortisol and attention in these studies

allowed for an examination of the relationship between high cortisol and cognitive function. From the previous review of the literature, two conclusions were put forth. First, moderate elevations of cortisol may impede attentional focusing (Mölle et al., 1997; Wolkowitz, 1994; Kopell et al., 1970), probably by decreasing inhibitory functions important for focal attention (Skosnik et al., 2000). Although this may impede functioning on tasks with distractors and multiple sources of information, this expansive mode of attention was hypothesized to facilitate attentional shifting in general. Second, a high cortisol response to stress facilitated selective attention to threatening stimuli in two recent studies (Epel et al., 2000; van Honk et al., 2000). Increased cognitive vigilance towards threatening information may represent one facet of the stress response. Thus, it was predicted that high cortisol responders would show (1) faster reaction time to all stimuli during the attention task, and (2) greater selective attention to negative stimuli than low cortisol responders.

Recovery from stress

One advantage of the present experimental design was that mood and cortisol were measured throughout the experiment and during a post-stress recovery period. Thus, the design allowed for an assessment of how attention mediates recovery from a stressful challenge. Rothbart, Posner and colleagues (1995; 1994) propose that the ability to shift attention away from a source of distress is an adaptive means of emotion regulation. Thus, it was proposed that attentional disengagement from negative stimuli would be an important determinant of HPA and mood regulation post-stress. It was hypothesized that high cortisol and low mood during the recovery phase of the experiment would be associated with an impaired ability to disengage attention from negative

stimuli. Likewise, rapid shifts away from negative stimuli were predicted to promote adaptive stress recovery.

State measures of depression and anxiety

There is an extensive clinical literature demonstrating abnormalities in information processing and HPA function in depressed and anxious populations (Mogg & Bradley, 1998; Mathews & MacLeod, 1994; Holsboer, 1992; Stokes & Sikes, 1987). Of particular relevance to the present studies, these clinical populations and non-clinical subjects with high trait anxiety show attentional biases for negative sources of information. Therefore, it was proposed that the attention and cortisol response to stress would be mediated in part by factors independent of the experimental manipulations, such as measures of depression and anxiety. It was hypothesized that participants with symptoms of depression and anxiety would exhibit greater selective attention to negative stimuli and a higher cortisol response to stress than those subjects free of depressive and anxiety symptoms.

Study 2

The second study reported in this thesis was designed to incorporate salient and ecologically-valid emotional stimuli into the attention task, and to elicit a prolonged stress experience in participants. For these purposes, pictorial depictions of emotion (Bradley et al., 1996; Lang et al., 1993) and a stressor that temporally overlaps with the attention task were used. Therefore, it was predicted that the mood, cortisol and attentional response to stress would be more pronounced in study 2 than study 1.

STUDY 1

METHOD

1. SUBJECTS

Student participants, 18-35 years of age, were recruited through newspaper advertisements in college newspapers (Concordia and McGill Universities) and visits to classrooms. Subjects were told that the goal of the study was to examine cognitive ability during competition. All participants were English-speaking, or demonstrated an adequate understanding of English on an english fluency test. They were all right-handed and had normal or corrected to normal vision. The criteria for exclusion of subject candidates were: (1) pregnancy; (2) lactation; (3) regular usage of prescriptive medication, except for birth control medication (women who were in the midst of changing birth control procedures were excluded); (5) colour blindness; (6) current psychiatric disorder; and (7) any major medical condition. Of the 138 subjects meeting inclusion criteria, three subjects were excluded from all analyses for failing to comply with the testing protocol. Thus, 135 subjects participated in this study (61 males; 74 females), with a mean age (± SD) of 23.8 ± 4.2 (18-36 years). 47 (21 males; 26 females) participants were randomly assigned to the negative stressor condition, 45 (20 males; 25 females) to the positive stressor condition, and 43 (23 males; 26 females) to the neutral condition

2. MATERIALS

Screening Measures: A diagnostic assessment was completed by means of a brief semi-structured clinical interview based on the Structured Clinical Interview for DSM-IV (First et al., 1997). Major diagnostic categories (axis-1) were assessed (substance abuse, depressive, anxiety, and psychotic disorders), as well as any mental health treatment or major medical condition. Tests for colour blindness and English reading comprehension were administered to exclude subjects with poor colour vision or an insufficient knowledge of English, both of which would impede performance of the cognitive tasks described below. Colour blindness was assessed by having subjects identify the ink colour of words presented on a computer screen (Ishihara, 1964). A cloze test, where subjects read a passage of English text and fill in the missing words, was used as a brief measure of english comprehension, the validity of which has been previously established (Aitken, 1977; Jonz, 1990).

Measures of affective state: Emotional response during the course of the study was measured with the bipolar form of the Profile of Mood States (POMS; McNair et al., 1988). This test consists of subjective ratings of 72 adjectives describing six mood states: agreeable-hostile, composed-anxious, elated-depressed, confident-unsure, energetic-tired, and clearheaded-confused. It is highly sensitive to changes in mood state in non-clinical populations (Ellenbogen et al., 1996; Benkelfat et al., 1994), and the authors report good psychometric properties (Lorr et al., 1982; McNair et al., 1988).

A visual analogue scale (VAS) was administered to assess how stressful subjects found the experiment. The VAS consists of five 100 mm horizontal lines,

each representing a different dimension, on which the subject is instructed to place a perpendicular mark that best describes their subjective state. The dimensions assessed were "stressed", "discouraged", "confident", "determined", and "negative thoughts". Questionnaires administered at the end of the experiment included the Beck Depression Inventory (BDI; Beck et al., 1961), a self-report measure of clinical depression and the Spielberger Trait-State Anxiety Inventory (STAI; Spielberger et al., 1983), a measure of both trait and state anxiety. Both have strong psychometric properties (Beck et al., 1961; Spielberger et al., 1983).

Stimuli: Words used in the modified spatial cueing task were negatively valenced words denoting failure and loss (i.e. loser, inferior, gloomy), positively valenced words denoting success and reward (i.e. winner, victory, glory), and neutral words denoting furniture or time (i.e. table, duration). Words were generated in the following manner. Forty negative, positive and neutral words, between 4 and 8 letters long, were identified from the literature on motivation and personality. The words were then evaluated by an independent pilot sample of 40 students (20 males and 20 females) using a 9 point likert scale ranging from "most closely related to success" (9) to "most closely related to failure" (1). Words that were not understood by a pilot subject, and words that were rated differently by male and female students were dropped. Negative, positive and neutral words were then matched for word length and frequency usage (Carroll et al., 1971). The 16 words with the highest mean rating (> 5.75, positively-valenced), the 16 words with the lowest mean rating (< 2.25, negatively-valenced), and the 16 words rated closest to the midpoint of the scale (3.75 - 4.25, neutral) were used as pretarget cues. These words are listed in Appendix 1. Words were presented in black bold

font, and were easily readable. Contrast of the words was high: luminance of the black letters and the white background were 0.87 cd/m^2 and 101 cd/m^2 respectively. Overall luminance of words within the rectangle was 82.7 cd/m^2. The size of words ranged from 0.58° x 1.45° (0.3 x 1.1 cm) to 0.58° x 2.57° (0.3 x 2.0 cm) of visual angle.

Equipment: The modified Stroop test was run on a 486 PC compatible computer, and the program designed by a computer programmer. The spatial cueing paradigm was run on a Power Macintosh 4400/200 with a 15-inch Apple Multiple Scan colour monitor. The task was presented using the PIXX (version 1.49) software developed by the Visual Perception Lab of Concordia University.

3. PROCEDURE

Overview: Subjects were initially screened by telephone regarding their medical and psychiatric history. They were instructed to eat breakfast on the morning of the experiment, but to refrain from all food consumption for one and a half hours before arriving at the laboratory. Participants commenced the experiment between 11:45 AM and 12:15 PM. Upon arrival, subjects were screened for english fluency and colour blindness, and a psychiatric assessment was conducted. Following these screening procedures, subjects who met inclusion criteria were enrolled in the study. The sequence of experimental tasks is depicted in Figure 1. The study began with a baseline relaxation period of 30 minutes (Fig. 1-A). In a dimly-lit room with relaxing music, subjects were instructed to rest in a comfortable chair and were allowed to read magazines. Subjects were then randomly assigned to one of three stressor conditions: a

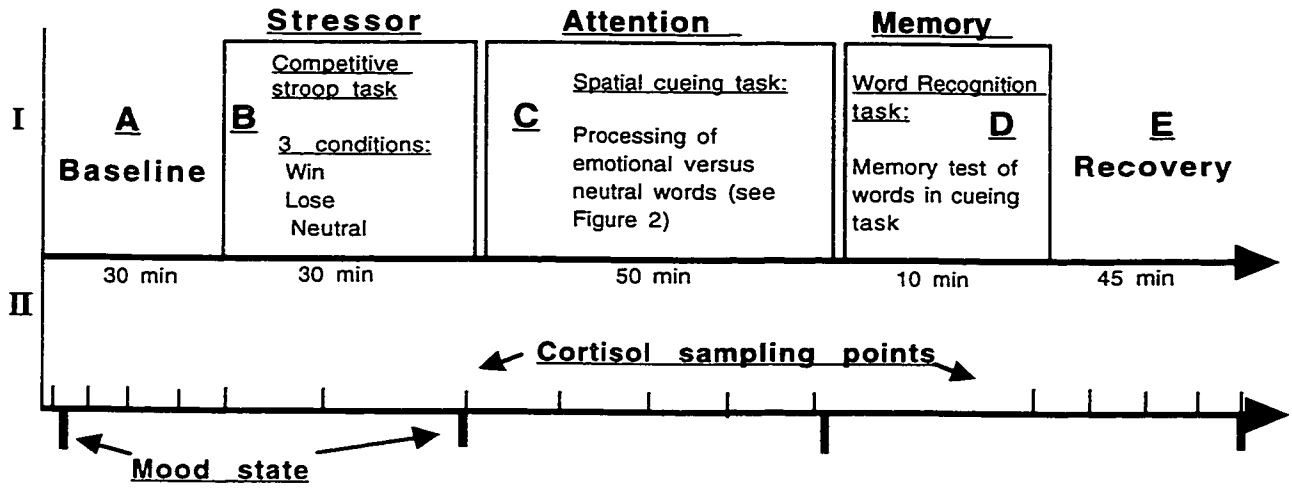

Figure 1. Sequence of experimental tasks (I), and cortisol and mood sampling points (II).

positive, negative, or a control condition (Fig. 1-B). In the positive and negative stressor conditions, subjects competed against a confederate, who was introduced as another subject participating in the experiment. The subject and confederate were placed in adjacent rooms connected by a large window and an open door. Instructions for the positive and negative stressor conditions were identical. Subjects and confederates were instructed to respond as quickly and as accurately as possible, and were told that they would receive $1 for every game they won, but only if they won a minimum of four games. Unknown to the subject, wins and losses were under experimenter control, according to a preset schedule. At the end of each block, subjects were given feedback by the experimenter regarding the speed and accuracy of their performance relative to the confederate. Subjects in the negative condition lost 9/12 games and did not earn any money. Meanwhile, they observed the confederate "earn" $9. In the positive condition, subjects won 10/12 games and were rewarded with $10. In the control condition, subjects performed the stroop task without a competitor, and received no monetary incentive or verbal feedback from the experimenter. The entire stress paradigm took approximately 20 minutes to complete. Upon completion of the stressor task, subjects immediately performed the spatial cueing paradigm (Fig 1-C) in a different room, followed by a word recognition task (Fig 1-D). Following a 45 minute rest period, all participants were debriefed. Subjects completed the BDI and STAI before leaving. As depicted in the lower portion of Figure 1, salivary cortisol and mood state (POMS) were measured at intervals throughout the experiment. The VAS was administered before, at mid-point, and following the stressor task. All participants were compensated $40 CAN for time spent in the laboratory. All procedures were approved by the Concordia University Research Ethics Committee.

Stressor: The social stressor was a competitive reaction time task - a modified, computerized version of the Stroop Colour-Word Interference Test (Stroop, 1935; Blondin & Waked, 1991). The subject was required to press the appropriate response key on the computer keyboard to name the actual colour of the print of the presented word. The presented word spelled either the same colour (congruent) or a different colour (incongruent) from the colour of the print. Subjects were given 30-45 practice trials, so that they felt competent doing the task. Subjects were then presented with a series of twelve blocks or games, each block consisting of 50 stimulus word trials. Each trial began immediately following response to the previous one, or at the rate of one per second. Performance was monitored for speed and accuracy, and results of the subject's performance were presented on the computer at the end of each block in all three conditions. Feedback concerning wins and losses, as well as the monetary reward, was given by the experimenter at the end of each block, along with a standardized set of verbalizations for each condition. In the negative condition, the subject was told, for example, "you lost again" or "he/she (confederate) has beaten you again". In the positive condition, verbalizations by the experimenter included "you win again" or "you are really cleaning up here". Confederates in this study were one male and one female student, who were randomly assigned to the positive and negative conditions.

Modified spatial cueing paradigm: Developed by Posner (1988; 1978) and adapted by Stormark et al (Stormark et al., 1995) to incorporate emotional stimuli, this task measures covert shifts of attention. The task is graphically presented in Figure 2. Subjects fixated on a centrally placed black "+" sign on a white background, which was flanked on both sides by a rectangle. The goal of the

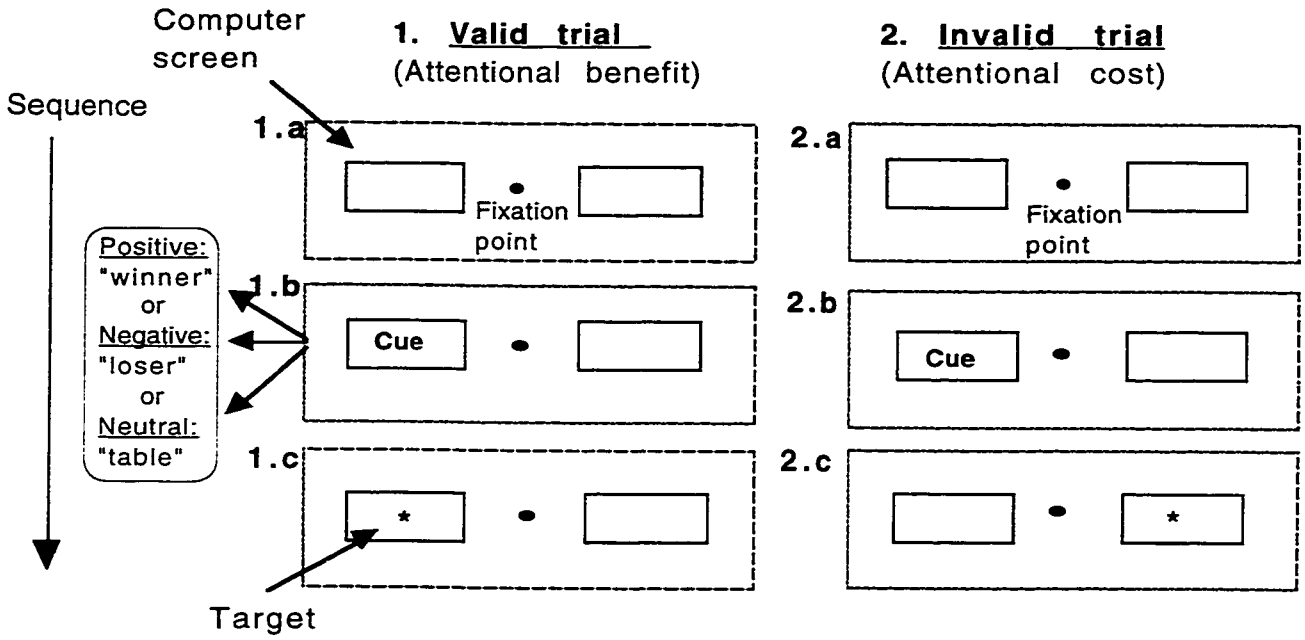

Figure 2. The sequence of events (from top to bottom) in the modified spatial cueing task for a valid (1) and invalid (2) trial. Following a fixation period (1.a and 2.a) , a valid (1.b) or invalid (2.b) pretarget cue is presented in one of two locations. Next, the target (*) appears at the location of the cue (1.c) on valid trials or at the other location (2.c) on invalid trials. Adapted from Stormark et al, 1995.

task was to respond with a single key press as fast as possible when the target (an asterisk) appeared in either of the rectangles. Preceding all target presentations, a pretarget cue appeared in one of the rectangles. This cue was indicative of the most likely location of the target on each trial. There were two types of trials in this task. On valid trials (384), the target appeared in the same hemifield of the cue. These trials elicit an attentional "benefit" because cueing attention to the location of the target speeds up reaction time. On invalid trials (96), the target appeared in the hemifield opposite of the location where the cue appeared. These trials elicit an attentional "cost" because cueing attention to the location opposite of the target delays reaction time. The remaining 96 trials (72 valid and 24 invalid) were "catch" trials; the target appeared after a delay period. Catch trials were meant to prevent subjects from developing an automatic response set due to the fixed cue-target interval in this experiment, and were not included in the statistical analyses. Subjects were instructed to respond with a key press as fast as possible when the target appeared, but to avoid making any premature responses (responding to the pretarget cue). They were informed that the pretarget cue will predict the location of the target approximately 80% of the time, and that this information will help them perform the task more efficiently. They were not instructed to read or pay attention to the meaning of the pretarget cues, which were negative, positive and neutral words.

Subjects performed the task in a chin rest 57 cm away from the monitor. The rectangle boxes had a visual angle of 2.2° (1.7 cm) in height and 2.6° (2.2 cm) in width. The centre of each rectangle was 1.9° of visual angle from the fixation point. In pilot subjects, words presented at this visual angle could be read while maintaining fixation on the centrally placed "+" sign (fixation point). In addition to 8 practice trials, the task consisted of 576 trials, divided into 12

blocks (4 blocks for each word category) of 48 trials. Within each block, all pretarget cues were from the same word category, and stimulus presentation was equally distributed between the right and left visual hemifields. The order of blocks varied randomly between subjects, except that two blocks of the same word category never occurred one after the other. The sequence of trials within a block was fixed for all subjects. Validly and invalidly cued targets (including catch trials) represent 79% and 21% of all trials respectively, a ratio shown to be effective in cueing attention (Posner, 1978). The rate of trial presentation was fixed, but subjects were allowed to take brief rest breaks between blocks. Stimulus onset asynchrony (SOA; interval between the onset of the cue and onset of the target) for valid and invalid trials was 360 ms, and the interval between trials (from the offset of the target to next cue onset) was either 1.85 or 1.35 seconds. For catch trials, the SOA was 790 ms. Targets were presented for 500 ms, and cues for 290 ms. The task took approximately 50 minutes to complete.

For this task, the measures were reaction time to respond to validly-cued and invalidly-cued targets for negative, positive and neutral words in milliseconds. In addition, an index of selective disengagement from negative words was computed by subtracting the mean reaction time for neutral words from negative words on invalid trials. A similar index was computed for attentional engagement, by subtracting reaction time for negative words from neutral words on valid trials. In both cases, a positive score indicates selective attention: subjects are faster to shift towards and slower to shift away from negative than neutral words. A negative score indicates selective avoidance: subjects are slower to shift towards and faster to shift away from negative than neutral words. Identical subtractions were performed for positive words.

Word Recognition Test: Subjects were asked to indicate which words out of a list of 120 had served as pretarget cues on the previous attention task. All neutral, positive and negative pretarget cues were included in the test, along with another 60 distractor words (20 from each word category). The primary measure is the mean number of correctly identified target words.

Cortisol sampling: The salivary cortisol sampling procedure was an adaptation of that used by Stahl & Dorner (1982). Subjects were asked to hold a strip of filter paper (65 mm x 25 mm) under their tongue until it is saturated with saliva. Saliva samples were then air dried, and frozen at minus 20 °C until they were assayed for cortisol. Cortisol levels were determined via competitive protein binding radioimmunoassay using a commercial kit (DSL-2000; Sanofi Diagnostics, Montréal). All assays were performed at the Douglas Hospital Research Laboratories (DHRL) using a radioimmunoassay procedure developed by Krey et al (1975). Sensitivity unique to saliva cortisol is high using this procedure (Laudat et al., 1988). Intra-assay and inter-assay variability (4.6% and 13.9% respectively) were within acceptable limits. Cortisol antibody (F3314) was obtained from Endocrine Sciences (CA) and [^{3}H] cortisol was purchased from New England Nuclear (Boston, MA) to serve as the tracer. Filter paper for sampling (Whatman qualitative 1) was obtained from Whatman International Ltd (Maidstone, UK).

Indices of cortisol output, in µg/dl, were determined for each experimental phase by the total production and by the application of the trapezoidal rule governing start-end "area under the curve" (AUC) calculations (Tallarida &

Murray, 1981). Indices of response magnitude were peak cortisol response during the stressor and attention phases, and the lowest point during baseline and recovery phases. Change scores were computed by subtracting the low point during baseline from peak cortisol production during the stressor phase of the experiment. Indices of recovery were the lowest cortisol levels achieved during the recovery phase at the end of the experiment.

4. DATA ANALYSIS

Mood data: Stressor condition X time MANOVAs were used to assess mood ratings on the POMS across time. Condition (negative stressor, positive stressor, neutral condition) was a between-subject factor and time (baseline, post-stress, post-attention, end of experiment) was a repeated measure. Multivariate significance was determined with Wilk's Lambda, and univariate ANOVAs were used to examine the relative effects of each mood scale. Post-hoc multiple comparisons were conducted with the Tukey HSD (honestly significant difference) test. Where appropriate, mood data were reduced to change scores by subtracting baseline mood ratings from those taken post-stress. These data were likewise analyzed using MANOVAs. Analyses of the VAS were done in a similar fashion, except that the time factor consisted of baseline, mid-stress, and post-stress ratings only.

Attention data: To assess the validity of the attention paradigm, a 4-way mixed design ANOVA (stressor condition X cue type X stimulus valence X hemifield) was conducted. Stressor condition was the between-subject variable, and cue type (valid, invalid), stimulus valence (negative, positive and neutral words) and

hemifield (left and right) were within-subjects variables. The goal of this analysis was to determine whether valid and invalid trials differed from one another. The influence of the experimental conditions on attention was analyzed by 3-way ANOVAs (stressor condition X stimulus valence X hemifield). Because valid and invalid trials represent separate empirical questions (orienting or allocation of attention versus disengagement), valid and invalid trials were analyzed separately. Where significant valence X condition or valence X condition X hemifield interactions occurred, apriori planned comparisons were used to compare negative and neutral words, and positive and neutral words within each of the stressor conditions.

Cortisol data: Cortisol was analyzed using a two-way mixed design ANOVA (stressor condition X phase). Cortisol samples were aggregated into four experimental phases: relaxation, stressor task, attention task and recovery. AUC, mean cortisol production and magnitude of response (peak and nadir values) were analyzed in this way, with appropriate contrasts to follow up significant interactions.

Depression and anxiety: Participants were divided by median split into "high" and "low" groups for depression (BDI) and anxiety (STAI). These grouping variables were analyzed as an additional factor in the above ANOVAs and MANOVAs.

Multiple Regression: Hierarchical multiple regressions were used to examine whether (1) clinical state (depression or anxiety), mood change, and the cortisol response to stress were associated with attention, and (2) whether clinical state,

mood change, attention were predictive of peak cortisol during stress and recovery levels of cortisol. For order of entry, potential confounding variables were entered first, followed by the temporal order of the variables of interest.

RESULTS

1. OVERVIEW AND DATA REDUCTION

For study 1, the analyses discussed below were carried out to examine four main issues: (1) the validity of the stressor manipulations and the spatial cueing paradigm (2) the effects of stress on attention and recognition memory, (3) the influence of other factors (depression, anxiety, high cortisol) on attention, and (4) the relationship between mood, cortisol and attention and their role in the regulation of the stress response. In terms of validity, the first question of interest was whether the negative and positive stressors, compared to the neutral condition, elicited the expected mood change. The second question was whether the cortisol response differed between the experimental conditions. These analyses were done to check the validity of the experimental methods, assessing whether the stress-induction procedures altered affective and biological parameters of the stress response. A third question of validity was whether the spatial cueing procedure effectively manipulated covert shifts of attention. Because this procedure is based on the premise that disengaging attention from an incorrectly cued spatial location delays reaction time compared to a validly cued location, it was expected that reaction time for invalid trials would be slower than valid trials.

Next, the effects of stress on subsequent attentional processing of and memory for emotional and neutral stimuli was examined. The goal of these analyses was to determine how the experimental manipulations influenced the way in which attention is allocated (valid trials), and shifted away from (invalid trials), negative stimuli relative to positive and neutral stimuli. The above

questions were subsequently re-examined to compare the outcomes in participants scoring high and low on baseline depression and anxiety, and those designated as cortisol "responders" and "non-responders". Finally, the relationship between mood, cortisol and attention was assessed using regression analyses in an attempt to test the hypotheses that (1) mood change affects attention, and (2) attention modulates parameters of recovery from a stressful episode. These same questions were assessed in the second study as well, in which pictorial depictions of emotion and a stressor that temporally overlapped with the attention task were used.

Before conducting the analyses, all data were screened and adjusted for outliers and distributional anomalies that may have violated statistical assumptions. For repeated measure ANOVAs, homogeneity of covariances were assessed with Box's M test, and all within-subject effects were Greenhouse-Geisser corrected. For measures of attention, all reaction times (RTs) less than 150 ms and more than 850 ms were excluded from the analysis. For each subject, RTs were averaged by word type (negative, positive, and neutral), cue validity (valid and invalid trials), and hemifield of presentation (right and left of fixation).

2. WAS MOOD STATE ALTERED BY THE STRESSOR CONDITIONS?

Profile of Mood States (POMS)

A condition X time MANOVA on the six POMS scales was conducted to test the effects of the stressor conditions on mood. A significant multivariate main effect of time [$F(18,1106)=28.4$ $p<.001$] and a condition X time interaction [$F(36, 1720)=3.0$ $p<.001$] were found. MANOVAs at each time point indicated that mood ratings differed between conditions at post-stress [$F(12,254)=2.6$, $p<.005$],

but not at baseline, post-attention, and the end of the experiment. Mood ratings at each time point are presented in Appendix 1. A MANOVA of change scores (post-stress minus baseline) also revealed significant differences between the stressor conditions [$F(12,254)=4.8$, $p<.001$]. As presented in Figure 3, group differences on all POMS scales were observed [relaxed-anxious: $F(2,132)=3.5$, $p<.05$; elated-depressed: $F(2,132)=17.6$, $p<.001$; energetic-tired: $F(2,132)=12.1$, $p<.001$; agreeable-hostile: $F(2,132)=14.9$, $p<.001$; confident-unsure: $F(2,132)=20.3$, $p<.001$; clearheaded-confused: $F(2,132)=13.1$, $p<.001$]. Overall, subjects exhibited a lowering of mood in response to the negative stressor, and either no change or a heightening of mood in response to the positive stressor. Mood response of participants in the neutral condition fell in between the positive and negative stressor groups, and tended to be mildly negative. The one exception to this pattern was the relaxed-anxious scale. Increased anxiety was reported in all three conditions, but it was greatest following negative stress and least following the positive stressor (see Figure 3).

Post-hoc group comparisons revealed that the mood response of neutral participants differed from participants in the negative stress condition on the elated-depressed, agreeable-hostile and clearheaded-confused scales of the POMS (Tukey HSD test, $p<.05$). Differences between the negative and positive stressor condition were observed on all scales (Tukey HSD test, $p<.05$). In sum, the stress-induction procedures elicited mood change on the POMS in the expected directions.

Visual Analogue scale (VAS)

VAS results were almost identical to those of the POMS. A condition X time MANOVA on the five VAS scales was conducted to test the effects of the

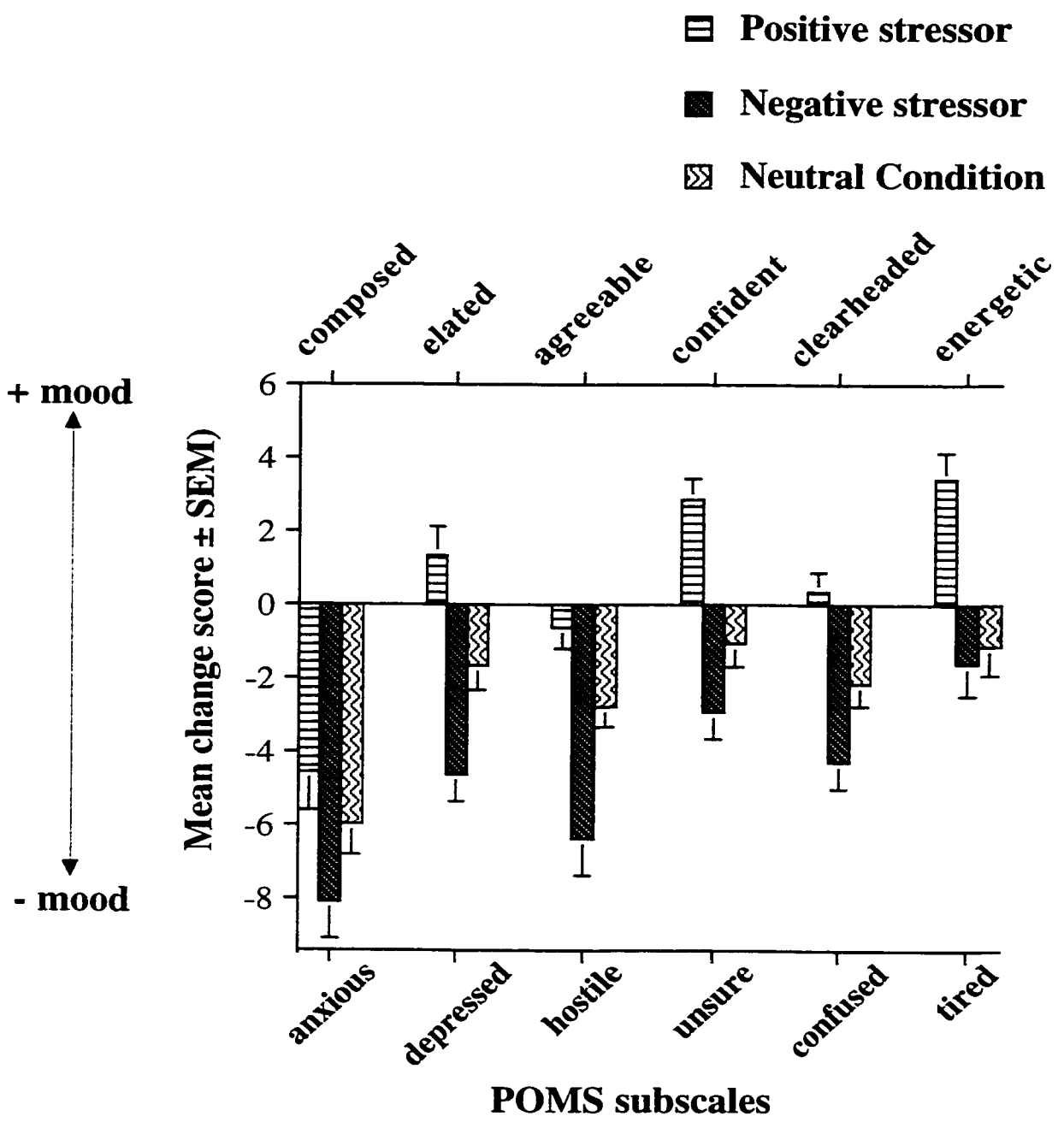

Figure 3. Mean change of mood (post-stress minus baseline) by experimental condition on the Profile of Mood States (POMS). Positive change scores indicate a heightening of mood and negative change scores a lowering of mood.

stressor conditions on mood. Significant multivariate main effects of time [$F(10,520)=24.7$ $p<.001$], condition [$F(10,256)=2.3$, $p<.05$] were observed, as well as a significant condition X time interaction [$F(20, 864)=3.0$ $p<.001$]. MANOVAs at each time point indicated that mood ratings differed between conditions at mid-stress [$F(10,256)=2.0$, $p<.05$] and post-stress [$F(10,256)=3.4$, $p<.001$], but not at baseline. Change scores (post-stress minus baseline) are presented graphically in Figure 4; significant differences between stressor conditions were observed on the discouraged [$F(2,132)=13.6$ $p<.001$], confident [$F(2,132)=11.6$, $p<.001$], determined [$F(2,132)=3.2$, $p<.05$] and negative thinking [$F(2,132)=5.9$, $p<.005$] scales. Overall, subjects reported being more discouraged, less confident, less determined and having more negative thoughts following the negative stressor than the other conditions. Interestingly, increased rating of feeling "stressed" was observed in response to all three conditions, with no differences among them. Thus, the subjective visual analogue ratings are consistent with those found on the POMS, supporting the validity of the stressor manipulations in altering mood state.

3. WAS CORTISOL ALTERED BY THE STRESSOR CONDITIONS?

To correct for significant positive skewness, a square root transformation was performed on all cortisol data. All ANOVAs were performed on transformed data, but figures and tables will contain original data for interpretation purposes. Data for two subjects was not interpretable, probably due to contamination of the samples, and were dropped from the analyses. Thus, cortisol analyses were based on 133 participants: 47 in the negative stress condition, 44 in the positive stress condition, and 42 in the neutral condition.

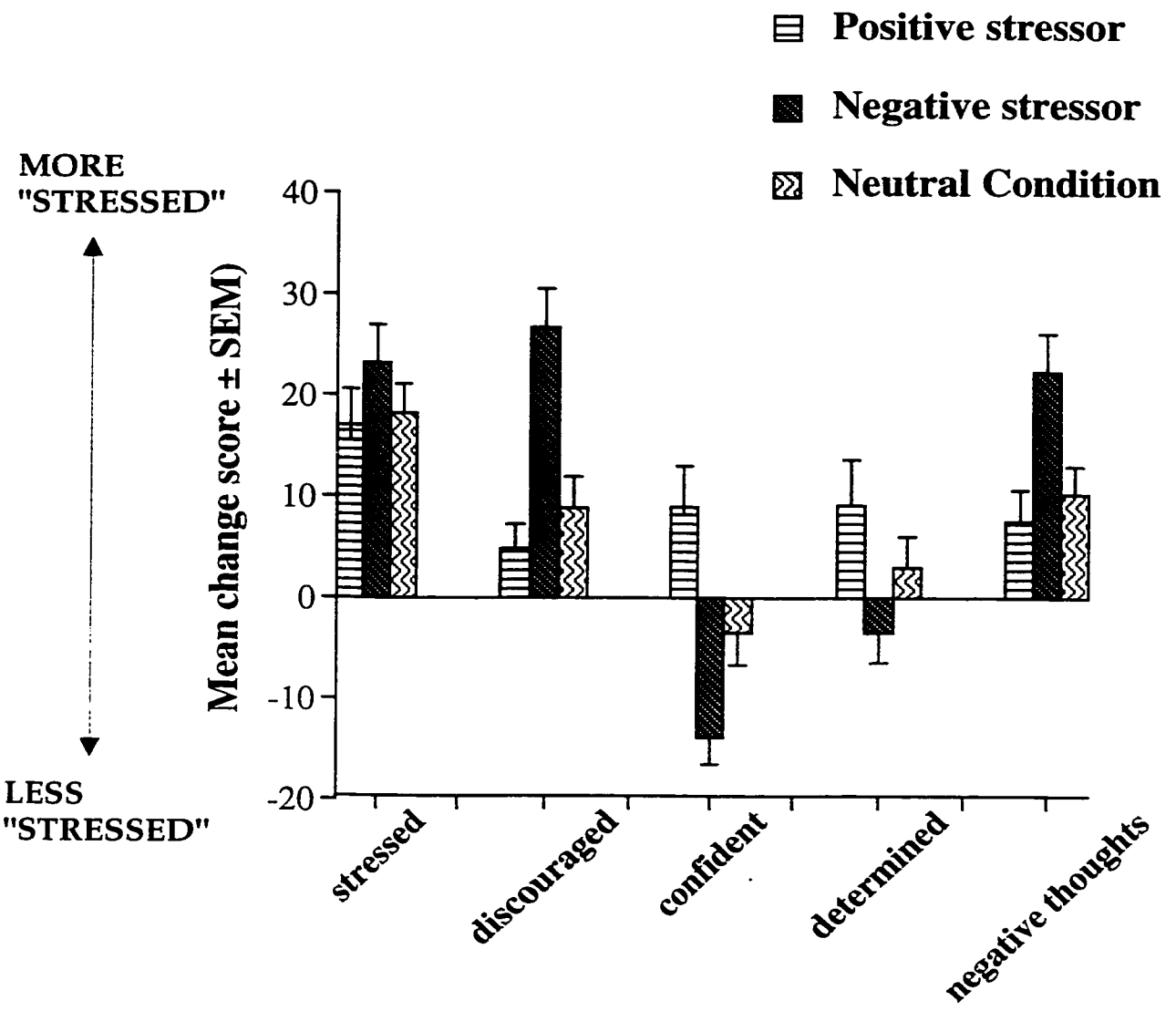

Figure 4. Mean change on the visual analogue scales (post-stress minus baseline) by experimental condition. Positive change scores indicate an increase in the descriptor (I feel more "stressed"), and negative change a decrease in the descriptor (I feel less "stressed").

Mean cortisol production in response to the different phases of the experiment (relaxation, stressor task, attention task, recovery) are shown in Figure 5-A. A two-way (condition x phase) ANOVA on mean and AUC (data not shown) cortisol output revealed no significant main effect of stressor condition, nor were any interactions found. A main effect of experimental phase was observed [$F(3,390)=3.3$, $p<.05$], but this was due to a significant decrease of cortisol levels during the recovery phase [$F(1,130)=5.3$, $p< .05$]. Thus, the stressor conditions did not affect mean cortisol production as expected. Possible explanations for this are individual variations in the timing of the cortisol response, high baseline values during the first relaxation phase, and the absence of sustained cortisol production across long experimental phases (30 to 50 minutes). For these reasons, analyses were then conducted on measures of response magnitude, using the lowest values during the relaxation and recovery phases, and the peak cortisol output during the stressor and attention tasks. A two-way (condition x phase) ANOVA of response magnitude yielded a significant main effect of phase $F(3,390)=178$, $p<.001$], indicating higher peak values during the stressor [$F(1,130)=330$, $p< .001$] and attention [$F(1,130)=259$, $p< .001$] phases than in either of the relaxation or recovery phases. Peak cortisol levels achieved during the stressor and attention phases were not significantly different, nor were there differences between stressor conditions. Thus, cortisol production transiently increased in response to all three conditions, but failed to differentiate between the stressors and a neutral control condition.

Given the lack of robust stress-induced changes in mean cortisol production in the sample as whole, subjects were divided into "responders" (n=66) and "non-responders" (n=67) based on a median split of cortisol change from baseline values. As depicted in Figure 5-B (mean values) and 5-C (peak

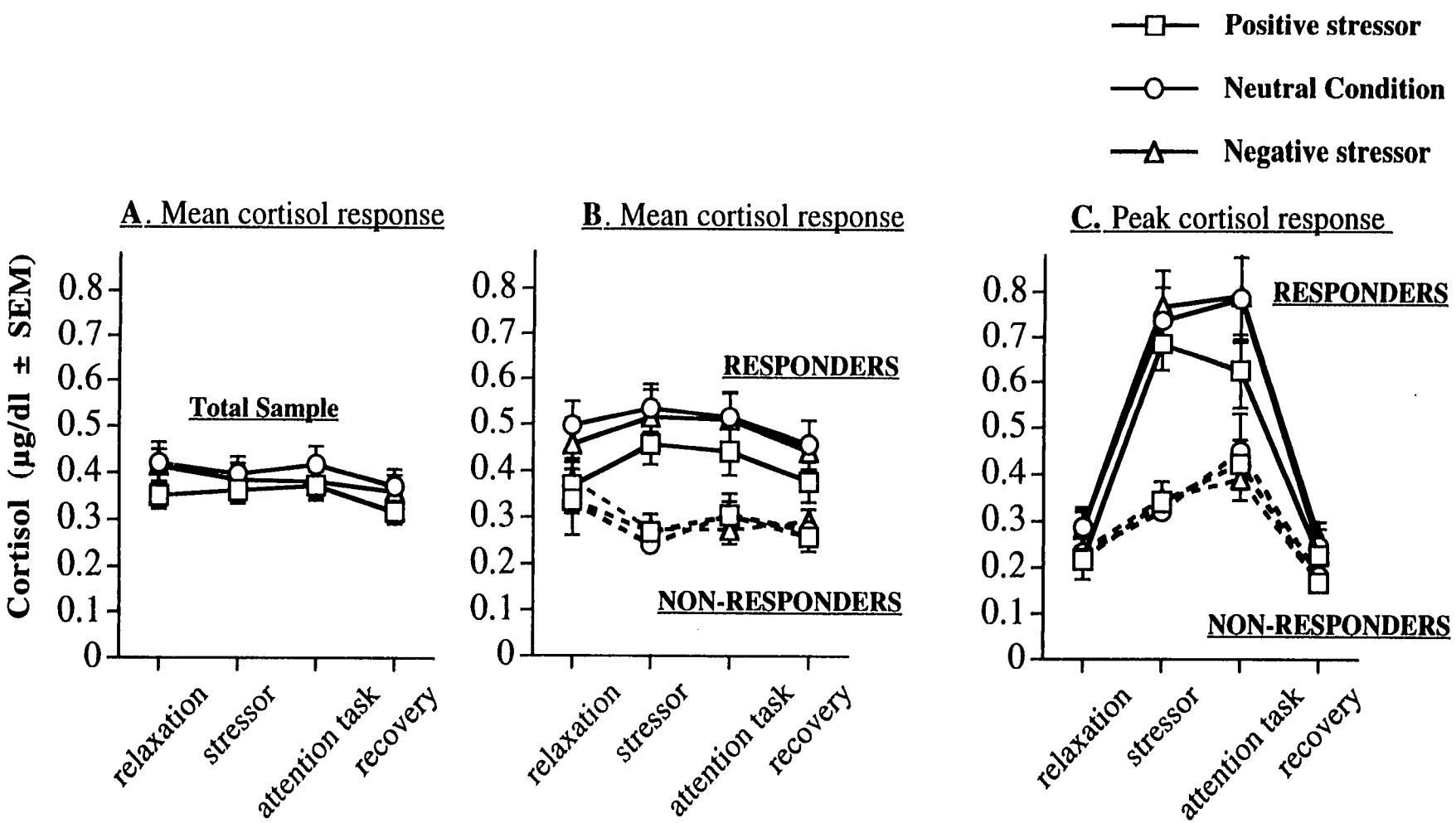

Figure 5. Mean (5-A and 5-B) and peak (5-C) cortisol at different stages of the experiment. Responders (solid lines) and non-responders (broken lines) were those participants with a cortisol response to stress in the upper and lower half of the distribution respectively. Figure 5-C shows cortisol low points during baseline and recovery, and peak cortisol during the stressor and attention phases of the experiment.

values), cortisol responders and non-responders can be clearly differentiated on the basis of their cortisol response to stress. 3-way ANOVAs (group x condition x phase) yielded significant main effects of group for both mean [$F(1,127)=24.6$, $p< .001$] and peak [$F(1,127)=41.1$, $p< .001$] values; no significant group x condition x phase interactions were found. Thus, there was a subsample of participants who responded to stress with significant HPA activation, and a subsample who barely showed any response. However, even among responders, cortisol production did not differentiate between the three conditions.

4. WAS ATTENTION ALTERED BY THE STRESSOR CONDITIONS?

Validity of the modified spatial cueing paradigm

Covert shifts of attention in this experiment were assessed by measuring reaction time to a stimulus that is either validly or invalidly cued. For the purposes of these analyses, hemifield refers to the side of visual space in which the target appears. To simplify the reporting of hemifield effects, all attentional results will be described by the direction of the attentional shift. On valid trials, right and left hemifield trials refer to shifts of attention towards words appearing in the right and left hemifield respectively. On invalid trials however, right and left hemifield trials refer to shifts of attention away from words appearing in the opposite hemifield (the left and right hemifield respectively). All results will be reported in this manner, as shifts of attention towards and away from pretarget stimuli.

To correct for significant positive skewness, an inverse transformation was performed on all reaction time data. All ANOVAs were performed on transformed data, but figures and tables will contain original data for interpretation purposes.

There were no differences between the results of the two data sets. To assess the validity of the spatial cueing paradigm, a 4-way ANOVA (condition X wordtype X hemifield X cue validity) was conducted on reaction time data. As shown in Figure 6, reaction to validly cued targets was significantly faster than invalidly cued targets [main effect of cue validity: $F(1,132)=140$, $p<.001$]. No interactions between cue validity and any other factor were found. These results support the validity of the modified spatial cueing paradigm. All subsequent analyses will be conducted on valid and invalid trials separately, because both measure different processes. Valid trials assess orienting and attentional allocation to a cued target, and invalid trials measure the efficiency of disengaging attention and shifting away from incorrectly cued stimuli.

Valid trials: Orienting and allocating attention

No important findings were observed on valid trials. A 3-way ANOVA (condition X wordtype X hemifield) found only a main effect of hemifield [$F(1,132)=115$, $p<.001$], due to faster reaction time to validly cued stimuli occurring in the right visual hemifield (Figure 6). Overall, the impact of the stressor conditions on attentional orienting and allocation was negligible.

Invalid trials: Disengaging attention

On invalid trials, aversive stress was found to influence selective attention to negative words. 3-way ANOVAs (condition X wordtype X hemifield) were conducted on invalid trials. A significant main effect of hemifield [$F(1,132)=31.8$, $p<.001$] and a trend for significance on the condition X wordtype X hemifield interaction [$F(4,264)=2.23$, $p<.07$) were observed. For shifts of attention away from the right and left hemifield, planned comparisons were performed to compare

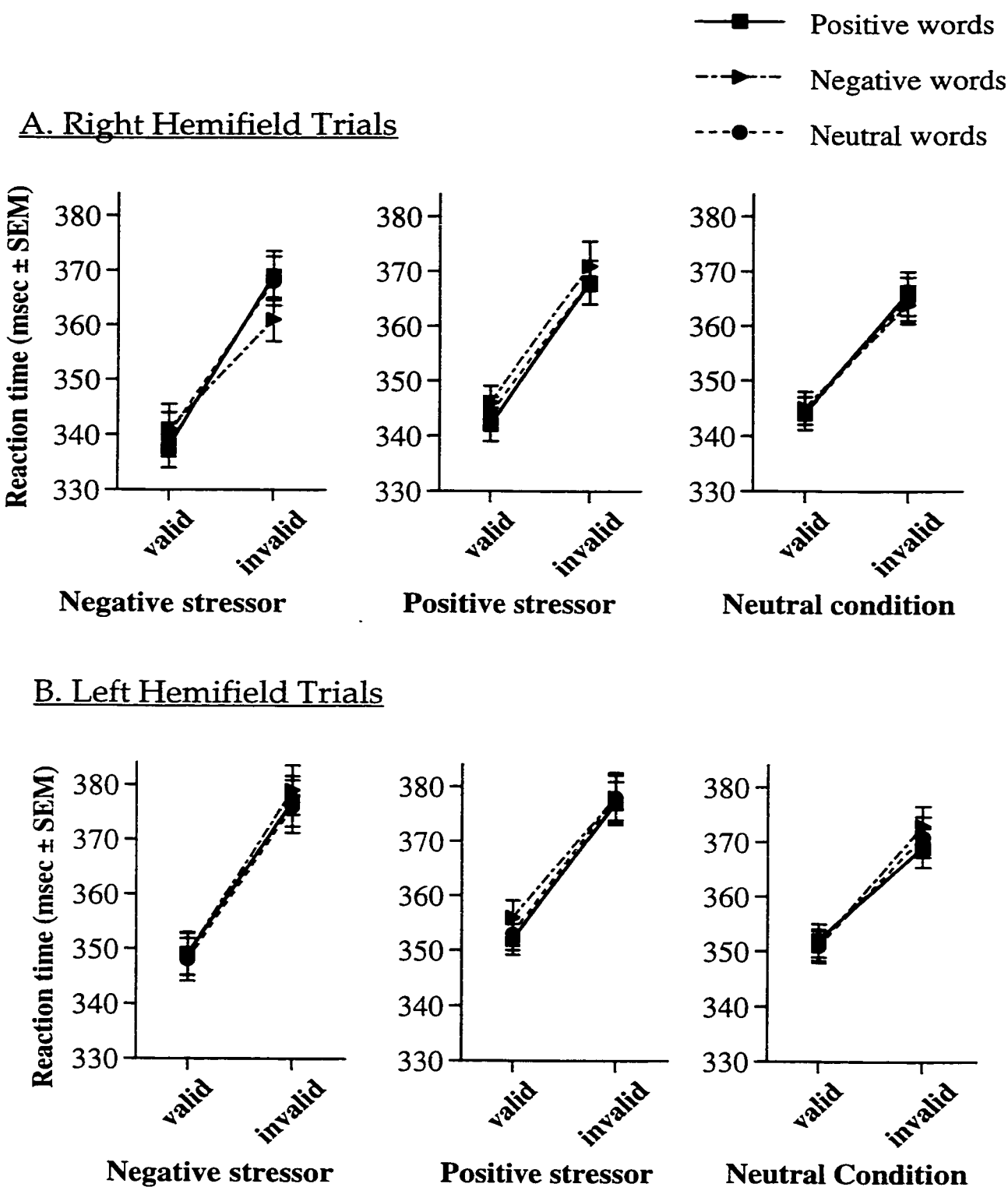

Figure 6. Reaction time data for valid and invalid trials by experimental condition. Right (A) and left (B) hemifield trials are those requiring a response to a target in the right and left hemifields respectively. For right hemifield trials, valid trials measure shifts of attention towards right hemifield words; invalid trials measure shifts of attention away from left hemifield words.

negative words with positive and neutral words within each of the stressor conditions. As depicted in Figure 6-A, it was found that reaction time to shift attention away from left hemifield words was significantly faster for negative words than neutral or positive words in the negative stressor condition [$F(1,46)=7.8$ $p<.01$]. This effect was not observed following the positive stressor or the neutral condition (Figure 6-A), nor was it found for shifts of attention away from right hemifield words (see figure 6-B). Thus, subjects shifted away more rapidly from a negative cue following a negative stressor. In contrast to the hypothesis that stress should elicit greater selective attention of negative information, these results indicate a process of selective avoidance of negative information following aversive stress, occurring only for shifts of attention away from left hemifield words.

Reanalysis of attention data in a subsample of mood responders

One problem with the above analyses of attention data was that the mood response between individuals within each stressor condition varied tremendously. For example, it was observed that some subjects felt dysphoric in response to winning, while others seemed indifferent to repetitive losing. This type of heterogeneity of response may be one reason for the lack of robust findings in the analyses of attention and stressor condition. For these reasons, the above data were reanalyzed in subsamples of subjects who showed the predicted mood change in response to the experimental manipulations. Mood change (post-stress minus baseline) scores on all POMS scales were summed, and a three-way split was applied to this data. Mood change was thus classified as a strong mood lowering (bottom third), mild mood lowering (middle third), and a heightening of mood (top third). Among subjects in the positive and negative

stressor condition respectively, 24 (53%) and 25 (53%) were classified in the top (mood heightening) and bottom (strong mood lowering) third of mood change scores. For the neutrals, only 16 (37%) of subjects fell into the middle third of mood change scores. Because this group was split almost equally between the three mood change classifications, they were dropped from further analysis. Thus, 3-way ANOVAs (condition X wordtype X hemifield) were conducted on reaction time data, comparing subjects with a strong mood lowering response to negative stress ("sad losers"; n=25) with those showing a heightening of mood to positive stress ("happy winners"; n=24).

No significant differences were found for valid trials, nor for shifts of attention away from right hemifield words. Although the condition X wordtype X hemifield interaction for invalid trials fell short of significance in the previous analysis, it was significant in this reanalysis [$F(2,94)=6.2$, $p<.005$]. For shifts of attention away from left hemifield words, sad losers were faster to shift away from negative (mean ± SEM; 354 ± 12 msec) than neutral (362 ± 13 msec) or positive words (367 ± 13 msec). In contrast, reaction times (± SEM) for happy winners were slower for negative words (387 ± 12 msec) relative to positive (381± 10 msec) and neutral (376 ± 11 msec) words, although this fell short of significance [$F(1,23)= 3.1$ $p<.1$]. Thus, subjects who experienced a robust mood lowering response to the stress of repeated loss during a competitive task seem to selectively shift attention away from negative words in the left hemifield. These analyses corroborate the above finding of selective avoidance of negative stimuli following aversive stress, and suggest that this effect is associated with significant mood lowering in response to stress.

5. WAS RECOGNITION MEMORY AFFECTED BY THE STRESSOR CONDITIONS?

A two-way ANOVA (condition X wordtype) was conducted on word recognition data. No main effect of condition or condition X wordtype interaction was found. A significant main effect of wordtype was observed [$F(2,264)=78.2$, $p<.001$], indicating that recognition of negative words was superior to neutral [$F(1,132)=115.6$, $p<.001$] and positive words [$F(1,132)=6.2$, $p<.05$]. In addition, recognition of positive words was superior to neutral words [$F(1,132)=89.6$, $p<.001$]. These results are presented in Figure 7. Although the effects of stress did not influence recognition memory, the main effect of wordtype supports the validity of using words differing in emotional valence in the spatial cueing paradigm. In addition, these results suggest that negative and positive words are encoded in memory more readily than neutral words.

6. WERE THE EFFECTS OF STRESS ON ATTENTION, MOOD AND CORTISOL INFLUENCED BY STATE DEPRESSION AND ANXIETY ?

Depression

Subjects were classified as low dysphoric or high dysphoric based on a median split of Beck Depression Inventory (BDI) scores. Although it is possible that BDI scores may have been influenced by the actual experimental manipulations[2], the BDI did not correlate with stress-induced POMS mood

[2] Because pre-experimental administration of questionnaires could have influenced baseline cortisol and mood, questionnaires were administered at the end of the study, following a relaxation (recovery) phase and debriefing. The VAS and POMS data indicate that there were no prolonged effects of the stressor manipulations extending into this phase of the experiment, suggesting that BDI scores were not biased by the experimental conditions.

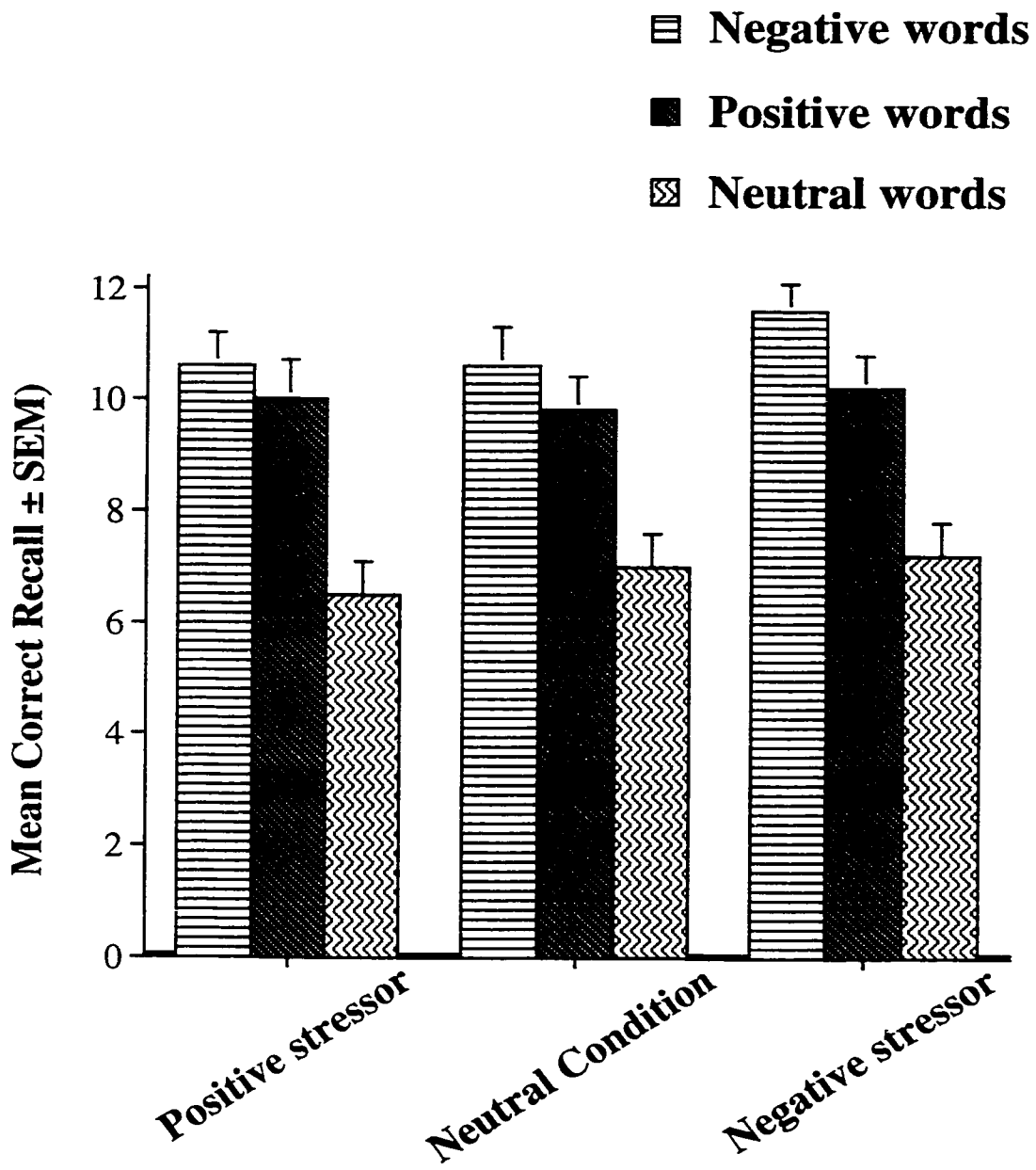

Figure 7. Mean number of words correctly identified, by experimental condition, on a recognition test of the words used in the spatial cueing task. The maximum score was 16.

change (depression: r=.03, NS; anxiety: r=.01, NS). These correlations suggest that the BDI is measuring negative affect or symptoms of depression independent of experimentally-induced mood change. As expected, the BDI correlated with baseline POMS depression (r=-.33, p<.001) and anxiety (r=-.37, p<.001) scores. The mean BDI score in high (n=58) and low dysphoric (n=77) subjects was 10.1 ± 4.6 (range 5-29) and 1.7 ± 1.5 (range 0-4) respectively. The groups were unequal because of the high prevalence of scores at the median (17 subjects with a BDI of 4); we opted to classify these subjects as low dysphoric subjects. The breakdown between stressor conditions was similar: 23 and 22 subjects in the positive stressor, and 25 and 22 subjects in the negative stressor condition were classified as low and high dysphoric respectively. In the neutral condition however, 29 subjects and 14 subjects were classified as low and high dysphoric respectively. Analyses with and without the neutral group were conducted, and the results were essentially the same. The high dysphoric group was composed of individuals with mild, non-clinical symptoms of depression, and the low dysphoric group consisted of fully euthymic individuals reporting no symptoms of depression.

Attention

Attentional shifting was impeded in high dysphoric participants following the aversive stressor. 4-way ANOVAs (group X stressor condition X wordtype X hemifield) revealed no significant findings for valid trials, and a significant group X condition interaction for invalid trials [F(2,129) = 3,13, p<.05]. This interaction was due to a significant group difference in the negative stressor condition [F(1,45)=6, p<.05], and is depicted in Figure 8. Low dysphoric subjects were more efficient in shifting attention away from all stimuli following the negative

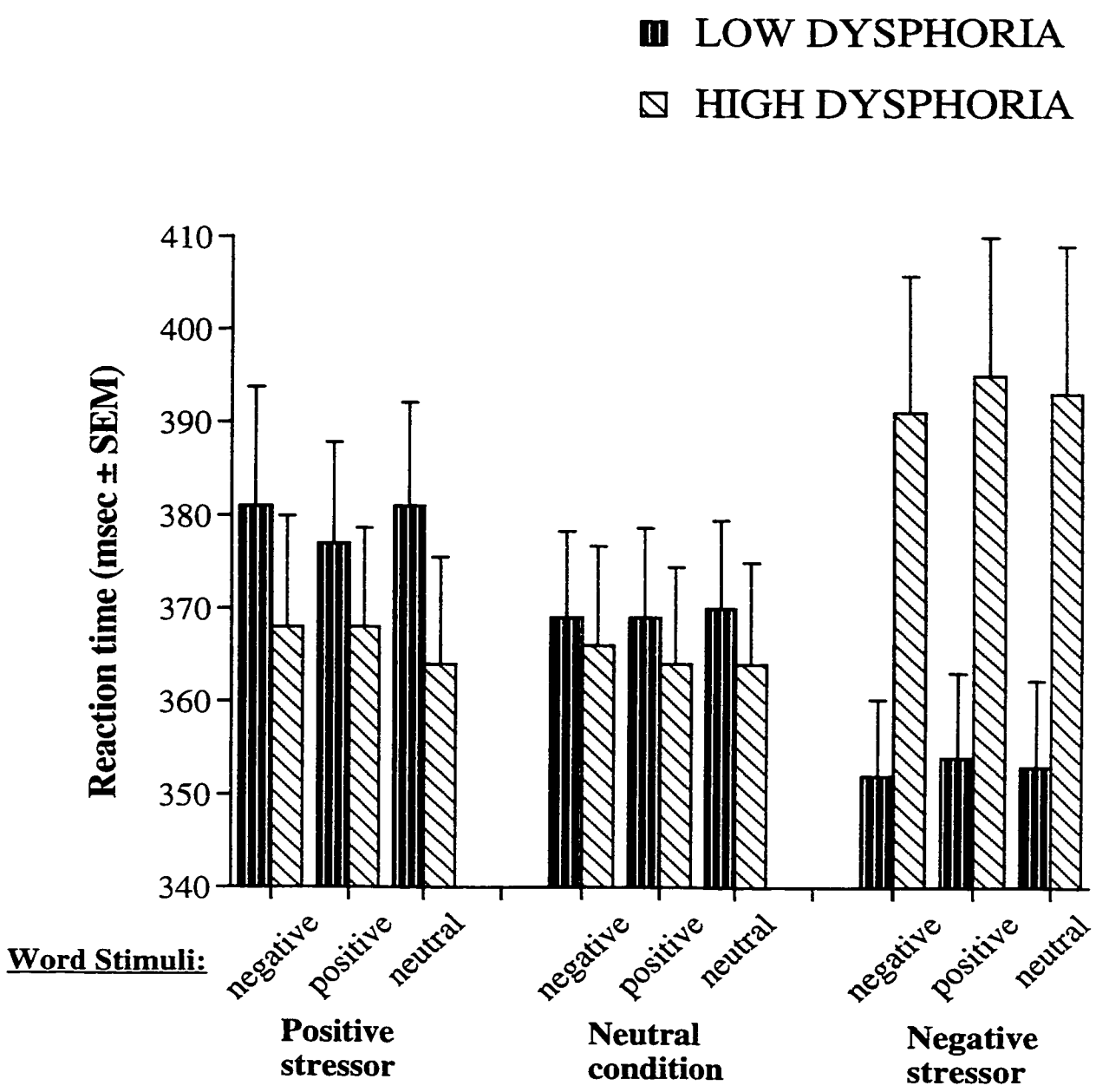

Figure 8. Reaction time data for invalid trials by experimental condition in participants who scored in the upper (high dysphoria) and lower (low dysphoria) half of the distribution of the Beck Depression Inventory. These data are shifts of attention away from words in the left hemifield.

stressor condition than either the positive or neutral condition. High dysphoric subjects, however, were slow in disengaging from all stimuli following the negative stressor condition. That is, they were characterized by poor attentional flexibility following aversive stress, but not in response to positive stress or the neutral condition.

Mood and cortisol

The slow attentional shifting observed in high dysphoric subjects following the negative stressor appeared largely independent of group differences in mood change and cortisol response to the stress. 2-way MANOVAs (dysphoric group X stressor condition) revealed no differences in mood response to the stressor conditions between high and low dysphoric participants on both the POMS and VAS. No group X condition interactions were found as well. As expected, a MANOVA revealed significant differences in mood between high and low dysphoric participants at baseline [$F(6,124)=5.0$, $p<.001$]. High dysphoric subjects reported lower mood on the relaxed-anxious [$F(1,129)=15.3$, $p<.001$], elated-depressed [$F(1,129)=16.6$, $p<.001$], confident-unsure [$F(1,129)=16.9$, $p<.001$], energetic-tired [$F(1,129)=20.4$, $p<.001$], and clearheaded-confused [$F(1,129)=6.9$, $p<.05$] scales of the POMS than low dysphoric subjects (data not shown).

A group X condition X experimental phase ANOVA on mean cortisol revealed a group X phase trend for significance [$F(3,381)=2.5$, $p=.06$]. These data are presented in Figure 9. This interaction is due to group differences during the relaxation and recovery phases of the experiment relative to the stressor and attention phases [$F(1,127)=6.7$, $p<.05$]. High dysphoric participants had higher mean cortisol production at baseline and during recovery than low dysphoric

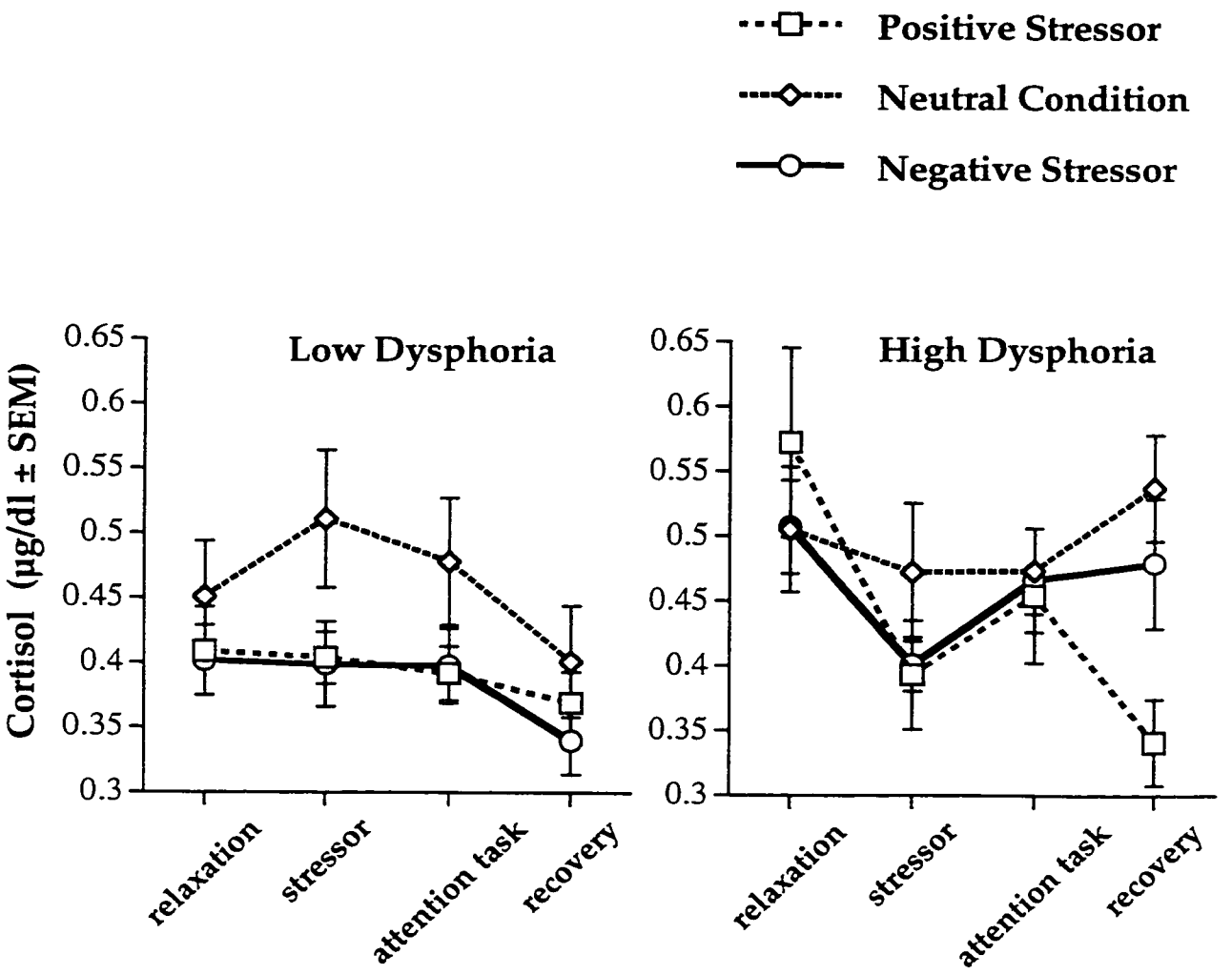

Figure 9. Mean cortisol response at different stages of the experiment in participants who scored in the lower (low dysphoria; left) and upper (high dysphoria; right) half of the distribution on the Beck Depression Inventory

participants. In fact, mean cortisol did not decrease in high dysphoric participants during the recovery phase of the neutral and negative stress conditions, in contrast to low dysphoric subjects (see Figure 9). No significant effects were observed for analyses using the peak cortisol response to stress and low points during relaxation and recovery, although the means were in the same direction (data not shown). In sum, high dysphoric participants were characterized by a deficit in attentional shifting occurring uniquely in response to aversive stress, but did not exhibit greater mood reactivity than low dysphoric participants. There was, however, some evidence that high dysphoric subjects tended to have higher baseline cortisol and less efficient cortisol recovery than low dysphoric subjects.

Anxiety

4-way ANOVAs (group X stressor condition X wordtype X hemifield) were conducted in subjects high and low in state anxiety on the STAI. No significant main effects or interactions were found for attention, mood or cortisol (data not shown). In contrast to state dysphoria, anxiety did not appear to influence orienting to and disengaging from emotional and neutral stimuli.

7. WERE THE EFFECTS OF STRESS ON ATTENTION AND MOOD DIFFERENT BETWEEN CORTISOL RESPONDERS AND NON-RESPONDERS?

Attention

A high cortisol response to stress was associated with a general alerting effect on attention. Cortisol responders and non-responders were compared through a 4-way ANOVA (group X stressor condition X wordtype X hemifield).

A main effect of group was observed for invalid trials [$F(1,127)=4.5$, $p<.05$], indicating that cortisol responders were more rapid in disengaging attention from all stimuli than non-responders (Figure 10). In addition, a group X hemifield interaction was found [$F(1,127)=4.0$, $p<.05$], indicating that the above effect in cortisol responders was more pronounced when shifting away from right hemifield words than left hemifield words. No significant effects were observed for valid trials.

Mood

A two-way (group X condition) MANOVA was conducted on VAS and POMS change score. For VAS ratings taken at the midpoint of the stressor (minus baseline), a significant group X condition interaction was found [$F(10,246)=2.2$, $p<.05$], with univariate significance on the "stressed" [$F(2,127)=5.1$, $p<.01$] and "discouraged" scales [$F(2,127)=4.5$, $p<.05$]. As depicted in Figure 11, subjects with a high cortisol response to stress were more stressed and discouraged during the positive stressor and neutral condition than participants with a low cortisol response. In contrast, cortisol responders were less stressed and discouraged than non-responders during the negative stressor. No significant differences were found for VAS ratings taken at post-stress.

Although a similar pattern of mood response was observed on the POMS between cortisol responders and non-responders, no significant multivariate effects were found (data not shown). In summary, cortisol responders were characterized by fast attentional shifting across conditions and wordtype, and subjective ratings of distress that were less differentiated between the experimental manipulations than non-responders. This pattern of attentional shifting and mood response suggests that cortisol responders were more aroused

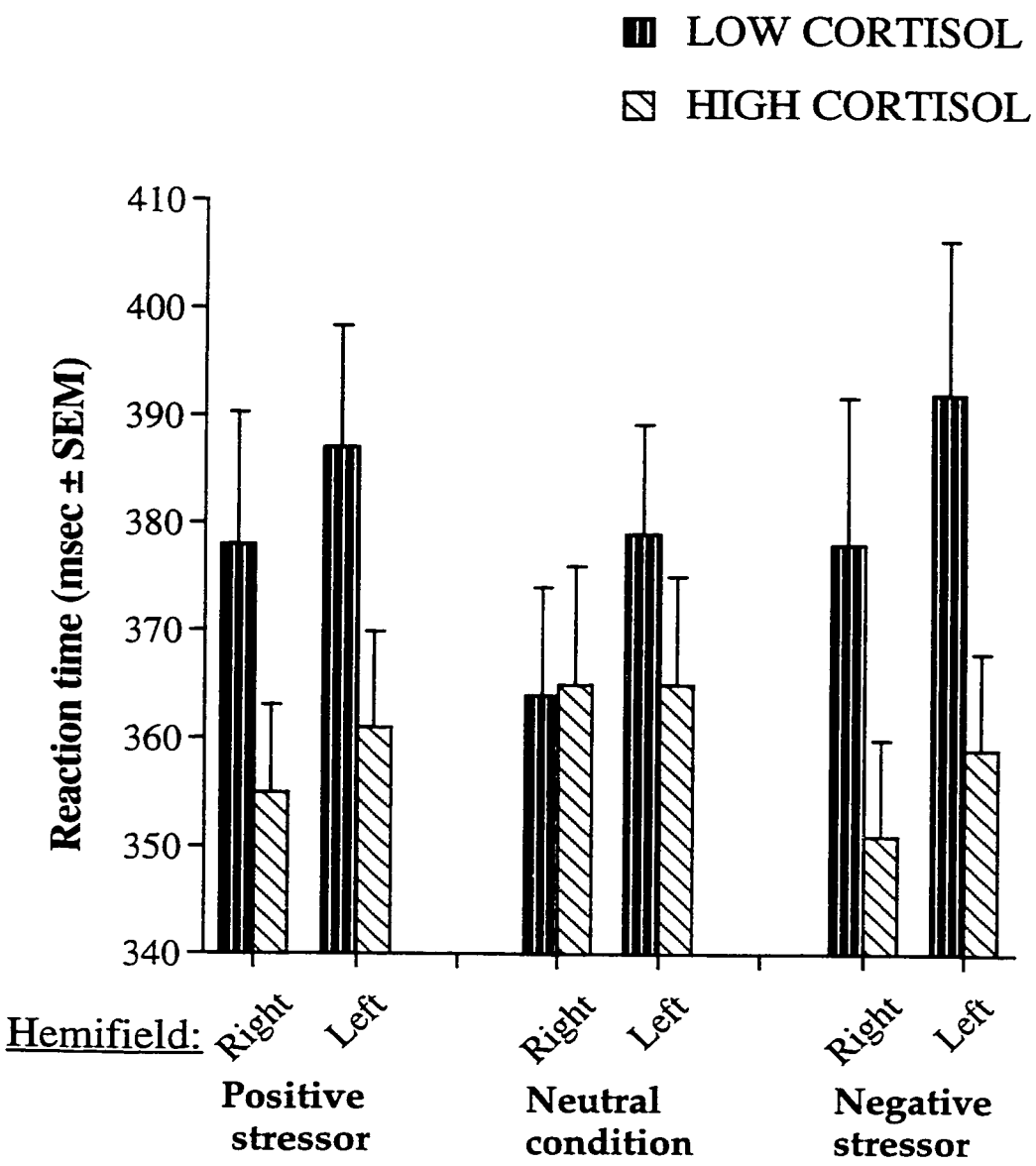

Figure 10. Reaction time for invalid trials by experimental condition and hemifield in cortisol responders and non-responders. Data presented is the average reaction time of negative, positive and neutral words. Right hemifield refers to shifts of attention away from words in the left hemifield. Cortisol response is defined as those subjects in the upper half of the distribution of cortisol change from baseline.

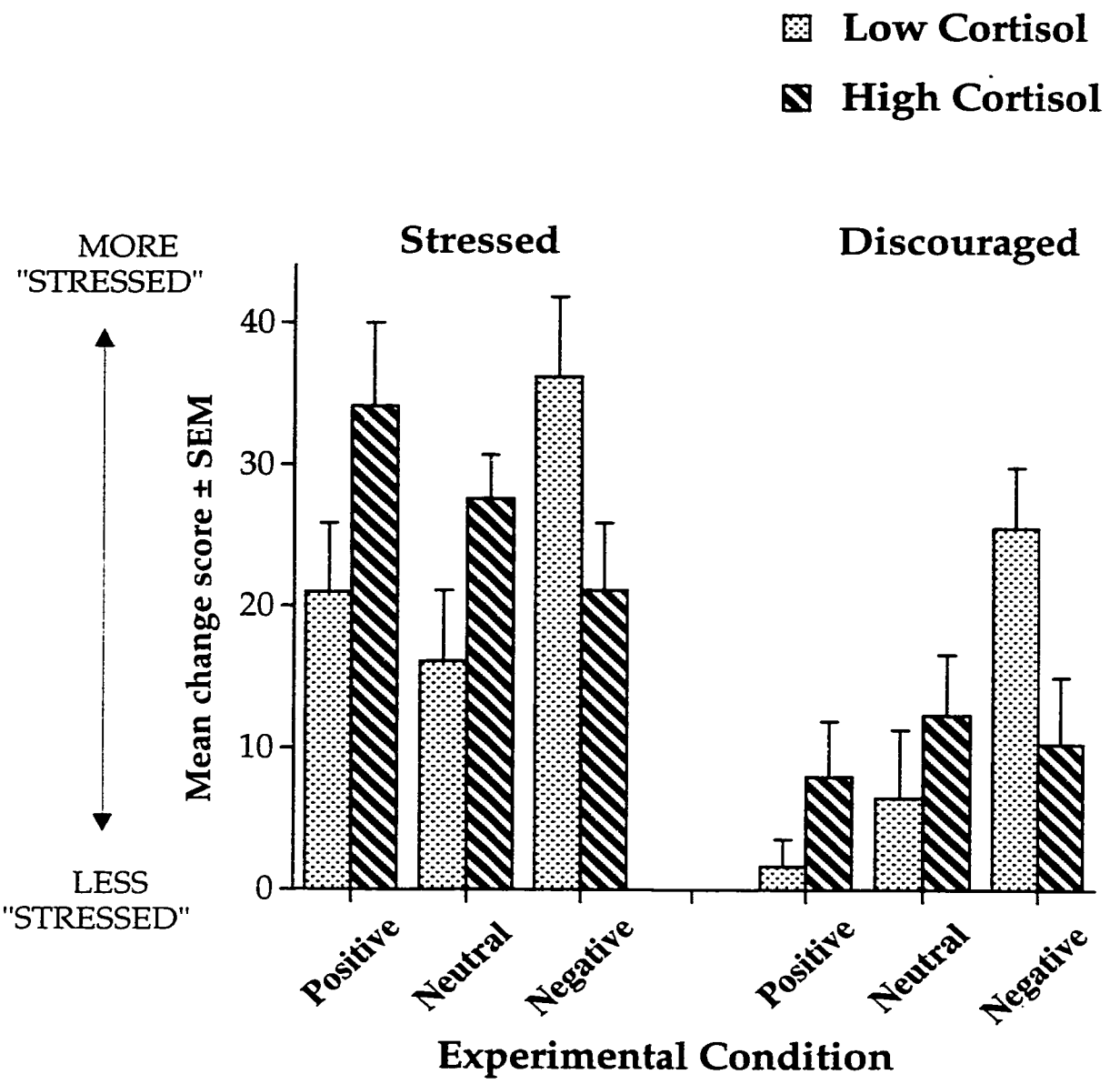

Figure 11. Mean change (mid-stress minus baseline) on the visual analogue scales by experimental condition in cortisol responders and non-responders. Positive change scores indicate an increase in the descriptor (i.e. I feel more "stressed").

in general by the experiment than cortisol non-responders.

8. WERE MOOD CHANGE AND CORTISOL REACTIVITY PREDICTIVE OF ATTENTIONAL DISENGAGEMENT FROM EMOTIONAL WORDS?

Predicting disengagement from emotional words

It was hypothesized that selective attention is important in emotional regulation, so hierarchical multiple regressions were conducted on mood, cortisol, and attention data. It was predicted that stress-induced mood change would be associated with measures of selective attention. These regressions utilized baseline mood, baseline cortisol levels, mood response and cortisol response to stress as predictors of selective disengagement from emotional stimuli. Separate analyses were performed for selective attention measures in the right and left hemifield, and for selective disengagement from negative and positive words. The order of entry for each step of predictors were as follows: (1) baseline mood (sum of all POMS scales), (2) baseline cortisol (mean production during relaxation phase), (3) mood change (sum of all POMS change scores), and (4) magnitude of cortisol response to stress. This ordering of variables approximates the temporal sequence of events during the experiment, from baseline state variables to reactive measures. For shifts away from left hemifield negative words, the regression equation was significant [$R=.29$, $F(4,128)=3.0$, $p<.05$], with the four predictors accounting for 6% (adjusted R^2) of the variance. Most of the variance was accounted for by one independent variable; only mood change on the POMS was a significant predictor of selective disengagement (Table 1). This result indicates that as mood state worsens, the tendency to shift away from

Table 1

Hierarchical multiple regression predicting attentional shifts away from negative words [a]

Predictors	r	ß	t	R	Adj. R^2	F change
Step 1: Baseline POMS	-0.15	-0.08	-0.9	0.15	0.02	3.0
Step 2: Baseline Cortisol	0.12	0.15	1.7	0.19	0.02	1.6
Step 3: Mood Response	0.24	0.24	2.7**	0.29	0.06	7.1**
Step 4: Cortisol Response	0.02	-0.03	-0.4	0.29	0.06	0.2

Note. n= 133; adj. R^2= Adjusted R^2; POMS: Profile of Mood States

[a] Computed by subtracting reaction time for neutral words from negative words on shifts away from the left hemifield

**p<0.01

negative stimuli in the left hemifield increases. These results corroborate the above findings of selective avoidance of negative stimuli following negative stress. They extend this finding to the sample as a whole, and suggest that mood lowering leads to attentional strategies of emotional regulation. For analyses of shifts of attention away from right hemifield negative words and for positive words, regression equations failed to reach significance (data not shown).

Predicting the efficiency of disengaging attention from all stimuli

The above regressions were repeated using the mean disengagement latency averaged across all three word types. This attentional measure assessed the general efficiency and speed of attentional shifting, irrespective of word valence. The BDI was added as a baseline predictor in step 1 because previous analyses indicate that it has important effects on general attentional shifting. For shifts of attention away from the left hemifield, the regression equation was significant [$R=.31$; $F(5,127)=2.7$, $p<.05$], accounting for 6% (adjusted R^2) of the variance. In contrast to the previous analyses, baseline POMS and BDI scores, but not mood change, were the only significant predictors of disengagement efficiency, accounting for all of the variance (Table 2-A). The results were the same for shifts of attention from the right hemifield [$R=.29$; $F(5,127)=2.3$, $p<.05$], except that the cortisol response to stress became a significant predictor of disengagement efficiency (Table 2-B). In both cases, negative baseline mood and ratings of depression were associated with slower attentional shifting. These results corroborate the results in high dysphoric subjects, suggesting that changes in attentional efficiency may be influenced by state factors independent of the experimental manipulations. In sum, there are clear distinctions between the

Table 2

Hierarchical multiple regression predicting the efficiency of attentional shifting

A. Shifting Attention Away from Left Hemifield Words[a]

Predictors	r	ß	t	R	Adj. R^2	F change
Step 1: Baseline Mood				0.28	0.07	5.6**
Beck Depression	0.15	0.23	2.5*			
Baseline POMS	0.17	0.28	2.9**			
Step 2: Baseline Cortisol	-0.03	0.01	0.2	0.28	0.06	0.1
Step 3: Mood Response	0.01	0.09	1.0	0.29	0.06	0.8
Step 4: Cortisol Response	-0.15	-0.10	-1.2	0.31	0.06	1.4

B. Shifting Attention Away from Right Hemifield Words[a]

Predictors	r	ß	t	R	Adj. R^2	F change
Step 1: Baseline Mood				0.23	0.04	3.7*
Beck Depression	0.15	0.19	2.0*			
Baseline POMS	0.11	0.19	1.9†			
Step 2: Baseline Cortisol	-0.04	0.01	0.1	0.24	0.03	0.2
Step 3: Mood Response	-0.01	0.05	0.6	0.24	0.03	0.2
Step 4: Cortisol Response	-0.21	-0.17	-2.0†	0.29	0.05	3.8†

Note. n= 133; adj. R^2= Adjusted R^2; POMS: Profile of Mood States

[a]Average reaction time across word valence

$^{\dagger}p < 0.06$; *$p<0.05$; **$p<0.01$

factors associated with changes in selective attention and those as associated with general processing efficiency. The former seem to be driven by mood change, while the latter by pre-experimental affective state and cortisol reactivity to stress.

9. WAS ATTENTIONAL DISENGAGEMENT FROM EMOTIONAL WORDS PREDICTIVE OF CORTISOL RECOVERY?

A hierarchical multiple regression was performed to assess whether selective attention to positive and negative words was predictive of the magnitude of cortisol recovery (low point during the recovery phase of the experiment). Predictor variables were entered in the following steps: (1) BDI depression, (2) mood change, (3) peak cortisol response to the stressor, and (4) selective disengagement from negative and positive words appearing in the left hemifield. The order of entry follows the time line of the experiment, and was meant to assess the relationship between attention and cortisol recovery independent of the contributions of affective state and peak cortisol response to stress. For this reason, selective attention measures were entered last. The regression equation was significant [$R=.68$, $F(5,127)=22$, $p<.001$], with the four predictors accounting for 44% (adjusted R^2) of the variance (Table 3). As expected, peak cortisol response to stress was highly predictive of cortisol recovery, accounting for most of the variance (adjusted $R^2=40\%$). Mood change did not significantly predict cortisol recovery, but ratings of depression did. Higher depression scores were predictive of elevated cortisol levels during recovery. Selective disengagement measures also contributed significantly to the

Table 3

Hierarchical multiple regression predicting cortisol recovery at the end of the experiment [a]

Predictors	r	ß	t	R	adj. R^2	F change
Step 1: Beck Depression	0.15	0.16	2.4*	0.15	0.02	3.2†
Step 2: Mood Response	-0.09	-0.11	-1.7	0.18	0.02	1.2
Step 3: Peak Cortisol	0.63	0.61	9.3**	0.66	0.42	91.3**
Step 4: Attention[b]				0.68	0.44	3.7*
Negative words	0.24	0.19	2.5*			
Positive words	0.12	-0.02	-0.2			

Note. n= 133; adj. R^2= Adjusted R^2

[a] Cortisol was the lowest level achieved during the recovery phase of the experiment

[b] Shifts away from left hemifield words; computed by subtracting reaction time of neutral words from negative (positive) words

† p<.08; *p<.05; **p<.01

model. Within this step, disengagement from negative words, but not positive, was predictive of cortisol recovery, indicating the tendency to shift away rapidly from negative words is associated with lower absolute cortisol recovery, even after accounting for peak cortisol and depression. This analysis was repeated for shifts of attention away from words in the right hemifield; selective disengagement did not significantly predict cortisol recovery (data not shown). For shifts of attention away from left hemifield words, these results are consistent with the hypothesis that shifting attention away from negative information is implicated in regulating affect and cortisol recovery following stress.

10. SUMMARY OF RESULTS

Effects of stress on mood, cortisol, attention and memory

The results of study 1 can be summarized as follows:

A. The experimental conditions altered mood in the expected direction (i.e. negative stress elicited a lowering of mood, etc.)

B. Cortisol production increased modestly in response to the experimental procedures, but did not differentiate between the neutral, negative, and positive stressor conditions.

C. The spatial cueing procedure was effective in drawing attention to spatial locations cued by words.

D. In response to aversive stress, participants shifted attention away from negative words more rapidly than from positive or neutral words.

E. Recognition memory was better for negative words than for positive and neutral words, but was not influenced by the experimental conditions.

Effects of depression and cortisol reactivity on attention:

A. Attentional shifting from all words was slower following aversive stress in dysphoric subjects than in those with low depression ratings.

B. Attentional shifting from all words was faster in cortisol responders than in non-responders regardless of the stressor condition.

Associations between affect, cortisol and attention in the sample as a whole:

A. A lowering of mood in response to stress was the most important predictor of the propensity to selectively shift away from negative words.

B. Baseline measures of affect and cortisol were the most important predictors of changes in the efficiency of attentional shifting.

C. Shifts of attention away from negative words and depression were important predictors of cortisol recovery during the relaxation phase of the experiment.

DISCUSSION

The aim of this study was to examine the mood, physiological and cognitive response to an interpersonal stressor characterized by repetitive loss or success. As described in the introduction, the first objective of this study was to show that the present manipulations were effective in inducing stress-related changes in mood and cortisol. The experimental manipulations did indeed alter mood in the expected direction: aversive and positive stress induced a negative and positive mood state respectively. The former, however, was more pronounced than the latter. Mood change following the positive stressor was modest and characterized by increased anxiety and subjective stress. The cortisol response to the experimental conditions was modest, and was observed primarily in a subsample of subjects (i.e. "responders"). In contrast to the prediction that the negative stressor condition would elicit greater cortisol production than the other conditions, no differences between conditions were observed. Thus, mood ratings, but not cortisol production, were differentially altered by the experimental conditions.

The primary goal of the experiment was to determine whether affective-motivational states induced by stress can influence selective attention to emotional words. The finding that reaction times were slower on invalid trials compared to valid trials suggests that the spatial cueing paradigm was indeed effective in manipulating covert attention. It was predicted that participants would selectively attend to negative words following an aversive stressful experience, and that this attentional response would prolong or exacerbate the mood and cortisol response to stress. In contrast, selective avoidance of negative

stimuli was observed in response to the aversive stressor. Subjects disengaged attention more rapidly from negative words than from positive or neutral words following the negative stressor, but not following the positive stressor or neutral condition. Facilitated disengagement was observed only when subjects were shifting attention away from negative words in the left hemifield and not vice versa. Additional analyses in participants with a robust mood lowering response to the negative stressor, as well as regression analyses in the total sample, suggested that the rapid disengagement of attention from negative stimuli was associated with a more negative mood response to stress but interestingly, lower cortisol during recovery from stress. Both of these effects are consistent with the view that selective attention may serve as a regulatory mechanism in the face of emotional arousal (Rothbart et al., 1995; Rothbart et al., 1994).

It was predicted that the attentional response to stress would be mediated, in part, by the participant's emotional state prior to beginning the experiment. Clinical measures of current depression and anxiety were used for this purpose. Although these factors did not influence selective attention to negative stimuli, non-selective changes in shifting efficiency were observed. High dysphoric subjects, scoring above the median on the BDI, exhibited poor attentional flexibility following aversive stress compared to low dysphoric subjects. Although cortisol reactivity and the mood response to stress were normal, dysphoric subjects were slow to disengage attention from all stimuli following the negative stressor, but not following either the positive stressor or neutral condition. In the total sample, slow attentional shifting was predicted by mood ratings at baseline and elevated depression scores. Thus, the hypothesis that affective state prior to the experiment would influence the attentional response to stress was supported, but the proposal that it would be selective towards

negative sources of information was not. An intriguing finding among dysphoric participants was that they had elevated mean cortisol levels during the relaxation phase at the beginning of the experiment and during the recovery phase. Furthermore, higher depression ratings were predictive of *higher* cortisol during the recovery phase of the experiment and *lower* reactivity[3] during the stressor phase in the total sample. These data suggest that subjects reporting sub-clinical symptoms of depression may have minor abnormalities of the HPA system, similar to those observed in depressed samples (Holsboer, 1995; Gotthardt et al., 1995; Trestman et al., 1991; Croes et al., 1993).

Another hypothesis tested in this experiment was that a high mood and/or cortisol response to stress would facilitate attentional shifting in general, and would elicit greater selective attention towards negative information. The mood response to stress and its influence on attention was discussed previously: greater mood lowering was associated with the propensity to shift away from negative words. Consistent with the first part of the prediction, cortisol responders showed a facilitation of attentional functioning compared to non-responders. That is, a high cortisol response to stress was associated with efficient attentional shifting, characterized by fast disengagement of attention from cued locations for all stimuli, regardless of the experimental conditions. Cortisol responders reported more subjective stress and discouragement during the positive stressor and neutral conditions, but a smaller increase in these ratings during the negative stress condition than cortisol non-responders. In other words, cortisol responders showed less variation in their mood response between conditions than non-

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[3] From a multiple regression analysis of peak cortisol change from baseline, not shown in this thesis, high ratings of depression (BDI) were predictive of a lower cortisol response to stress ($p < 0.05$). High ratings of anxiety (STAI), however, were predictive of a high cortisol response to stress ($p < 0.05$).

responders. Perhaps, cortisol responders were more engaged in the experiment than non-responders, and were able to benefit cognitively, through efficient attentional shifting, from the arousing effects of stress.

The present results suggest a mechanism whereby normal subjects cope with stressful events by shifting attention away from negative information. This attentional avoidance response may reflect a means of regulating negative emotion, and perhaps serves to facilitate HPA recovery from stress. However, the present study was based on the use of word stimuli, and it was felt that the conclusions drawn would be stronger if similar results were obtained using another form of emotional stimuli. Words are not threatening in themselves; it is only when information is extracted that they become emotionally arousing. A second study addressed this issue by using pictorial depictions of emotion (Bradley et al., 1996; Lang et al., 1993; Lang, 1995), which have greater ecological validity and salience. Because attention was measured upon termination of the stressor in the previous study, allowing for a possible diminution of the stress response, the second study used a stressor that temporally overlapped with the attention task. It was hoped that this design would provide a more robust test of the impact of stress on selective attention to emotionally-valenced information and on the HPA response. On the basis of the results of the first experiment, it was predicted that aversive stress would lead to greater attentional avoidance of negative stimuli, and that this response would serve to regulate HPA activity and the subsequent mood response.

STUDY 2

METHOD

1. SUBJECTS

The sample consisted of 66 (32 males; 34 females) participants recruited from Concordia and McGill University. The inclusion criteria were the same as the previous study. The mean age (± SD) of the sample was 22.0 ± 3.4 (18-33 years). Twenty-two (11 males; 11 females) participants were randomly assigned to the negative stressor, 22 (10 males; 12 females) to the positive stressor, and 22 (11 males; 11 females) to the neutral condition.

2. MATERIALS

All materials were the same as those used in study 1, except that coloured pictorial stimuli were presented during the modified spatial cueing and recognition memory tasks. Pictures were taken from the International Affective Picture System (IAPS), a set of 400 pictures developed by the Centre for the Study of Emotion and Attention at University of Florida. This set of pictures has standardized affective ratings from over 600 participants, and has been extensively validated (Lang et al., 1997; Bradley et al., 1996; Lang et al., 1993; Lang, 1995). Pictorial stimuli were either negatively valenced pictures depicting threat (i.e. man with gun, angry face, etc.) or dysphoria (i.e. crying infant, dead animal, etc), positively valenced pictures (i.e. smiling face, kittens, etc) or neutral pictures depicting neutral faces or objects. Eighteen negative pictures with

affective ratings below 3.3 (on a 9 point scale, from unpleasant to pleasant), 18 positive pictures with ratings above 6.0, and 18 neutral pictures with ratings between 4.75-5.25 were selected for the study. These pictures were altered slightly for use in the spatial cueing task. First, all pictures were scaled to a smaller size and trimmed to highlight the most salient aspect of the picture. Second, adjustments in luminance were made to pictures so that all three picture categories were matched on this variable. Mean luminance (± SD) was 15.7 ± 3.4 cd/m^2 (range 12.2 - 24.2) for positive pictures, 14.3 ± 4.2 cd/m^2 (8.8 - 24.1) for negative pictures, and 14.3 ± 6.1 cd/m^2 (8.3 - 28.4) for neutral pictures. A one-way ANOVA on these data revealed no significant differences. The IAPS reference numbers and examples of the pictures used in this study are listed in Appendix 1.

3. PROCEDURE

Overview

The procedure was the same as in study 1, with the exception that the stressor (competitive Stroop colour naming task) was divided into two parts, and the spatial cueing and recognition memory tasks were adapted for pictorial stimuli. As depicted in Figure 12, the attention task was administered upon completion of the first part of the stressor, which was then followed by the second part of the stressor. The other change was to administer the picture recognition test after the recovery phase of the experiment rather than before. Because emotional pictures could activate the HPA system, the recognition test was administered after cortisol sampling was complete.

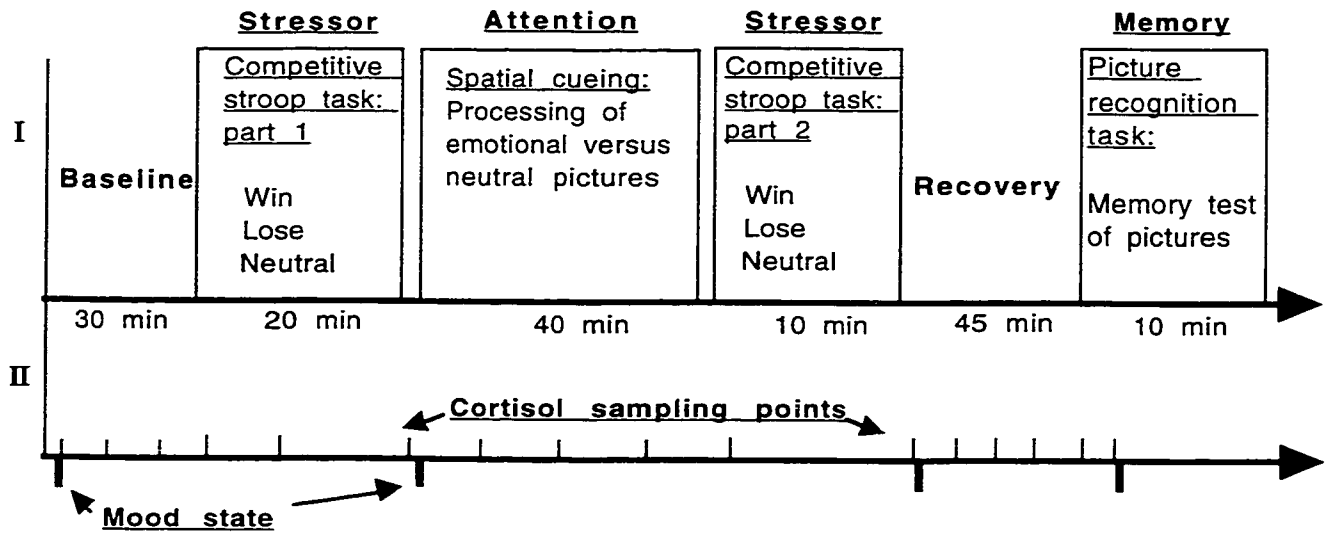


Figure 12. Sequence of experimental tasks (I), and cortisol and mood sampling points (II).

Stressor

The stressor task was performed in the same way as described in study 1, except that subjects played eight games in the first part (stressor 1) and four in the second part (stressor 2). In study 1, subjects played twelve games in a row. In the first part of the stressor, subjects in the positive condition won seven out of eight games, and earned $7. Subjects in the negative condition lost seven out of eight games, earned no money, and observed the confederate be rewarded with $7. All subjects were told that they would continue competing later on, and immediately performed the spatial cueing task. Upon completion of the cueing task, subject continued competing against the confederate for another four games (part 2), where all subjects won two games. Subjects in the positive condition were rewarded with an additional $2. Because subjects must win four games to begin earning money, those in the negative condition earned no money. In the control condition, subjects completed the first eight blocks of the task, and then completed the remaining four after the attention task. This change of procedure was meant to prolong the stressor so that the attention task was administered during the "stress experience" rather than upon its termination.

As a result of these changes in the procedure, the adminstration of tests and the handling of cortisol samples were slightly different from those in the first study (see Figure 12). The POMS was administered at baseline, post-stress 1, post-stress 2, and end of experiment. The VAS was administered at baseline, post-stress 1, and post-stress 2. Cortisol was sampled approximately every 10 minutes as before, but data aggregation for all cortisol measures included baseline, first part of the stressor, attention task, second part of the stressor, and relaxation phases.

Modified spatial cueing paradigm

The structure of the task was the same as that used in the first study (see Figure 2). Subjects fixated on a centrally placed grey "+" sign on a black background, which was flanked on both sides by a grey rectangular box. Visual angle of each box was 4.8° (3.7 cm) in height and 4.1° (3.2 cm) in width. The centre of each box was 2.35° of visual angle from the fixation point. Preceding all target presentations, a picture appeared in one of the boxes. The picture acted as a pretarget cue because it was indicative of the most likely location of the target. Within each block, all pretarget cues were from the same picture category, and stimulus presentation was equally distributed between the right and left visual hemifields. The order of blocks varied randomly between subjects, except that two blocks of the same picture category were never consecutive. The sequence of trials within a block was fixed for all subjects.

The whole task consisted of 432 trials, divided into 12 blocks (4 blocks for each picture category) of 36 trials. Validly and invalidly cued targets (including catch trials) represented 78% and 22% of all trials respectively. The rate of trial presentation was fixed, but subjects could take brief rest breaks every 18 trials. The SOA for valid and invalid trials was 667 ms, and the interval between trials was 1.85 seconds. For catch trials, the SOA was 1200 ms. Targets were presented for 500 ms, and cues for 600 ms. All reaction time measures were computed in the same manner as in study 1.

Picture recognition test

A computerized picture recognition test was administered in which subjects were asked to indicate which pictures had served as pretarget cues. They were presented a total of 129 pictures, of which 54 were pretarget cues and

75 distracters. Pictures were presented until a two-choice key press (recognize/do not recognize) was made. The primary measure was the mean number of correctly identified target pictures.

RESULTS

1. OVERVIEW AND DATA REDUCTION

The analyses discussed below followed the same sequence as study 1. Four main issues were addressed: (1) the validity of the stressor manipulations, by assessing the mood and cortisol responses to stress, (2) the effects of stress on attention and recognition memory, (3) the influence of other factors (depression, anxiety, high cortisol) on attention, and (4) the relationship between mood, cortisol and attention and their role in the regulation of the stress response. One additional issue examined here was whether the design in study 2 was more stressful than study 1. To assess this, the mood and cortisol response between study 1 and the first part of the stressor in study 2 were compared. All other issues were assessed using the same analyses as those used in study 1. All data screening and transformations were the same as those in study 1.

2. WAS MOOD STATE ALTERED BY THE STRESSOR CONDITIONS?

Mood ratings at each time point are presented in Appendix 3. A MANOVA on post-stress 1 change scores revealed a significant multivariate main effect for condition [$F(12,116)=3.1$, $p<.005$], with significant univariate differences on the elation-depression [$F(2,63)=7.7$, $p<.005$], agreeable-hostile [$F(2,63)=3.2$, $p<.05$], confidence-unsure [$F(2,63)=11.9$, $p<.001$], and clearheaded-confused [$F(2,63)=10$, $p<.001$] scales of the POMS. These data are presented graphically in Figure 13. Overall, subjects exhibited a lowering of mood in response to the first part of the negative stressor, and either no change or a

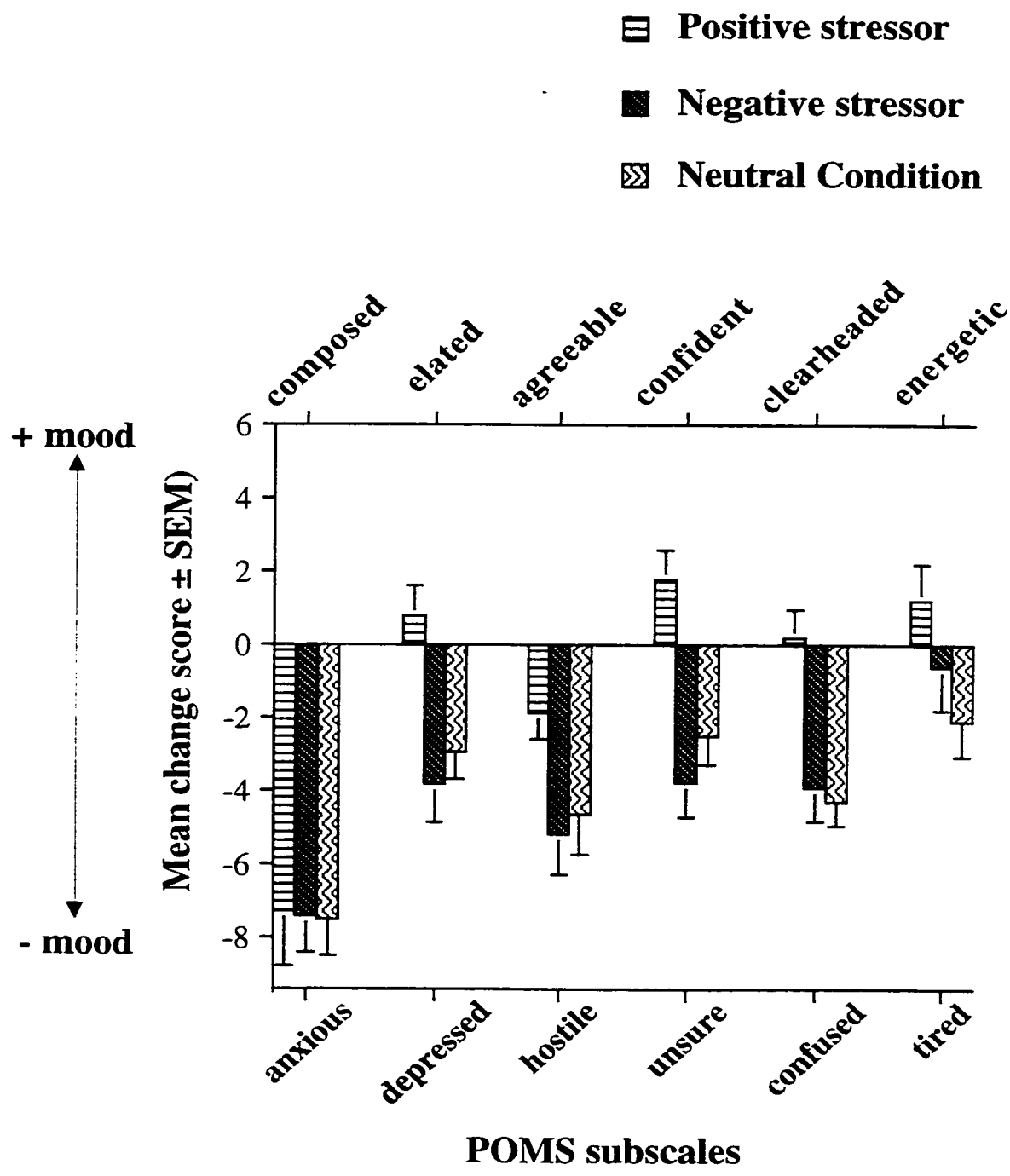


Figure 13. Mean change of mood (post-stress minus baseline) by experimental condition on the Profile of Mood States (POMS). Positive change scores indicate a heightening of mood and negative change scores a lowering of mood from baseline.

heightening of mood in response to the first part of the positive stressor. Post-hoc Tukey HSD tests revealed significant differences between the positive and negative stressor conditions on the depression-elation, confidence-unsure and clearheaded-confused scales ($p<.05$), but no differences between the negative stressor and neutral condition on any POMS scale. The exception to the above pattern was the composed-anxious scale, where all conditions yielded equivalent increases in anxiety (see Figure 13). Thus, the mood results support the validity of the stressor manipulations, but indicate that the neutral condition was mildly aversive.

Mood change following the second part of the experimental conditions was similar to that following the first part (see Appendix 3). A significant multivariate main effect of condition [$F(12,116)=3.4$, $p<.001$] was observed, with univariate significance on the elation-depression [$F(2,63)=5.2$, $p<.01$], confidence-unsure [$F(2,63)=8.5$, $p<.005$], and clearheaded-confused [$F(2,63)=3.1$, $p=.05$] scales of the POMS. Thus, a lowering of mood was maintained until the end of the second part of the stressor task in subjects exposed to an aversive stressor, but not for those in the neutral condition.

The results of the VAS were almost identical to those of the POMS, and were similar to those reported in study 1. For these reasons, VAS results are not reported. However, this data is presented graphically in Figure 15 (section 4), where study 1 and 2 are compared.

3. WAS CORTISOL ALTERED BY THE STRESSOR CONDITIONS?

Cortisol results were the same as to those reported in study 1, and are shown in Figure 14. Mean and AUC (data not shown) cortisol production did

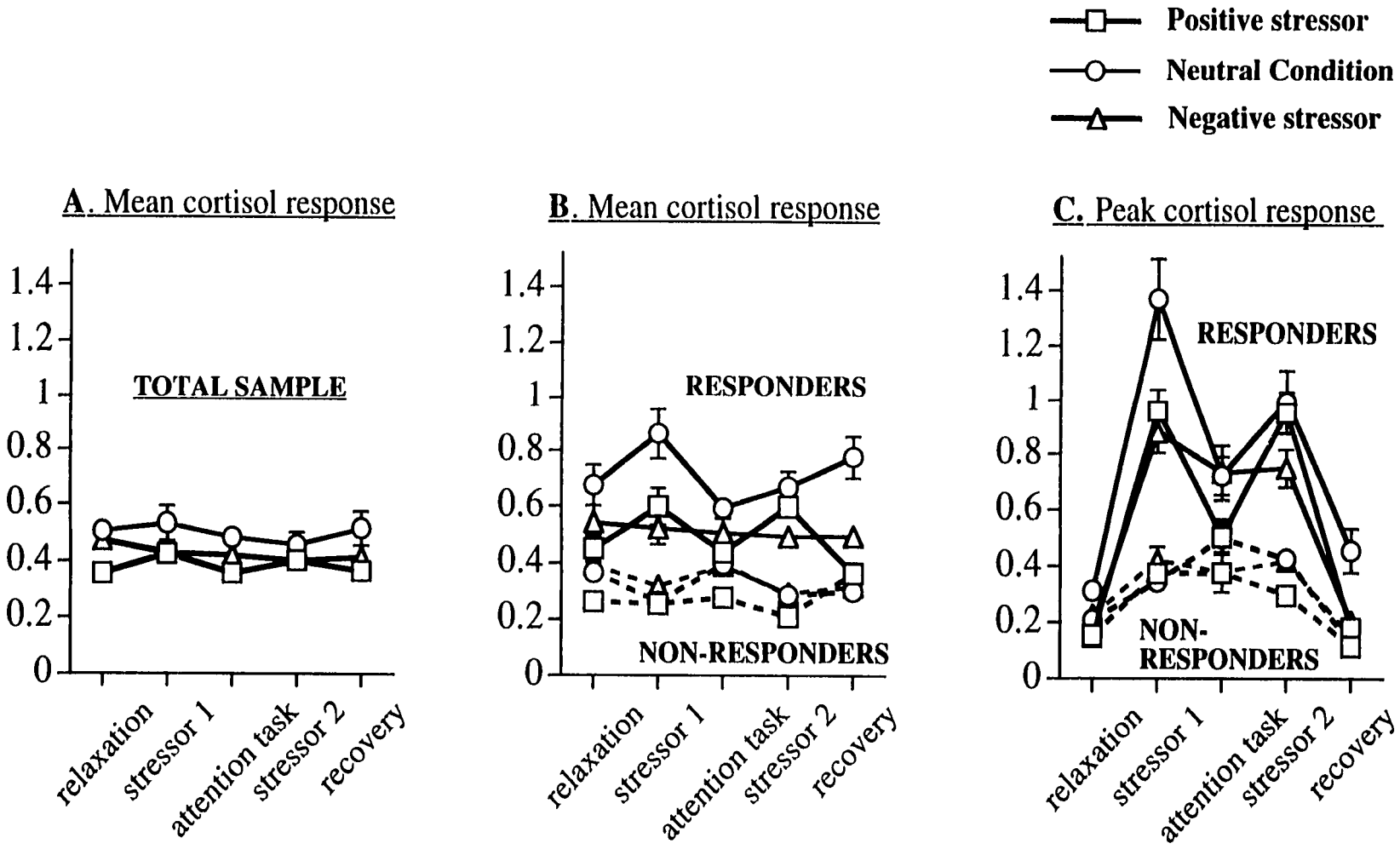


Figure 14. Mean (14-A and 14-B) and peak (14-C) cortisol at different stages of the experiment. Responders (solid lines) and non-responders (broken lines) were those participants with a cortisol response to stress in the upper and lower half of the distribution respectively. Figure 14-C shows cortisol low points during baseline and recovery, and peak cortisol during the stressor (part 1 & 2) and attention phases of the experiment.

not differ between the experimental phases (relaxation, stressor-part 1, attention task, stressor part 2, recovery), nor between the conditions. However, a condition x phase ANOVA of response magnitude (lowest value for relaxation and recovery phases, and peak value for stressor and attention phases) yielded a significant main effect of phase [$F(4,252)=65.8$, $p<.001$]. However, there were no differences between stressor conditions. Thus, cortisol production increased in response to all three conditions, but failed to differentiate between the stressors and a neutral condition.

Subjects were divided into either responders and non-responders based on a median split of cortisol change from baseline, which is depicted in Figure 14-B (mean values) and 14-C (peak values). 3-way ANOVAs (group x condition x phase) yielded significant main effects of group for both mean [$F(1,60)=13.0$, $p< .005$] and peak [$F(1,60)=18.7$ $p< .001$] values, but no significant interactions. Thus, a subsample of participants responded to stress with significant HPA activation, while the remaining participants showed a negligible response. However, even among responders, cortisol production did not differentiate between the three conditions.

4. WAS THE MOOD AND CORTISOL RESPONSE TO STRESS GREATER IN STUDY 2 THAN STUDY 1?

It was predicted that the changes in the experimental design of study 2 would make it more stressful than study 1. Change from baseline on the VAS following the stressor in study 1 (12 stroop blocks) and first part of the stressor in study 2 (8 stroop blocks) were compared. A study X stressor condition MANOVA revealed a significant main effect of study [$F (5,191)=2.8$, $p<.05$].

Univariate tests found significant differences on the stressed [F (1,195)=3.9, p<.05] and confident [F (1,195)=8.0, p<.01] scales, and trends for significance on the discouraged [F (1,195)=3.7, p=.055] and negative thinking [F (1,195)=3.1, p=.08] scales. These results are depicted graphically in Figure 15-A. These findings indicated that subjective ratings were more negative following the first part of the stressor task in study 2 than following the stressor task in study 1. These same analyses were conducted on the POMS, but no multivariate significant effects were observed.

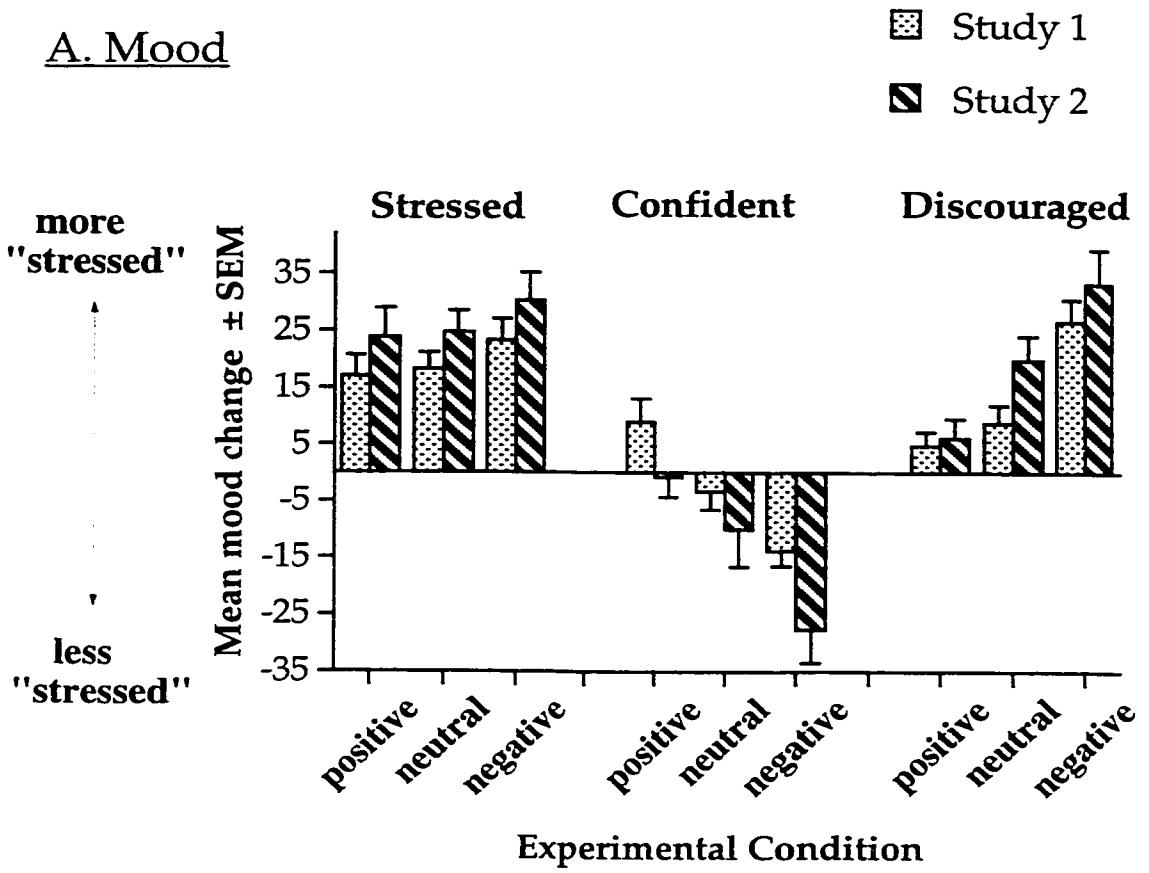
A study X stressor condition ANOVA was conducted on cortisol change from baseline. A significant main effect of study was observed [F (1,193)=14, p<.001), with peak cortisol levels being greater in study 2 than 1 (see Figure 15-B). In summary, both cortisol and subjective VAS ratings indicate that study 2 was more stressful than study 1.

5. WAS ATTENTION ALTERED BY THE STRESSOR CONDITIONS?

Valid trials: Orienting and allocating attention

As was observed in study 1, reaction time to validly cued targets was significantly faster than invalidly cued targets [F(1,63)=107, p<.001], supporting the validity of the modified spatial cuing paradigm with pictures (Figure 16). In contrast to study 1, attentional allocation was significantly influenced by the experimental manipulations and picture valence. A 3-way ANOVA (condition X picture valence X hemifield) on the reaction time data from valid trials revealed a number of main effects. First, a main effect of hemifield was observed [F(1,63)=31.3 p<.001], indicating faster reaction time to stimuli appearing in the right than left hemifield. Second, a main effect of stressor condition was found

A. Mood



B. Cortisol

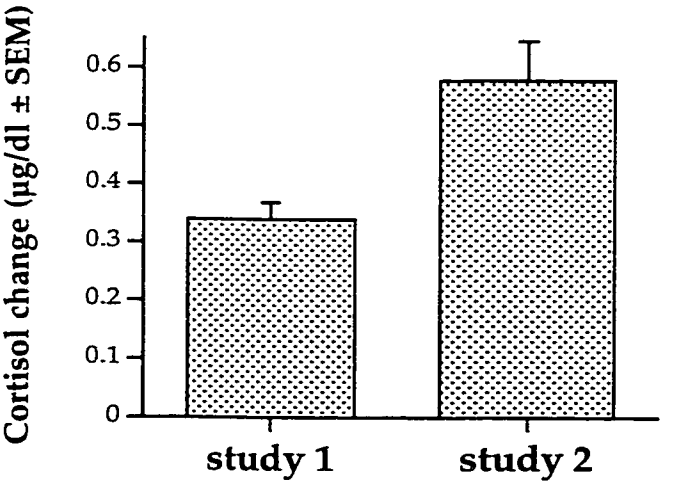


Figure 15. Mean change on the visual analogue scales (VAS; A) and in cortisol (B) between study 1 and 2. VAS scores are the mean change from baseline, by experimental condition, for ratings taken following the stressor in study 1 and following the first part of the stressor in study 2. Cortisol data are the peak change from baseline across all conditions .

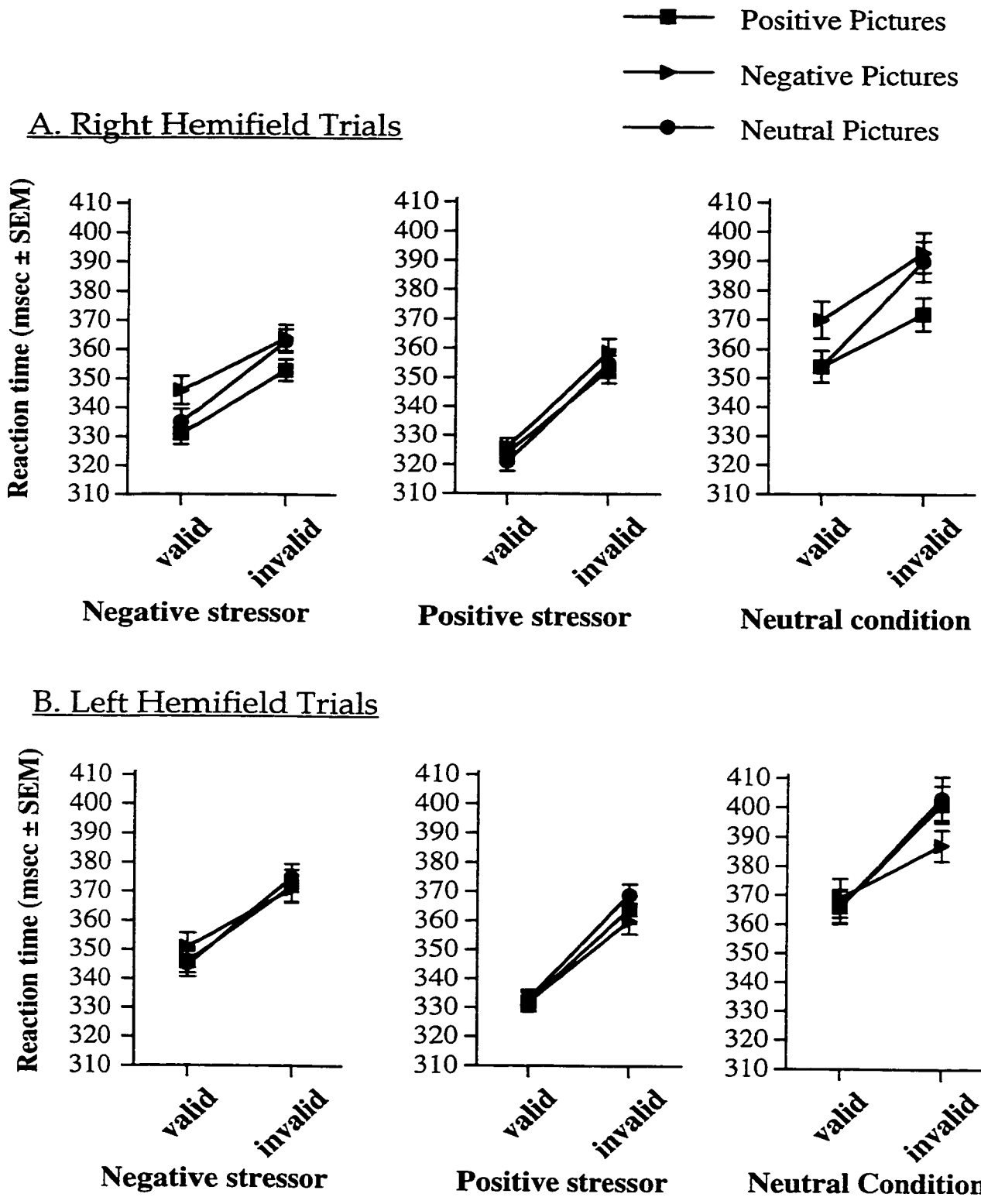


Figure 16. Reaction time data for valid and invalid trials by experimental condition. Right (A) and left (B) hemifield trials are those requiring a response to a target in the right and left hemifields respectively. For right hemifield trials, valid trials measure shifts of attention towards right hemifield words; invalid trials measure shifts of attention away from left hemifield words.

[F(2,63)=3.2, p=.05]. As depicted in Figure 16, response latency to all picture categories was fastest during the positive stressor, followed by the negative stressor. Neutral participants were the slowest to respond. These effects, independent of the valence of the picture, indicate a general stress-induced potentiation of cognitive performance. Third, a main effect of picture valence was observed [F(2,126)=7.2, p<.005], as well as a picture valence X hemifield interaction [F(2,126)=10.6, p<.001]. Planned comparisons revealed that reaction time was slower when cued by a negative picture than a positive or neutral picture [F(1,63)=11.3, p<.005]. Comparisons within each hemifield revealed that the slow response latency for locations cued by negative pictures was significant for stimuli presented in the right hemifield [F(1,63)=33, p<.001], but not the left hemifield. In sum, negative pictures disrupted or delayed attentional allocation at a cued location, and that this effect was stronger for stimuli occurring in the right than left visual hemifield. In addition, the experimental manipulations resulted in an alerting effect, where information processing, regardless of picture valence, was faster during the positive and negative stressor conditions than the neutral condition. No interaction between picture valence and stressor condition was found, indicating that the effect of negative pictures on attentional allocation was independent of the experimental conditions and their effects on processing efficiency.

Invalid trials: Disengaging attention

For invalid trials, the valence of pictures, but not the experimental conditions, affected attentional disengagement. As observed in all previous analyses of attention, a 3-way ANOVA (condition X picture valence X hemifield) of reaction time data yielded a main effect of hemifield [F(1,63)=23.3 p<.001],

indicating that subjects shifted from the left to right hemifield faster than from right to left. As observed for valid trials, the interaction between picture valence and hemifield was significant [$F(2,126)=8.5$, $p<.001$]. Comparisons within each hemifield revealed two different picture valence effects contributing to this interaction. First, subjects shifted away more rapidly from positive pictures in the left hemifield than neutral or negative pictures [$F(1,63)=14.0$, $p<.001$], but not when shifting away from right hemifield pictures (see Figure 16-A). Second, disengagement from negative pictures was significantly faster than positive and neutral pictures when shifting away from pictures in the right [$F(1,63)=4.7$, $p<.05$], but not left, hemifield (see Figure 16-B). In summary, attentional disengagement was potentiated by both positive and negative pictures presented to specific hemifields. The rapid shifting of attention away from negative pictures in the right hemifield was consistent with the finding of delayed attentional allocation for negative picture in the right hemifield on valid trials. It may be that subjects were shifting attention away from negative stimuli, causing delays in engagement and faster disengagement. No main effect or interactions involving stressor condition were found, indicating that the effects of pictorial stimuli on attentional disengagement were independent of the experimental manipulations.

6. WAS RECOGNITION MEMORY AFFECTED BY THE STRESSOR CONDITIONS?

A 2-way ANOVA (condition X picture valence) was conducted on the picture recognition data. No significant main effect of stressor condition or interaction was found. A significant main effect of picture valence was found [$F(2,126)=65.7$, $p<.001$], indicating that recognition of negative pictures was

superior to neutral [F(1,63)=126.1, p<.001] and positive pictures [F(1,63)=67, p<.001]. In addition, recognition of positive pictures was superior to neutral pictures [F(1,63)=5.9, p<.05]. Picture recognition data are presented in Figure 17. These results support the validity of using pictorial stimuli differing in emotional valence, and indicate that negative and positive pictures are encoded in memory more readily than neutral pictures. However, picture recognition was not influenced by the stressor conditions.

7. WERE THE EFFECTS OF STRESS ON ATTENTION, MOOD AND CORTISOL INFLUENCED BY STATE DEPRESSION AND ANXIETY?

Depression

Subjects were classified as high and low dysphoric based on a median split of BDI scores. The BDI correlated with baseline POMS depression (R=-.31, p<.05) and anxiety (r=-.26 p<.05) scores as expected, but did not correlate with stress-induced change scores on these scales (r=-.18, NS, r=-.08, NS respectively). These correlations suggest that the BDI was measuring negative affect or symptoms of depression independent of experimentally-induced mood change. The mean BDI score in high dysphoric (n=29) and low dysphoric (n=37) subjects was 9.8 ± 4.5 (range 5-19) and 1.5 ± 1.4 (range 0-4) respectively. The groups were unequal because of the high prevalence of scores at the median (6 subjects with a BDI of 4); we opted to classify these subjects as low dysphoric subjects. The breakdown between stressor conditions was similar: 13 and 9 subjects in the positive condition, 12 and 10 subjects in the negative condition, and 12 subjects and 10 subjects in the neutral condition were classified as non-dysphoric and high dysphoric respectively.

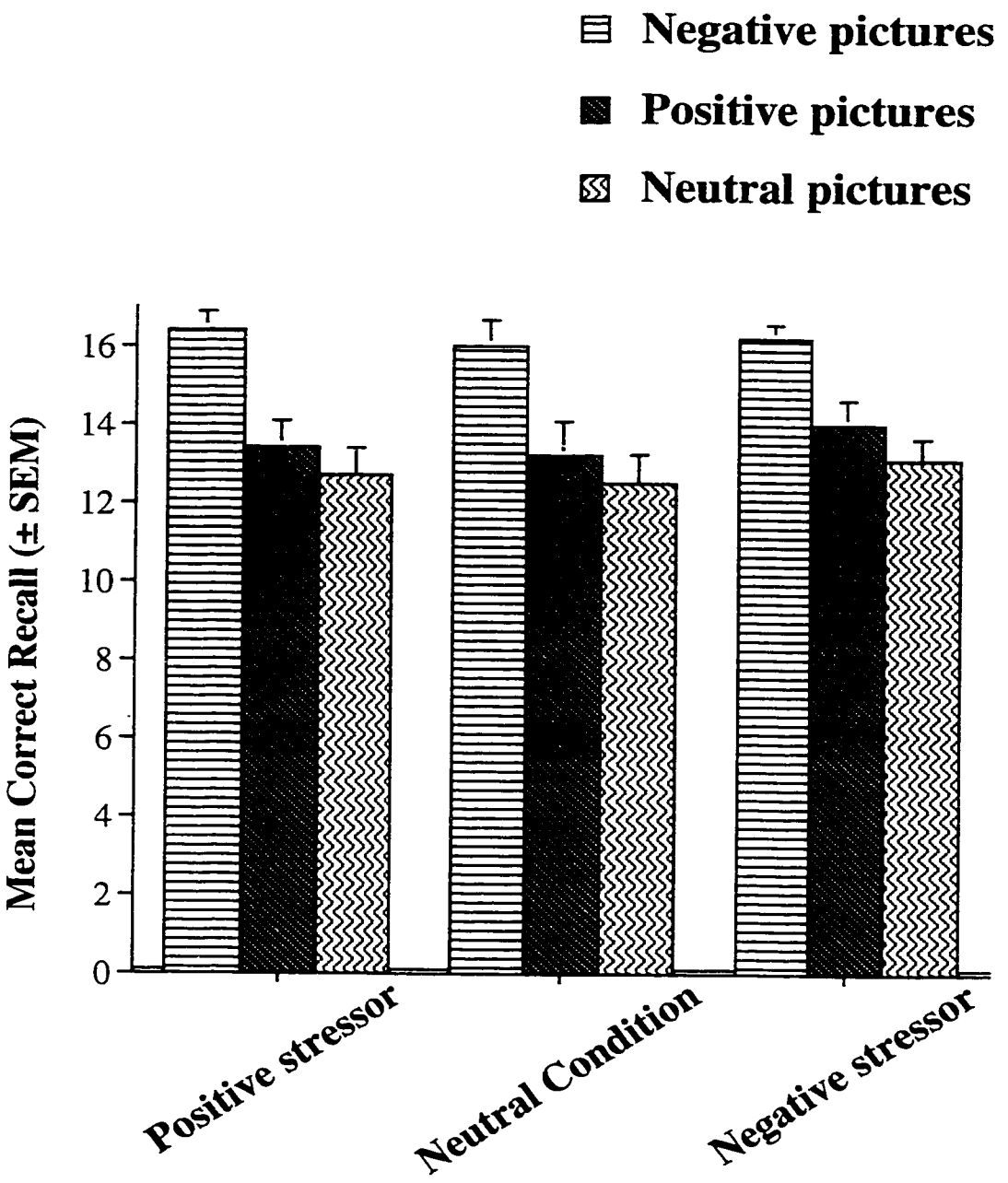


Figure 17. Mean number of pictures correctly identified, by experimental condition, on a recognition test of the pictures presented during the spatial cueing task. The maximum score was 18.

Attention

To test for group differences, a 4-way ANOVA (group X stressor condition X picture valence X hemifield) was conducted on reaction time data for valid and invalid trials. No significant effects were observed for valid trials. On invalid trials, two significant interactions were found. First, a significant group X condition interaction was observed [$F(2,60)= 5.3$, $p<.01$], due to group difference for the positive stressor [$F(1,20)= 4.9$ $p<.05$] and neutral conditions [$F(1,20)= 5.4$ $p<.05$]. As depicted in Figure 18, high dysphoric subjects in the positive stressor condition were faster to disengage attention from all picture categories than the low dysphoric group. In contrast, high dysphoric subjects in the neutral condition were slower to disengage attention from pictorial stimuli than low dysphoric subjects. In fact, reaction time among low dysphoric participants was similar between stressor conditions. These results suggest that the high dysphoric group was more sensitive to the alerting effect of the stressor manipulations, as described in section 5, than low dysphoric subjects. Of interest, the slow disengagement during the neutral condition in high dysphoric participants was similar to the attentional response of dysphoric subjects following the negative stressor in study 1.

Second, a significant group X condition X picture valence interaction was found [$F(4,120)= 2.63$ $p<.05$]. Analyses within each condition revealed a significant group X picture valence interaction in the positive stress condition [$F(2,40)= 4.2$, $p<.05$], a trend for significance in the neutral condition [$F(2,40)= 3.2$, $p=.054$], and no effect in the negative stressor condition. During the positive stressor, high dysphoric participants shifted attention away more rapidly from positive than neutral or negative stimuli, while low dysphoric participants tended to disengage more slowly from positive pictures than neutral or negative

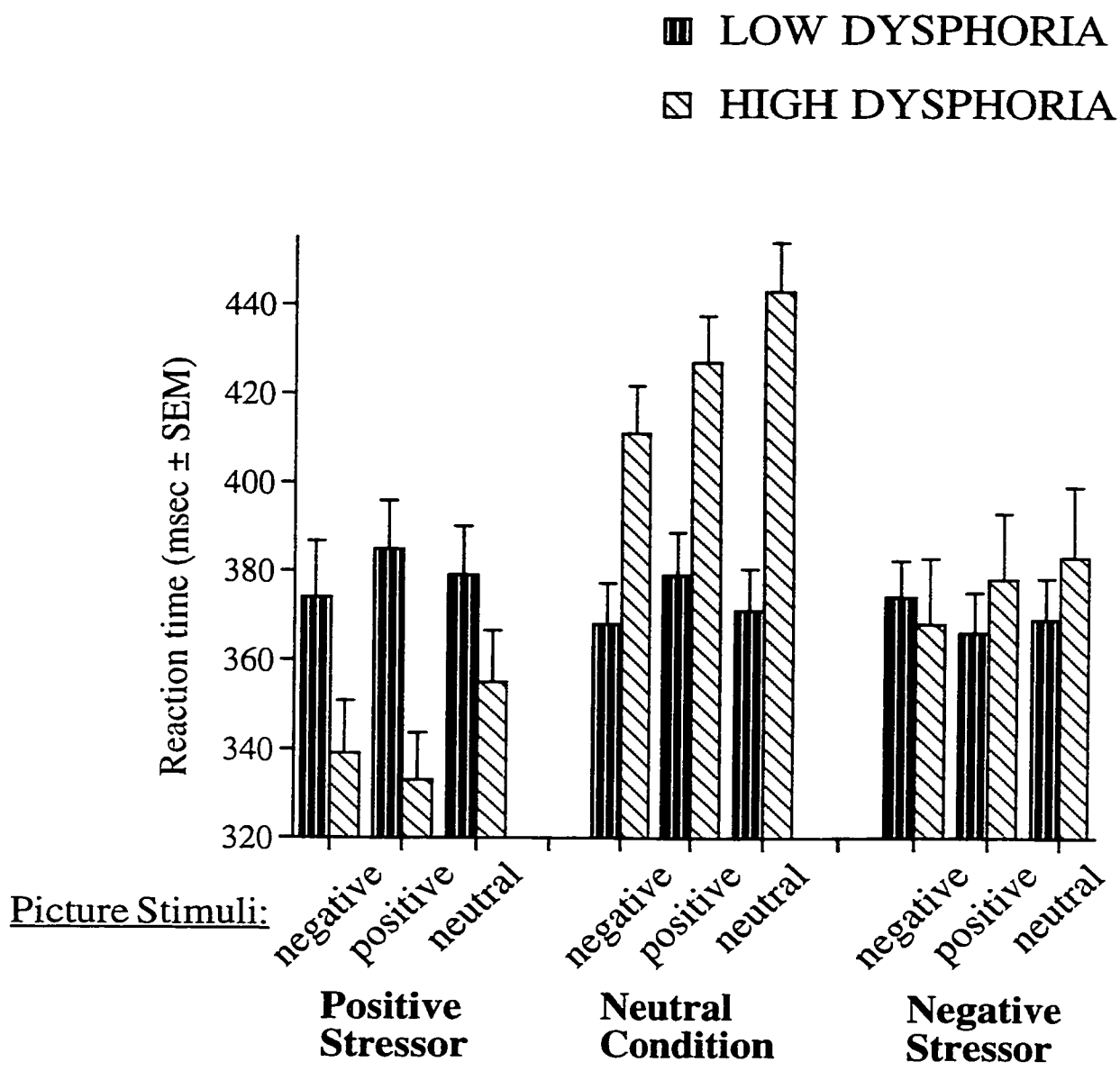


Figure 18. Reaction time data for invalid trials by experimental condition in participants who scored in the upper (high dysphoria) and lower (low dysphoria) half of the distribution of the Beck Depression Inventory. These data are shifts of attention away from pictures in the right hemifield.

pictures [see Figure 18; $F(1,20)= 4.6$, $p<.05$]. In other words, selective attention and avoidance of positive pictures was observed in low and high dysphoric subjects respectively following the positive stressor.

Mood and cortisol

To increase power, all additional analyses in the following sections dropped the tired- energetic scales of the POMS, and the "confident" and "determined" dimensions of the VAS, which were not significantly influenced by the experimental conditions. On the POMS, group X stressor condition MANOVAs revealed no significant multivariate effects at post-stress 1 or post-stress 2. On the VAS, a trend for significance was found for the main effect of group at post-stress 1 [$F(3,58)=2.2$, $p=.092$). Univariate tests showed that high dysphoric subjects reported more discouragement [$F(1,60)=4.2$, $p<.05$], negative thinking [$F(1,60)=4.5$, $p<.05$] and subjective stress [$F(1,60)=3.7$, $p=.059$) following the experimental conditions than the low dysphoric group (data not shown). Furthermore, VAS ratings were more negative for high than low dysphoric participants at post-stress 2 [multivariate main effect of group: $F(3,58)=3.2$, $p<.05$], with univariate effects on the subjective stress [$F(1,60)=4.5$, $p<.05$] and negative thinking [$F(1,60)=9.3$, $p<.005$] dimensions (data not shown). No group X condition interactions were found.

No significant group differences in cortisol production at baseline, in response to stress, or during the recovery phase of the experiment were found. Thus, these results provided some evidence that high dysphoric subjects were more sensitive to the experimental manipulations than the low dysphoric group. However, these differences were not great enough to affect HPA reactivity or mood state measured by the POMS. In summary, high dysphoric participants

were more sensitive to the experimental procedures than low dysphoric subjects, showing (1) slow attentional shifting in the neutral conditions, (2) more subjective affect in response to stress, and (3) increased alertness in response to the active stressors. In addition, low dysphoric participants selectively attended to positive pictures during positive stress, while high dysphoric participants avoided them.

Anxiety

A median split of the state STAI was used to classify subject into high and low state anxiety groups. The STAI correlated with baseline POMS depression ($r=-.40$, $p<.005$) and anxiety ($r=-.58$ $p<.001$) scores as expected, but did not correlate with stress-induced change scores on these scales ($r=-.21$, NS, $r=-.14$, NS respectively). The mean STAI score in high anxiety (n=34) and low anxiety (n=32) subjects was 36.5 $\pm$ 6.0 (range 30-52) and 24.4 $\pm$ 2.7 (range 20-29 respectively). The breakdown between stressor conditions was similar: 10 and 12 subjects in the positive condition, 10 and 12 subjects in the negative condition, and 12 subjects and 10 subjects in the neutral condition were classified as low and high anxious respectively.

Attention

In contrast to study 1, state anxiety was found to influence attentional shifting. Although no significant effects of state anxiety were observed for valid trials, significant group X stressor condition X picture valence X hemifield [$F(4,120)=2.8$, $p<.05$] and group X picture valence X hemifield [$F(2,120)=3.2$, $p<.05$] interactions were found for invalid trials. To simplify these interactions, group X condition X picture valence ANOVAs were conducted within each hemifield. For shifts of attention away from pictures in the right hemifield, a

significant group X picture valence interaction was found [$F(2,120)=4.4$, $p<.05$]. As depicted in Figure 19-A, high anxious subjects were faster to disengage from negative pictures than positive or neutral stimuli relative to the low anxious group [$F(1,60)=9.8$, $p<.005$], with the effect being most apparent in the negative stressor [$F(1,20)=7.4$, $P<.05$] and neutral conditions [$F(1,20)=5.0$, $P<.05$]. Thus, high anxious participants avoided negative pictures in the right hemifield during the negative stressor and neutral condition.

For shifts of attention away from pictures in the left hemifield, a different pattern of results was observed. A group X condition X picture valence interaction was found [$F(4,120)=3.5$, $p<.05$]. This interaction, depicted in Figure 19-B, indicated that high anxious subjects, relative to the low anxious group, were slower to disengage from negative pictures than neutral pictures following the negative stressor [$F(1,20)=6.5$, $p<.05$]. That is, high anxious subjects selectively attended to negative pictures following the negative stressor, but only when disengaging attention from pictures in the left hemifield. It was also found that high anxious subjects, relative to those low in anxiety, disengaged faster from positive pictures than neutral pictures in the neutral condition [$F(1,20)=6.8$, $p<.05$]. This finding suggests that high anxious subjects, like high dysphoric participants, avoided positive pictures.

In sum, high anxious subjects selectively attended to negative pictures during the negative stressor and avoided positive pictures in the neutral condition when pictures were presented in the left visual hemifield. In contrast, they showed an avoidance of negative pictures when they appeared in the right hemifield.

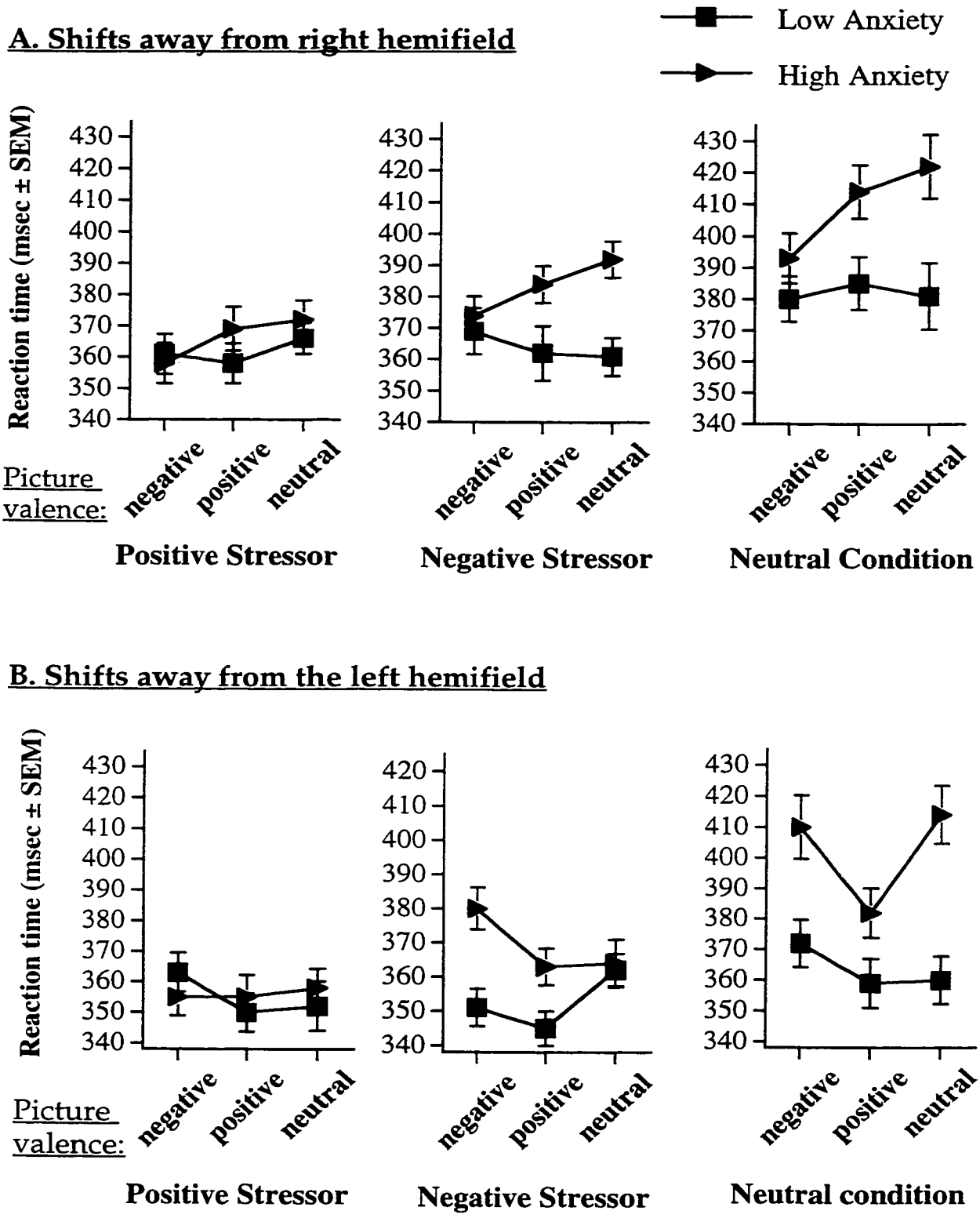


Figure 19. Reaction time data for invalid trials by experimental condition in participants who scored in the upper (high anxiety) and lower (low anxiety) half of the distribution of the State-Trait Anxiety Inventory. These data are for shifts of attention away from right (A) and left (B) hemifield pictures.

Mood and cortisol

Mood results indicated that high anxious participants were more sensitive to the experimental manipulations than low anxious subjects, particularly to the negative stressor. For POMS change scores, group X stressor condition MANOVAs revealed a significant multivariate main effect of group at post-stress 1 [$F(5,56)=2.4$, $p<.05$], and a significant group X condition interaction [$F(10,112)=2.4$, $p<.05$] at post-stress 2. For the former main effect, univariate tests showed that high anxious subjects, relative to those low in anxiety, reported more negative affect on the elated-depressed [$F(1,60)=3.9$, $p=.053$] and agreeable-hostile scales [$F(1,60)=4.7$, $p<.05$] of the POMS. These data are presented in Figure 20-A, and indicate a more pronounced mood response across conditions in high than low anxious subjects. At post-stress 2, univariate group X condition interactions were found on the elated-depressed [$F(2,60)=4.1$, $p<.05$], agreeable-hostile [$F(2,60)=3.6$, $p<.05$], and confident-unsure scales [$F(2,60)=5.0$, $p<.05$] of the POMS. This interaction reflects greater ratings of negative mood in high than low anxious participants following the second part of the negative stressor (see Figure 20-B). Similar results were found for the VAS (data not shown).

No significant group differences in cortisol production at baseline, in response to stress, or during the recovery phase of the experiment were found. In summary, high anxious subjects showed a more pronounced mood lowering response than low anxious subjects in general, and maintained their negative mood during the second part of the negative stressor, but not in the other conditions. The attentional profile of high anxious subjects was characterized by contrasting processes of selective attention and avoidance of negative pictures. The former occurred in response to the negative stressor and when pictures were presented to the left hemifield, and the latter was observed when pictures were

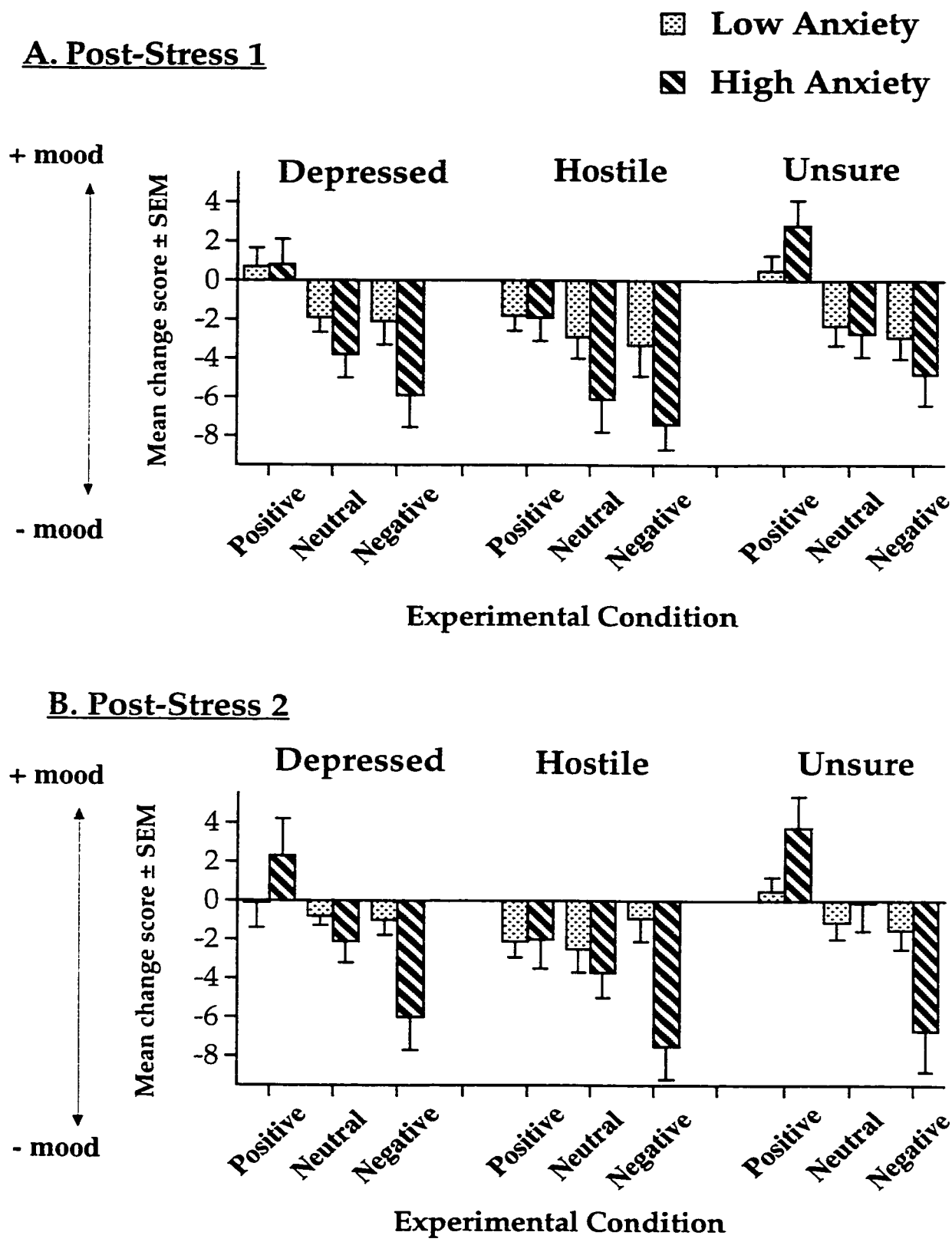


Figure 20. Mean change of mood on the POMS by experimental condition in participants high and low in state anxiety. Graphs A and B refer to change from baseline following the first and second part of the stressor respectively.

presented to the right hemifield.

8. WERE THE EFFECTS OF STRESS ON ATTENTION AND MOOD DIFFERENT BETWEEN CORTISOL RESPONDERS AND NON-RESPONDERS?

The performance of cortisol responders and non-responders to stress on the attention paradigm was compared through a 4-way ANOVA (group X stressor condition X picture valence X hemifield). No significant main effects or interactions were found for invalid trials, and only a group X hemifield interaction [$F(1,60)=4.2$, $p<.05$] was found for valid trials. This interaction was due to high cortisol responders having slower reaction times (mean ± SD, msec) to stimuli presented in the left hemifield (responders: 351 ± 22; non-responders: 347 ± 23), but faster reaction time to stimuli in the right hemifield relative to cortisol non-responders (responders: 338 ± 22; non-responders: 342 ± 24). Examination within each hemifield revealed no significant differences between cortisol responders and non-responders. Although this interaction consistent in part with the finding of previous study, where a high cortisol response to stress was associated with fast attentional disengagement, the differences between high and low cortisol responders were modest in the present study.

9. WERE MOOD CHANGE AND CORTISOL REACTIVITY PREDICTIVE OF ATTENTIONAL DISENGAGEMENT FROM EMOTIONAL PICTURES?

It was predicted that mood change in response to stress would be

associated with changes in selective attention. Regression analyses were performed in the same manner as those done in the previous study (see study 1, Section 8; Tables 1 and 2). In contrast to study 1, the mood and cortisol response to stress were not predictive of selective attention to emotional pictures or attentional efficiency in general (data not shown).

10. WAS SELECTIVE ATTENTION TO EMOTIONAL WORDS PREDICTIVE OF RECOVERY FROM STRESS?

Predicting cortisol post-stress

A regression analysis was performed to assess wether selective attention to emotional pictures predicted the magnitude of cortisol recovery. The regression was conducted in the same manner as the one done in study 1 (see section 9; Table 3). With the exception of peak cortisol, no other variables significantly predicted cortisol recovery (data not shown).

Predicting mood post-stress

Two regression analyses were performed on mood ratings taken at the end of the second part of the stressor. The dependent variable for the first regression was the change from baseline on the total POMS, and for the second regression the change from baseline on the POMS relaxed-anxious scale. The latter scale was chosen because ratings of anxiety differed from all other POMS scales (see Figure 13), showing a robust increase in response to all experimental conditions. Predictors for both regressions were baseline cortisol, baseline mood, cortisol response to the first part of the stressor, mood response to the first part of the stressor, and selective attention towards negative pictures in the left hemifield.

The regression equation was significant for the relaxed-anxious scale [R=.52, F(5,60)=4.5, p<.005], but not the total POMS, with the five predictors accounting for 21% (Adjusted R^2) of the variance (see table 4). As expected, mood change after the first part of the stressor was predictive of anxiety ratings at the end of the second part. Two of the four remaining predictors were significant: cortisol response to stress and selective attention towards negative pictures were predictive of subjective anxiety upon termination of the stressor. These results indicate that greater attentional avoidance and a lower cortisol during the study predict less anxiety post-stress. These results are consistent with the hypothesis that shifting attention away from negative information is implicated in regulating affect following stress. However, shifts of attention were not predictive of cortisol recovery, in contrast to the findings of study 1.

Correlations between attention and cortisol within the stressor conditions

It is possible that the influence of attention on cortisol, as observed in study 1, was masked by the robust effects of stress-induced arousal on attention in this study. If this were true, the relationship between attention and cortisol may be limited to the neutral condition, where arousal effects were not observed. Therefore, the relationship between attention, mood change, cortisol change, and cortisol recovery in each stressor condition was examined post-hoc. Because it was hypothesized that attention may modulate HPA activation, change in cortisol following the second part of the stressor, and therefore after the attention task, was used in these analyses. The sample size precluded any regression analyses by stressor condition, so Pearson product moment correlations were used. Selective attention towards negative pictures correlated significantly with

Table 4

Hierarchical multiple regression predicting anxiety at the end of the experiment

Predictors	r	ß	t	R	adj. R^2	F change
Step 1: Baseline POMS	0.01	-0.01	-0.1	0	-0.02	0
Step 2: Baseline cortisol	-0.05	0.05	0.4	0.05	-0.03	0.2
Step 3: Mood response	0.37	0.33	2.9**	0.39	0.11	10.9**
Step 4: Cortisol response	-0.3	-0.21	-1.7	0.45	0.15	4.2*
Step 5: Attention towards negative pictures[a]	-0.32	-0.27	-2.3*	0.52	0.21	5.5*

Note. n= 66; adj. Rsq= Adjusted R^2

[a] computed by subtracting reaction time for negative pictures from neutral pictures on shifts towards the left hemifield

*p<.05; **p<.01

baseline cortisol, cortisol change, and cortisol recovery in the neutral condition, but not in the other conditions (see table 5). For all cortisol measures, selective attention to negative pictures was associated with cortisol. Although cortisol change correlated with shifts of attention towards negative pictures presented to the right and left hemifields, significant correlations for baseline cortisol and cortisol recovery were found only with pictures presented to the left hemifield. These results suggest the relationship between attention and cortisol regulation, although not found in the full sample, was present in the neutral condition where arousal effects on attention were minimal.

11. SUMMARY OF RESULTS

Effects of stress on mood, cortisol, attention and memory

The major results of study 2 can be summarized as follows:

A. The experimental manipulations altered mood in the expected direction, except that the neutral condition elicited a mild lowering of mood similar to the negative stressor.

B. Cortisol production increased modestly in response to the experimental procedures, but did not differentiate between the neutral, negative, and positive stressor conditions. Cortisol change was greater in the second study than in the first.

C. The stressor manipulations elicited an alerting effect on attention, where reaction time was fastest during positive stress and slowest during the neutral condition.

D. Regardless of the stressor condition, participants were slower to shift attention toward negative pictures than positive or neutral pictures.

Table 5

Pearson product moment correlations between attention and cortisol by experimental condition

		Attention Towards Negative Pictures[a]	
		Right Hemifield	Left Hemifield
Positive Stressor	Baseline cortisol	-0.04	0.15
	Cortisol change	-0.20	-0.32
	Cortisol during recovery	-0.24	-0.14
Negative Stressor	Baseline cortisol	0.01	0.12
	Cortisol change	-0.02	-0.02
	Cortisol during recovery	0.00	-0.02
Neutral Condition	Baseline cortisol	0.24	0.56**
	Cortisol change	0.53*	0.51*
	Cortisol during recovery	0.29	.45*

Note. n=22 in each condition. Baseline and recovery cortisol are the low points reached during these phases.

[a]computed by subtracting reaction time for negative pictures from neutral pictures on shifts towards the right and left hemifields.

*p <.05; **p<.01

E. When presented to the right hemifield, participants shifted attention away from negative words more rapidly than from positive or neutral words.

F. Recognition memory for negative pictures was better than positive and neutral pictures, but was not influenced by the experimental conditions.

Effects of depression and anxiety on attention:

A. Attentional shifting from all pictures during the neutral condition was slower in high dysphoric subjects than those with low depression ratings.

B. High dysphoric participants were more sensitive to the alerting effects of stress on attention, exhibiting faster reaction time during the positive and negative stressors than low dysphoric participants.

C. Relative to low anxious subjects, high anxious participants exhibited selective attention and avoidance of negative pictures presented to the left and right hemifields respectively.

Associations between mood, cortisol and attention

A. Attentional avoidance and a low cortisol response to stress were the most important predictors of lower ratings of anxiety at the end of the experimental procedures in the full sample

B. Selective attention to negative pictures correlated with cortisol at baseline, during stress, and at recovery in neutral participants, but not in participants in the negative or positive stressor conditions.

DISCUSSION

Two important changes were introduced in study 2. First, pictorial depictions of emotion were incorporated into the spatial cueing paradigm because they are thought to be more ecologically-valid and meaningful than verbal stimuli. Second, the experimental conditions were divided into two parts, with the first part being before and the second part after the attention task. Subjects completed the first part of the stressor, where they either win or lose repeatedly, and then *anticipate* the continuation of the task. As expected, the procedural changes of study 2 resulted in greater subjective stress and cortisol change than study 1.

The results of study 2 were similar in some respects to study 1, but different in others. The mood and cortisol response to the experimental conditions followed the same patterns as those observed in study 1, with the expected differences in mood change but not in cortisol. The only difference between the studies was that the mood response in the neutral and negative stress conditions of study 2 did not differ statistically. There were a number of important findings in study 2. First, emotional pictures influenced attention independent of the stressor conditions. On valid trials, attentional engagement was slower for negative pictures than for positive or neutral pictures. Although this finding was not observed in study 1, it is consistent with the avoidance response reported in the previous study for invalid trials. Subjects may have shifted attention away from aversive pictures, which would have impeded attentional engagement during valid trials and potentiated disengagement during invalid trials. Consistent with this interpretation, subjects disengaged attention more rapidly from negative

pictures than from positive and neutral pictures in study 2. Thus, attentional avoidance of negatively-valenced stimuli was observed for both verbal and pictorial stimuli, with the former occurring in response to negative stress and the latter in response to pictorial depictions of emotion, regardless of the stressor condition.

Second, the stressor conditions had a strong "arousal" effect on attentional functioning, where shifts of attention towards all stimuli were faster during the positive and negative stressors than the neutral condition. This stress-induced potentiation of attentional functioning was unique to study 2 and was likely due to the changes in the experimental procedures. This finding was similar to what was observed in subjects with a high cortisol response to stress in study 1, who showed faster reaction time to all stimuli relative to those subjects with a low cortisol response. It is likely that both of these findings reflect the influence cognitive arousal and increased alertness on attention (Fernandez-Duque & Posner, 1997; Revelle, 1993).

Third, individual differences in depression and anxiety accentuated some of the effects described above. Participants with elevated ratings of depression on the BDI exhibited a different mood and attentional response to stress than low dysphoric participants. They reported more stress and discouragement during the experimental conditions, and were more susceptible to the arousing effects of stress on attention than those with low rating of depression. During the neutral condition however, dysphoric participants were slower to shift away from all stimuli than non-dysphoric subjects, an effect similar to the slow attentional shifting in response to aversive stress among dysphoric participants of study 1. These results were consistent with the prediction that dysphoric participants would be more sensitive to the influence of stress on attention. However,

dysphoric participants showed no evidence of selective attention to negative stimuli, as was observed in study 1.

Anxious subjects were particularly sensitive to emotional pictures and the procedural changes of study 2. In contrast to study 1, they exhibited a more pronounced mood lowering response to the experimental conditions, and were more sensitive to the valence of pictures and the hemifield of presentation than low anxious subjects. Anxious participants showed robust attentional avoidance of negative pictures in the right hemifield during the negative stressor and neutral conditions. In contrast, they selectively attended to negative pictures in the left hemifield during the negative stressor, but not during the positive stressor or neutral condition. The implications of these findings in dysphoric and anxious participants will be discussed below.

Finally, both attentional avoidance of negative pictures and low cortisol were predictive of lower ratings of anxiety at the end of the study in the full sample. This finding suggests that attentional avoidance of negative pictures facilitates the regulation of stress-induced emotional arousal. However, the interactions between mood, cortisol and attention reported in study 1 were not replicated in study 2. Mood change was not predictive of shifts of attention away from negative stimuli, nor did this attentional response predict lower cortisol levels during recovery. This is not surprising given the changes in the paradigm, the smaller sample size, and the robust effect of arousal on attention. It is possible that the effects stress-induced arousal on attention may have masked important interactions between mood, cortisol and selective attention. There were indications of this. First, the attentional avoidance effect was greatest in the neutral condition and weakest in the positive stress condition, where the effects of arousal were strongest. Second, differences between high and low anxious

participants in attentional functioning were greatest during the neutral condition and were hardly evident during the positive stress condition. These observations suggest that attentional differences between picture valence tended to dissipate as the effect of arousal increased. Finally, selective attention to negative pictures was positively correlated with cortisol change, baseline and recovery levels of cortisol in the neutral condition, but not in the other conditions. Thus, associations between cortisol, attention and mood change may have been masked by the robust effects of arousal observed during the stressor conditions.

GENERAL DISCUSSION

The effects of stress on attention were characterized by two major findings: one involving selective attention and the other a change in general processing efficiency or alertness. In regard to the former, the initial prediction that subjects would selectively attend to negative stimuli in response to aversive stress was not supported. In contrast, selective avoidance of pictorial depictions of negative emotion (study 2) and negatively-valenced words (study 1) was observed, with the latter effect occurring in response to the negative stressor. In the following sections, a number of issues concerning this finding will be examined. Then, the relationship between of stress, HPA function, and changes in processing efficiency will be discussed. Other important findings in these studies included the influence of depression and anxiety on attention and cortisol, and asymmetrical responses in spatial attention. Following discussion of these issues, limitations of the current studies and directions for future research will be considered.

1. ATTENTIONAL AVOIDANCE OF EMOTIONAL STIMULI

Attentional avoidance and motivational studies of attention

The attentional avoidance of negative words was inconsistent with certain motivational theories of attention (Derryberry & Tucker, 1994; Lang, 1995) and with a number of studies demonstrating that affective-motivational factors facilitate selective attention to congruent sources of information (Öhman et al., 2000; Lang et al., 1998; Mogg et al., 1998; Derryberry, 1993; Derryberry, 1991;

Derryberry & Reed, 1994; Derryberry, 1987; Bradley et al., 1997a; Reed & Derryberry, 1995; Pratto, 1994). The discrepancy may be due to the different experimental manipulations and measures of attention between the present studies and previous ones. First, studies by Derryberry and colleagues (see Derryberry and Tucker, 1994 for review) manipulated motivational state on a momentary basis, by providing feedback (success and failure on the previous trial) and assigning different incentive values to stimuli during reaction time tasks. Given that these attentional manipulations are brief, their findings are not comparable with the present studies, where actual failure and success experiences were elicited.

Second, the spatial cueing task differs from other measures of attention used in past research. The dot probe and emotional stroop tasks, the most commonly used tasks of emotional influences on attention, measure a general index of attentional allocation to salient stimuli. Other measures, such as search tasks (i.e. finding an angry face in an array of happy faces) or the potentiation of the startle reflex by emotional stimuli, assess attentional engagement by negatively-valenced stimuli (Öhman et al., 2000; Lang et al., 1998; Lang, 1995; Hansen & Hansen, 1994). None of these methodologies directly assess attentional shifting to and away from stimuli. The spatial cueing task is unique in that it allows for avoidant reactions to emotional stimuli, particularly through its disengagement trials (Stormark et al., 1997). Thus, the decomposition of attention into shifts of attention towards and away from stimuli may, in part, explain the discrepancy between the current findings and other studies of motivational influences on attention.

In contrast to the above literature, there are conceptualizations of attentional functioning that are consistent with the attentional avoidance of

negatively-valenced information. Mogg and Bradley (1998) hypothesized that incoming stimuli are quickly assessed for threat value by a "valence evaluation system", which is influenced by numerous factors such as state anxiety, situational context, interoceptive information, and past learning. This appraisal system is believed to occur at an early stage of sensory processing, similar to the rapid and coarse analysis of stimulus features described by Ledoux (2000) and Öhman et al (2000). The output of the system feeds into a "goal engagement system", where the allocation of resources for cognitive processing and behavioral response are determined. At this junction, current goals may be interrupted and an orienting response to threat initiated. Alternatively, current goals may be pursued and processes of inhibition initiated. These authors speculate that this two-stage process results in either selective attention or avoidance, depending on the type of stimulus, current state of the individual and the individual's subjective appraisal of threat. For example, if a stimulus has high threat value (i.e tarantula), or if the individual appraises mildly threatening stimuli as having high threat value (i.e. anxiety patients), then the allocation of attention to negative information would be expected. However, if the threatening stimulus is appraised as being of mild threat value, and is incompatible with current goals, then attentional avoidance would be expected. Mogg and Bradley (1998) propose that attentional biases for threatening stimuli serve to prepare the organism for response. Attentional avoidance of stimuli with low threat value would allow the organism to maintain its focus on current goals, and promote mood regulation.

Attentional avoidance of negative-valenced words has been observed in a number of the normal comparison samples of studies investigating attentional biases in clinical populations or high trait anxiety samples (MacLeod et al., 1986;

Bradley et al., 1995; Bradley et al., 1997a; Mogg et al., 1993a). In particular, subjects with low levels of trait anxiety, depression or anxiety-sensitivity demonstrate avoidance of negatively-valenced stimuli (Stewart et al., 1998; Byrne & Eysenck, 1995; Gotlib et al., 1988b; McCabe & Gotlib, 1995). In addition, healthy subjects who worry about future cardiac problems are reported to avoid, rather than attend to, cardiac-related words on an attentional search task (Constans et al., 1999). Furthermore, there is some evidence that low trait anxiety participants tend to avoid negative information under conditions of naturalistic examination stress (Mogg et al., 1994; MacLeod & Mathews, 1988). However, a number of studies using mood induction or laboratory stress have not found this effect (Richards et al., 1992; Mogg et al., 1993b; Mogg et al., 1990). The discrepancy between the present results and these other laboratory manipulations may be due to sample size: the sample in study 1 was almost three times larger than the studies mentioned above. For pictorial stimuli, attentional avoidance in non-clinical comparison samples was also observed in one study (Bradley et al., 1997b), but not in others (Mogg & Bradley, 1999; Bradley et al., 1998). Overall, attentional avoidance has been described in theoretical formulations and observed in the experimental literature, but it is not a particularly robust phenomenon.

The attentional avoidance observed in the current studies is also consistent with research examining the relationship between emotional state and memory or learning. It is well known that mood state facilitates mood-congruent learning (Blaney, 1986). However, a number of studies indicate that mood state enhances learning or recall of mood-*incongruent* material as well (Smith & Petty, 1995; Rinck et al., 1992; Sedikides, 1994; Parrott & Sabini, 1990). The prevailing explanation of mood-incongruent effects is that they are an active means of

regulating emotion (Blaney, 1986). The relationship between emotional regulation and attentional avoidance will be discussed further in the sections that follow.

Stimulus exposure duration and the activation of conscious goals

One important determinant of attentional avoidance may be the exposure duration of the emotional stimulus. In the present studies, stimuli were presented at an exposure duration allowing full conscious awareness. In addition, stimuli of the same affective valence were grouped together in blocks. One consequence of both these factors is that participants could invoke intentional strategies to meet the demands of the task. Differences between conscious processing strategies and those outside of awareness are becoming increasingly important in understanding the relationship between attention, emotion and psychopathology (Öhman et al., 2000; Mogg & Bradley, 1998). For example, attentional biases for threatening information in anxious patients occurs even when the stimuli are presented outside of subjective awareness. In contrast, depressed patients show an attentional bias only for supraliminal information, suggesting that the underlying attentional dysfunction may differ between clinically anxious and depressed individuals (Mogg & Bradley, 1998; McCabe & Gotlib, 1993; Bradley et al., 1995; Mathews et al., 1996; Mogg et al., 1995; Mogg et al., 1993a; MacLeod & Rutherford, 1992). With one exception (van Honk et al., 1998), reports of attentional avoidance have only been observed with supraliminal stimuli.

Stormark and colleagues (1997) provide a good example of the influence of cue exposure on attentional biases. They hypothesized that attention to emotional cues can be conceptualized as an approach-avoidance process, similar

to that of the model by Mogg and Bradley (1998). In their formulation, attention is initially drawn to an emotional stimulus, but subjects will avoid further processing of the stimulus when it conflicts with their current goals. They tested this hypothesis in treated alcoholics and social drinkers using a spatial cueing task similar to that of the current study. They found that alcoholics were slower to shift away from alcohol-related words than neutral words when the words were presented briefly (SOA of 100 ms). When words were presented for a longer exposure time (SOA of 500 ms), alcoholics were faster to shift away from alcohol-related words than neutral words. These effects were specific to alcoholics; no effects of alcohol-related words on attention were observed in social drinkers. The latter finding is remarkably similar to the attentional avoidance response observed in study 1, which used a similar SOA (366 ms). These results suggest that attention is automatically drawn to motivationally-significant cues when presented for brief exposure times, but that conscious processes can override this bias with longer exposure durations. Alcohol-related stimuli may have activated a conditioned drug urge in alcoholics, followed by an active attempt to terminate the urge. Perhaps, participants in the present studies were attempting to terminate an affective response to repetitive loss by avoiding negative stimuli. In sum, the duration of cue exposure may explain why attention is preferentially engaged by emotional stimuli in some instances, and avoided in others. Long exposure to an emotional cue may initiate intentional responses to self-regulate and attentional avoidance, while shorter exposure times may trigger reflexive or automatic processes that capture attention.

Cognitive operations underlying attentional avoidance

The preceding discussion about automatic and intentional processes raised

certain questions about the cognitive operations underlying attentional avoidance. To better understand this issue, the stimulus events and associated mental operations occurring during the modified spatial cueing task will be briefly reviewed (Posner et al., 1987; Posner, 1978). First, the presentation of a cue is detected, which elicits an exogenous shift of attention in a similar manner as would occur for any abrupt change in the visual field (Jonides & Yantis, 1988). Second, attention is then engaged at the location of the word or picture cue. When spatial attention is focused on a word, semantic information and affective valence are automatically extracted (McCann et al., 1992; Lambert et al., 1988; Pratto, 1994). Similar operations occur when using pictures as cues, although picture processing is more complex than word processing (i.e. integration of physical features, object identification, affective valence, familiarity, etc.; Sergent, 1995). Up until this point, sensory processing can be considered stimulus-driven or "bottom-up". However, attention is probably held at the cued location in part by "top down" or goal-directed processes. Specifically, the explicit expectation that the cue is predictive of the target's probable location should elicit a top-down influence on attention. Third, the target stimulus is presented and is detected automatically through both stimulus-driven (abrupt onset stimulus) and goal-directed attentional influences (task instructions). At this point, an interrupt operation is initiated and current operations such as semantic processing are terminated. When attention is already engaged at the location of the target on valid trials, a response is quickly initiated. For invalid trials, attention must be disengaged from its current focus and engaged at the location of the target before a response is initiated. Given the variety of mental operations performed in this task, and the fact that the use of words and pictures as cues has rarely been studied in the empirical literature, the exact cognitive operations being influenced

by stress and emotion are not yet fully known.

As noted in the previous discussion of cue exposure duration and attention, it is unlikely that attentional avoidance was initiated at an early stage of stimulus processing. In study 1, attentional avoidance probably occurred after semantic processing of the negative words, and may reflect a facilitation of the "interrupt" and "disengage" operations through top-down mediation. This formulation is consistent with the fact that attentional avoidance occurred only on invalid trials and was associated with the experience of negative affect. That is, the top-down influence may have been a goal-directed strategy to terminate the experience of negative emotion. Avoidance of negative pictures was pronounced on valid trials and it occurred across conditions. These results suggest that semantic processing of negative pictures disrupted the "engage" function of attention. It is speculated that participants prematurely moved attention away from the pictures during the long exposure duration (600 ms), and were therefore unable to maintain attentional engagement at the cued location. This formulation is also consistent with the finding of faster attentional shifts away from negative pictures than neutral pictures on invalid trials. If participants were moving attention away from negative pictures prematurely, reaction time would be delayed on valid trials and facilitated on invalid trials. Thus, this effect was likely mediated through top-down influences on the "interrupt" and "disengage" operations of attention as well, triggered by the dysphoric and threatening content of the negative pictures. Perhaps emotion regulation, elicited by aversive stress in study 1 and disturbing pictures in study 2, was the common top-down influence on attention. In the next section, the relationship between attentional avoidance and adaptive coping with stress will be considered. It is likely that the goal-directed influences on spatial attention described in this

section serve an important regulatory function in coping with stress.

Attention and the regulation of emotion and HPA activity

As noted in previous sections, attentional avoidance of negative information following stress may represent an adaptive coping response to emotional arousal. In study 1, participants with the greatest decline in mood were the fastest to shift attention away from negative stimuli. Although this relationship was not found in study 2, attentional avoidance of negative pictures was associated with reduced levels of anxiety at the end of the experiment. These relationships suggest that the attentional response to stress acts as a form of emotion regulation. Rothbart and colleagues (1995; 1994) note that attentional processes, particularly those implicated in the ability to disengage, are important in coping with distressing information. Although the allocation of attention to threatening stimuli is necessary in response to potential danger, shifting attention to alternate sources of information or potential coping options may be more adaptive in negotiating common stressors. Thus, the ability to orient to and shift away from distressing information may represent an important dimension of coping with negative emotion.

In addition to its relationship to mood change, the attentional avoidance response of negative information was predictive of low cortisol levels during the recovery phase of study 1. This finding suggests that the regulation of emotional arousal through attentional avoidance facilitated termination of the stress response, allowing for efficient post-stress normalization of cortisol levels. Although this relationship was not observed in study 2, cortisol production was associated with selective attention to negative pictures when the arousing effects of stress on attention were absent. Cortisol levels throughout the experiment

(baseline, change from baseline and recovery) were positively correlated with selective attention to negative pictures in the neutral condition, but not in the other conditions. Within the neutral sample, high cortisol was associated with selective attention to distressing pictures, and low cortisol was associated with an avoidant attentional style. Perhaps the arousing nature of the positive and negative stressors, which served to speed up reaction time and minimize individual differences, masked the relationship between cortisol and attention observed in the neutral condition.

Given that the cortisol response to stress is readily affected by cognitive and psychosocial factors such as subjective appraisal and social support (Francis et al., 1996; Seeman & McEwen, 1996; Henry, 1992; Sapolsky, 1990; Gunnar, 1994; Breier et al., 1987; Ursin et al., 1978), it is not surprising that cortisol levels were associated with attentional processes in the present studies. It has recently been reported that high cortisol reactivity was associated with selective attention to threatening information on an emotional stroop task (van Honk et al., 2000; Epel et al., 2000). If attentional avoidance of negative information is important for both cortisol and mood regulation, then it may represent a key factor in coping with stress. A question for future research is whether the absence of this response is a risk factor for other maladaptive cognitive-affective processes and stress-related forms of psychopathology. Studies in young children provide some support for this view. Children who made few attentional shifts and tended to fixate on a novel toy at 13 months of age were described by their mothers as having more sadness, discomfort and shyness at age 7 relative to children with a more "flexible" attentional style (Rothbart et al., 1994). Whether a similar association exists in older age groups at risk for anxiety and depression has not yet been examined.

In sum, attentional avoidance of negative stimuli appears to be dependent on a number of factors such as cue exposure duration, current goals, and subjective appraisal of the emotional stimulus. In the present studies, the avoidance response was perhaps elicited by the conscious goal of regulating emotional arousal, which would be consistent with the top-down nature of this attentional response. The association between attentional avoidance and the regulation of mood and cortisol indicates that selective attention may serve an important adaptive function in coping with stress. In the following sections, the facilitation of attentional functioning in response to stress and high cortisol reactivity will be examined.

2. PROCESSING EFFICIENCY, STRESS AND AROUSAL

Stress-related changes in the speed of attentional shifting

Participants with a high cortisol response to stress disengaged attention more rapidly than cortisol non-responders across all conditions. This effect in cortisol responders was consistent with the prediction that high levels of cortisol would facilitate attentional shifting. A similar finding was recently reported in a study examining the effects of a stressful video game on inhibitory attentional processes (Skosnik et al., 2000). Although the mean cortisol response to the task was modest, increased cortisol was associated with faster reaction time and less inhibition on a negative priming task. These results suggest that stress may serve to increase attentional flexibility by decreasing inhibition of non-attended space, resulting in a less focused mode of attention. In study 2, attentional shifts towards all stimuli were faster during the positive and negative stressors than the neutral condition. However, the relationship between processing efficiency and

cortisol in study 1 was not replicated in study 2. Nevertheless, correlations between reaction time and peak cortisol (r=-0.18) and cortisol change (r=-0.19) were in the expected direction. Thus, it is likely that both the participants in study 2 and the cortisol responders of study 1 exhibited increased arousal in response to stress. Unlike the avoidance response described in Section 1, these findings reflect a change in processing efficiency or alertness independent of the emotional valence of the stimuli.

It has long been recognized that the individual's state of arousal can affect cognitive performance (Yerkes & Dobson, 1908; Broadbent, 1971). Studies of cognitive performance, including simple reaction time tasks, have shown that increased energetic arousal, either through self-report, caffeine administration or time-of-day manipulations, can facilitate cognitive performance (Revelle, 1993; Matthews et al., 1990; Matthews et al., 1989). Of interest is the fact that this relationship is largely restricted to difficult tasks that require attention without short-term memory load (Matthews et al., 1990). The attention tasks used in the current studies fit these criteria; they were difficult because of their external pacing and lengthy duration, and required minimal short term memory. The observed arousal effects in attentional shifting probably reflect a change in sustained attention or vigilance, defined as the ability to maintain consistent performance over time (Parasuraman et al., 1998; Robertson & Manly, 1999).

Noradrenergic and corticosteroid influences on attention

There are at least two formulations which seek to explain how arousal can influence attention: one concerns the influence of the noradrenergic locus coeruleus arousal system on attention and behavioral flexibility (Aston-Jones et al., 1999), and the other concerns the direct effect of endogenous corticosteroids

on cognitive function (Lupien & McEwen, 1997). With respect to the former, ascending monoaminergic and cholinergic pathways, which innervate wide areas of the neocortex, play an important role in maintaining arousal and modulating attention (Mesulam, 1998). In particular, cortical input arising from the locus coeruleus is believed to mediate arousal effects on selective attention (Aston-Jones et al., 1999; Robbins, 1997; Smith & Nutt, 1996). For example, application of NE to various cortical regions increases the signal to noise ratio by dampening spontaneous firing rates (Foote et al., 1983). Locus coeruleus firing activity in monkey varies not only with general arousal levels (i.e. drowsiness, sleep, waking), but also with level of performance on a vigilance task, suggesting that phasic arousal in this system modulates selective attention (Rajkowski et al., 1994). From extensive work in the rat, Robbins (1997) concluded that these noradrenergic pathways are responsible for sharpening attentional focus and lowering susceptibility to distraction during stressful or arousing circumstances, both of which enhance discriminative responding in animal models of attention.

As described in the introduction, this noradrenergic "vigilance" system densely innervates the posterior attention system, a network of structures critical in orienting to stimuli and shifting attention in space (Posner, 1993; Posner & Petersen, 1990). The net cognitive effect of this interaction is that, under conditions of arousal, orienting may become more efficient (Posner, 1993). For example, increasing alertness during a spatial cueing task by presenting an auditory warning signal at the beginning of each trial results in faster reaction time for both validly and invalidly cued trials, relative to trials with no warning signal (Fernandez-Duque & Posner, 1997). In non-human primates, administration of the noradrenergic alpha-2 agonists clonidine, which is thought to decrease central NE activity through its action at presynaptic sites (Svensson

et al., 1975), blocked the alerting effect of a warning signal on reaction time in a cueing experiment (Marrocco & Davidson, 1998). These results suggest a noradrenergic modulation of arousal effects on attentional orienting. In sum, the effects of noradrenergic arousal on attention are believed to help maintain a state of vigilance and focused attention, characterized by increased concentration, enhanced discriminative responding and rapid shifts of attention. Because it is well established that acute stress activates the locus coeruleus-NE system (Redmond, 1987), this type of noradrenergic-driven alertness may underlie the observed facilitation of attentional functioning in response to stress.

The other explanation of the arousal effects observed in the present studies refers to the direct effects of cortisol on information processing (Lupien & McEwen, 1997; Wolkowitz, 1994). As described in the introduction (Section 4), Lupien and McEwen (1997) propose that differential activation of Type 1 (mineralocorticoid) and Type 2 (glucocorticoid) corticosteroid receptors influence different cognitive functions. Type 1 receptors are implicated in the adaptive integration of sensory information and attentional function, while Type 2 receptors are involved in the consolidation of memory. According to certain authors (Mölle et al., 1997; Born et al., 1987; Born et al., 1986), corticosteroids widen the scope of attention on tasks demanding sustained focus, so that attention is more expansive and less focal. A wider scope of attention may have facilitated shifting towards and away from cued locations. Thus, Type 1 receptor activation and related changes in attentional function may help explain why stress facilitated processing efficiency in the present studies.

It should be noted that the response to acute stress may include a myriad of active CNS agents (neurotransmitters, hormones, peptides, etc) other than cortisol. The present studies provide only correlational data suggesting an

association between a high cortisol response to stress and cognitive performance. Furthermore, some studies have found equivocal (Lupien et al., 1994) or no evidence of a relationship (Schmidt et al., 1999; Wolkowitz et al., 1990; Newcomer et al., 1994) between attention and corticosteroids. However, these studies were based on the administration of high levels of synthetic glucocorticoids, and used different attentional measures than the ones examined here. Synthetic glucocorticoids, such as prednisone or dexamethasone, preferentially activate the Type 2 receptor system, which is implicated in the consolidation of memory rather than attention. It is possible that the modest increase in endogenous cortisol observed in the present studies preferentially stimulated Type 1 receptors, which are believed to modulate the early stages of sensory processing. In fact, it has been shown that modest stress-induced changes in cortisol can affect sensory processing (Fehm-Wolfsdorf et al., 1993). Cortisol responders, with cortisol levels of the same magnitude as those reported in the present studies, exhibited a higher sensory detection threshold than non-responders. Because this study was a replication of an earlier one using hydrocortisone to increase circulating corticosteroid levels, the effect of stress on sensory processing threshold is likely dependent on cortisol (Fehm-Wolfsdorf et al., 1989). Thus, it is possible that the facilitation of attentional shifting in response to stress could be mediated by modest increases in cortisol and Type 1 receptor activation.

The facilitation of attentional shifting in response to mild stress may have important evolutionary significance. Preparation for rapid action and flexibility of action have been cited as key functional attributes of human emotion (Clore & Ortony, 2000). While a rigid action pattern is critical for responding to imminent threat, flexibility of action is important for long-term survival, particularly in a

social environment. A flexible, wide-scope attentional style may be beneficial in coping with daily sources of stress. For example, identifying multiple coping options in response to stress may be more adaptive than ruminating about the stressor. Thus, the stress-induced changes in the speed of attentional shifting observed in the present studies may reflect this type of behavioral flexibility. In the next section, individual differences and their effects on selective attention and non-selective changes in processing efficiency will be examined.

3. INDIVIDUAL DIFFERENCES, STRESS, AND ATTENTION

Attentional functioning in dysphoric participants

It was predicted that participants with elevated ratings of depression on the BDI would be more susceptible to an attentional bias for negative stimuli than those with low ratings. Although dysphoric participants exhibited changes in the speed of attentional shifting, they were not differentially sensitive to negative stimuli. The two studies however yielded results that differed with regard to the stressor conditions's effect on attentional disengagement. In study 1, dysphoric subjects were slower to disengage from all stimuli following the negative stressor than non-dysphoric participants. In study 2, disengagement from all stimuli in dysphoric participants, compared to those who were euthymic, was slower in the neutral condition and faster during the positive and negative stressor conditions. It is possible that emotional pictures were sufficiently disturbing to dysphoric subjects to elicit a deficit in processing efficiency in the neutral condition that matched the effects of negative stress in dysphoric subjects of study 1. The rapid attentional shifting in dysphoric participants following positive stress indicates that they were more sensitive to the arousal effects of study 2 than were the non-

dysphoric participants. Consistent with these attentional responses to stress, dysphoric subjects reported more subjective stress and discouragement than non-dysphoric participants. These findings indicate that participants with elevated depression scores were particularly sensitive to pictorial depictions of emotion and the procedural changes made in study 2.

There have been inconsistent results regarding attentional biases in depression and non-clinical dysphoria, with some studies reporting selective attention to negative stimuli (Bradley et al., 1997a; Mathews et al., 1996; Gotlib & McCann, 1984; Mogg et al., 1995; Ingram et al., 1994) and others finding no such evidence (Mogg et al., 1993a; MacLeod et al., 1986; Gotlib et al., 1988a; Gilboa & Gotlib, 1997; Hedlund & Rude, 1995). One possible reason for these inconsistent findings is that attentional biases in depression occur primarily when stimuli are presented for long durations (500-1000 ms; Mogg & Bradley, 1998; Mathews & MacLeod, 1994). Nevertheless, there was no evidence of selective attention to negative stimuli in the present studies where words and pictures were presented for 300 ms and 600 ms respectively. Alternatively, psychomotor and cognitive slowing during neuropsychological testing has been reported in depressed patients (Murphy et al., 1999; Purcell et al., 1997; Ilsley et al., 1995). It is possible that dysphoric subjects in the present studies were characterized by a similar type of cognitive slowing following negative stress and in response to emotional pictures, although none could be considered clinically depressed using DSM-IV criteria. At the same time, however, subjects with elevated depression scores exhibited a number of signs of vulnerability to depression. First, the dysphoric subjects reported lower mood at baseline than non-dysphoric participants, which lasted throughout the experiment. Second, a past psychiatric history was reported more often by dysphoric than non-dysphoric participants (data not

shown). Third, baseline and recovery levels of cortisol were higher in the dysphoric than non-dysphoric subjects of study 1. Furthermore, higher ratings of depression were associated with lower cortisol reactivity during the experimental manipulations, and higher cortisol levels during recovery. These findings suggest that there are subtle HPA abnormalities specific to dysphoric individuals that are reminiscent of the high basal cortisol and greater diurnal variation in cortisol secretory patterns observed in depressed samples (Holsboer, 1995; Stokes & Sikes, 1987), as well as the blunted cortisol response to stress reported in a number of studies of depressed patients (Gotthardt et al., 1995; Trestman et al., 1991; Croes et al., 1993).

Cognitive biases (Gilboa & Gotlib, 1997; Ingram et al., 1994; Hedlund & Rude, 1995), general emotional instability (Lauer et al., 1997; Grigoroiu-Serbanescu et al., 1991; Hirschfeld et al., 1989; Krieg et al., 1990; Maier et al., 1992), and a heightened sensitivity to stressor and neurobiological challenges (Klaassen et al., 1999; Holsboer et al., 1995; Benkelfat et al., 1994; Zahn et al., 1989) have been proposed as vulnerability factors for depression. Of relevance to the present studies, the healthy offspring of patients with major affective disorder displayed an enhanced cortisol response to a dexamethasone-corticotropin releasing hormone challenge relative to controls (Holsboer et al., 1995). This effect is believed to reflect a dysfunction in the negative feedback control of cortisol secretion, and is consistent with the high baseline and recovery levels of cortisol observed in the dysphoric participants of the present studies. With regard to cognitive factors, only one study has reported a deficit in selective attention. Previously-depressed participants, following a negative mood induction, were more vulnerable to distraction by both positive and negative words than neutral words on a dichotic listening task (Ingram et al., 1994).

Depressive rumination, a form of self-focused attention, has also been proposed as a risk factor for depression (Nolen-Hoeksema, 1987). In sum, impaired attentional disengagement and abnormalities in HPA functioning may represent vulnerability markers of depression. One can speculate that stress-induced deficits in attentional disengagement are linked to a tendency to ruminate on negative themes, leading to poor emotional and stress-HPA regulation. Interpretation of the present data, however, awaits replication in studies of participants chosen apriori for clinical depression and risk for depression.

Attentional functioning in anxious participants

In contrast to dysphoric participants, subjects with high ratings of anxiety on the STAI exhibited stress-induced changes in selective attention. However, significant effects were found only in study 2. The use of emotional pictures and changes in the experimental paradigm, that make it more stressful than the paradigm used in study 1, are likely reasons for this discrepancy. In fact, high anxious subjects in study 2 showed a more pronounced and long-lasting mood lowering response to stress than participants with low ratings of anxiety. The attentional pattern observed in high anxious participants included both avoidance of and selective attention to negatively-valenced pictures. There was a distinct asymmetry in this response: the former was observed when shifting away from right hemifield pictures and the latter when shifting from left hemifield pictures.

The attentional avoidance response was similar to that observed in the sample as a whole, and was discussed earlier. The selective attention response, where anxious subjects were slow to disengage attention away from negative pictures following the negative stressor, was the only finding consistent with the

study's prediction that aversive stress would elicit selective processing of negatively-valenced information. This result is consistent with a large body of evidence indicating that anxiety patients and subjects high in trait anxiety selectively attend to negative words on the dot probe and emotional stroop tasks (Mathews & MacLeod, 1994; Mogg et al., 1995; Mathews & Klug, 1993; Mathews et al., 1990; Mogg et al., 1992; Mogg et al., 1993a; MacLeod & Mathews, 1991; MacLeod et al., 1986; Chen et al., 1996; Lavy et al., 1993; McNally et al., 1992; Foa et al., 1991). Selective attention to pictorial depictions of negative emotion has also been reported in subjects high in trait anxiety (Mogg & Bradley, 1999; Bradley et al., 1998; Byrne & Eysenck, 1995). It should be noted however, that the findings obtained in the present study are based on a small sample of "anxious" individuals with only moderate levels of self-reported anxiety. Further study of attentional disengagement that targets highly anxious individuals is needed.

4. STRESS, ASYMMETRY AND SPATIAL ATTENTION

Because stimuli were presented on the right and left side of the midline in foveal vision, asymmetrical responses in spatial attention were observed in the current studies. An asymmetry in spatial attention, although less studied, parallels the observed asymmetry in the visual system, where left visual field stimuli preferentially activate the right hemisphere and right visual field stimuli activate the left hemisphere. In terms of orienting, asymmetries in spatial attention are best described by the activation-orienting hypothesis (Kinsbourne, 1970; Heilman, 1995; Reuter-Lorenz et al., 1990). This hypothesis states that unilateral hemispheric activation biases attention in the direction contralateral to the

activated hemisphere, so that each hemisphere preferentially orients attention in the contralateral direction. In the present studies, asymmetrical findings are presented in Table 6. It should be noted spatial cueing trials can be interpreted by the hemifield in which the cueing stimulus (words or pictures) appears (top of Table 6) or the hemifield in which the target stimulus appears (bottom of Table 6). Asymmetrical findings that are independent of the emotional valence of the cue will be interpreted with respect to the hemifield of the *target*; a rightward shift indicates the orienting of attention to the target in the right hemifield. Asymmetrical findings related to the emotional valence of the cue will be interpreted with respect to the hemifield of the *cue* (i.e. shifts away from left hemifield words). In the following sections, some of these asymmetrical findings will be discussed. Unfortunately, not much is known about asymmetry in attentional functioning, and what will follow is largely speculative.

Asymmetrical findings independent of emotional valence

There were two asymmetrical findings independent of emotional valence of the cueing stimulus. First, reaction time was faster when responding to right hemifield targets (rightward shifts) than left hemifield targets (leftward shifts) in both experiments, an effect independent of stressor condition or trial type. This effect is likely attributed to the fact that all subjects responded to targets with a right hand key press. Previous research indicates that reaction time to stimuli directed to one hemisphere are responded more quickly by the contralateral than ipsilateral hand (Berlucchi et al., 1971). Thus, right hemifield targets preferentially activate the left hemisphere, facilitating a right hand response.

Second, high cortisol responders of study 1 were faster to shift away from words than non-responders, and this effect was more pronounced for shifts of

Table 6

Effects of hemifield presentation on attention for study 1 (words) and study 2 (pictures)

	Shifts of attention			
	Towards the Rt Hemifield	**Away from the Rt Hemifield**	**Towards the Lt Hemifield**	**Away from the Lt Hemifield**
All subjects				
Words	Fast RT for all stimuli	---	---	Fast RT for all stimuli Avoidance of negative stimuli
Pictures	Fast RT for all stimuli Avoidance of negative stimuli	--- Avoidance of negative stimuli	--- ---	Fast RT for all stimuli Avoidance of positive stimuli
High Anxiety				
Words	---	---	---	---
Pictures	---	Avoidance of negative stimuli	---	Selective attention of Avoidance of positive stimuli
High Cortisol				
Words	---	Fast RT for all stimuli	---	---
Pictures	---	---	---	---
	Rightward shift	**Leftward shift**	**Leftward shift**	**Rightward shift**

Note. Rt = Right; Lt = Left; RT = Reaction time; Avoidance = rapid shifts away from cues on invalid trials, and slow RT on shifts towards targets on valid trials; Selective Attention = slow shifts away from cues on invalid trials

attention to left hemifield targets (leftward shift). The facilitation of leftward shifts, and therefore processing of the target in the left hemifield, suggests a right hemisphere advantage in cortisol responders. Because a high cortisol response to stress was likely indicative of high arousal during the study, this finding can be attributed to the asymmetrical influence of arousal on attention. As described by a number of authors (Robertson & Manly, 1999; Heilman, 1995; Posner, 1993; Whitehead, 1991), the right hemisphere is critical in maintaining arousal and sustained attention. Because of this asymmetry, it is hypothesized that a right hemisphere processing advantage should occur under conditions of arousal and sustained vigilance. Indeed, Whitehead (1991) reported a right hemisphere advantage (left visual hemifield) on a choice reaction time task demanding sustained visual attention. This effect is similar to what was observed in cortisol responders, who showed facilitated processing of left visual field targets. Thus, a right hemisphere processing advantage under conditions of arousal may explain the asymmetry observed in cortisol responders.

Asymmetrical findings for emotional stimuli: Verbal stimuli

Attentional shifts away from negative words were facilitated when moving attention away from the left hemifield (right hemisphere) following the negative stressor. This finding indicates that aversive stress, negative stimuli and the process of attentional disengagement interact in the right hemisphere to elicit an avoidance response. Although this result is consistent with a right hemisphere dominance for the processing of emotional information (Ross, 1984; Bowers et al., 1985; Ley & Bryden, 1979), these studies have typically used non-verbal stimuli. Alternatively, the right hemisphere avoidance response may be mediated by negative affect and asymmetrical brain activation. Electroencephalographic

(EEG) studies of brain activation have reported an association between negative affect, both dispositional and situational, and greater right than left hemispheric activation in non-clinical populations (Davidson, 1998; Davidson, 1995; Nitschke et al., 1999; Wheeler et al., 1993) and non-human primates (Kalin et al., 1998). Of interest, greater right than left parietal activation, critical for attentional orienting (Posner & Petersen, 1990), was observed in subjects exhibiting somatic anxiety in response to distressing narratives (Heller et al., 1997). Because the attentional avoidance observed in study 1 occurred in response to aversive stress and was associated with negative mood change, it is possible that the negative stressor stimulated asymmetrical brain activation favouring the right hemisphere. Under conditions of heightened right activation, the presentation of negative words to the right hemisphere could have facilitated contralateral avoidance shifting, consistent with the activation-orienting hypothesis. Although speculative, this hypothesis may help explain the asymmetry of attentional avoidance in study 1.

The lateralized avoidance response of negative words in the left hemifield (right hemisphere) is consistent with an asymmetry in neuroendocrine function. Kalin and colleagues (1998) demonstrated that relative right frontal EEG activity was correlated with basal cortisol levels at one and three years of age in monkeys. Presentation of negative film clips to the right hemisphere increased cortisol production, while presentation to the left hemisphere elicited no change in cortisol (Wittling & Pflüger, 1990). Because subjective arousal and mood ratings did not differ between film presentations to the right and left hemispheres, these results suggest that the presentation of aversive stimuli to the right hemisphere is important in activating the HPA system (Wittling, 1995). The present studies were consistent with these findings: selective attention to negative words presented to the right hemisphere, but not the left, was predictive of cortisol levels

during the recovery phase of study 1. Among neutral participants of study 2, baseline and recovery levels of cortisol were associated with selective attention to negative pictures presented to the right hemisphere. Wittling (1995) also reports that right hemisphere-mediated cortisol production was associated with less somatic complaints and better health. Thus, the interaction between right hemisphere avoidance of negative stimuli and cortisol functioning may reflect an adaptive process in coping with stress, perhaps leading to better health outcome.

Asymmetrical findings for emotional stimuli: Pictorial stimuli

In contrast to study 1, the presentation of negatively valenced pictures to the right hemifield (left hemisphere) elicited attentional avoidance across experimental conditions. This finding is contrary to the traditional view that the right hemisphere is dominant for the processing and expression of emotion (Ross, 1984; Bowers et al., 1985; Ley & Bryden, 1979). However, there are many inconsistencies in the neurological and psychological literature, and it is unlikely that there is a simple, clear-cut asymmetry in the processing of emotional information (Kolb & Taylor, 2000; Sergent, 1995). In fact, current ideas about the processing of emotional content generally focus on cortical-subcortical interactions, rather than right-left dichotomies (Ledoux, 2000). For example, it has been hypothesized that left frontal brain regions have an important inhibitory influence on subcortical regions involved in emotional behaviour, perhaps for the purpose of maintaining goal-directed, approach-type behaviours (Tomarken & Keener, 1998; Gainotti et al., 1993). In a recent PET study of regional metabolic rates in normal subjects, Davidson and colleagues (1999) reported that (1) amygdala activation was associated with self-reported negative affect, and that (2) left prefrontal activation was negatively correlated with activation of the

amygdala. These findings suggest that the left prefrontal cortex is exerting an inhibitory role on emotional behaviour. Consistent with these studies, left frontal activation using EEG has been associated with a repressive-defensive personality style, believed to be characterized by the inhibition of negative affect (Tomarken & Davidson, 1994). Thus, left prefrontal areas may be critical in modulating emotional reactivity for adaptive goal-directed purposes, which could theoretically underlie the attentional avoidance response of negative pictures presented to left hemisphere.

Although it is not known why attentional avoidance was observed in the left hemifield for words and in the right hemifield for pictures, this distinction highlights the differences between verbal and pictorial modes of processing emotional information. It is likely that these asymmetrical effects represent two different mechanisms of responding to emotional information. The left hemifield avoidance of words is perhaps driven by negative mood change. The right hemifield avoidance of pictures, however, seems to be related to the disturbing content of the negative pictures. It is of interest that few studies of emotion and attention, with the exception of PET and EEG research, report results concerning asymmetrical effects. Future studies will need to pay closer attention to asymmetries in stress reactivity and emotional processing.

5. LIMITATIONS AND METHODOLOGICAL CONSIDERATIONS

Cortisol

A number of limitations of these studies warrant consideration. First, the fact that cortisol production did not differ between the conditions poses a number of problems with the validity of the experimental manipulations. A

cortisol increase following a positive competitive situation is not surprising; a number of studies have shown equivalent (Booth et al., 1989; McCaul et al., 1992; Mazur et al., 1997; Gladue et al., 1989), and sometimes greater (Suay et al., 1999; Elias, 1981), cortisol output in those winning relative to those losing. The cortisol response and modest mood lowering in the neutral condition, however, was problematic. One explanation of the cortisol response in the neutral condition was that computer feedback on Stroop performance (number of errors, time to complete task, etc.) followed each block of trials for all the experimental conditions. It is possible that the feedback led participants to "compete" against themselves, trying to improve their performance over the course the test. In addition, the stroop task was externally-paced (words presented at rate of 1/ second, or 100 ms following response), a factor which increased the difficulty of the task (Renaud & Blondin, 1997). These factors may have made the neutral condition stressful. Indeed, ratings of subjective stress and anxiety on the POMS did not differ between the neutral and stressor conditions.

Alternatively, the failure of cortisol to differentiate between conditions may have been due to anticipatory effects, independent of winning and losing. Anticipatory rises in cortisol prior to an actual competition have been reported in a number of studies (Suay et al., 1999; Booth et al., 1989; McCaul et al., 1992). Participants in the neutral condition were informed just prior to performing the Stroop task (at the end of the first relaxation phase) that they would not be competing, which may have elicited anticipatory stress. A re-examination of cortisol data sampled just prior to and during the stressor revealed a substantial anticipatory rise in cortisol for all conditions (data not shown). For these reasons, the neutral condition was a conservative control condition which was somewhat effortful and/or distressful. Despite these limitations, the experimental design of

these studies was validated by the mood response, which did differ between conditions.

A related issue was the absence of mean and AUC differences between the relaxation and stressor phases of the experiments. For both studies, only peak levels of cortisol achieved during the stressor phase showed a stress-related increase. Possible reasons for the discrepancy between mean and peak cortisol data include high baseline values during the first relaxation phase, the absence of sustained cortisol production during the stressor phases, and individual variations in the timing of the cortisol response. For many participants, cortisol reached peak levels and then returned quickly back to baseline, perhaps reflecting efficient HPA negative feedback. Thus, high levels of cortisol were not sustained over the lengthy stressor phases (40 minutes). Furthermore, there was much variability in the timing of peak cortisol, as some subjects responded quickly, in anticipation of stress, and others in response to the stressor. For these reasons, mean and AUC cortisol production in response to the stressors was modest in the full subject samples. Consistent with other human studies of brief psychological stress on HPA function (Kirschbaum et al., 1995; Cacioppo et al., 1995; Lovallo et al., 1990), only a part of the sample in each study responded to stress with a robust increase in cortisol, perhaps due to individual differences in how the laboratory stressor was appraised (Kirschbaum et al., 1995). For this reason, analyses were conducted on cortisol responders and non-responders, which may be the most appropriate method of examining this type of data. That is, it may serve to identify those subjects who are truly engaged and affected by the experimental manipulations.

Attention

Cognitive findings based on reaction time data can be subject to multiple interpretations. The current studies are subject to this criticism, particularly in reference to the finding of attentional avoidance of negative information. While traditional cueing effects have been extensively validated with different measures (Corbetta et al., 1993; Luck et al., 1994; Henderson, 1996), the current findings of delayed engagement and fast disengagement have rarely been reported in the cognitive-neuroscience literature. For example, the rapid shifts of attention away from negative words could conceivably reflect a non-specific potentiation of attentional shifting, rather than a specific avoidance response of the emotional valence of the stimuli. Perhaps it was the arousing nature of negative stimuli, rather than the emotional content, that elicited rapid attentional shifts away from negative words. However, the avoidance hypothesis is consistent with other studies using different attentional tasks (see section 1). A delay in attentional engagement of negative pictures may indicate interference in processing rather than avoidance. Perhaps negative pictures elicit more elaborate processing than neutral or positive pictures, which interferes with subsequent processing of the target stimulus on valid trials. However, one would expect similar interference to occur on invalid trials, which was not observed. In fact, disengagement from negative pictures was facilitated relative to neutral and positive pictures.

Eye movements during the spatial cueing task were not measured, which could represent a potential confound. However, there is a large body of research indicating that covert shifts of attention are independent of eye movements when stimuli are presented within foveal vision (Johnson & Yantis, 1995; Posner et al., 1980; Henderson, 1996; Hillyard et al., 1990; Rugg et al., 1987; Posner, 1978). The visual angle between fixation and target locations in the current studies was

smaller (1.8° for words and 2.35° for pictures) than traditional cueing experiments where eye movements were recorded (Posner, 1978). In addition, pilot testing demonstrated that subjects could read the words presented and still maintain visual focus on the fixation point. Thus, it is unlikely that eye movements during the experiment posed a major problem.

Generalizability of the results

The generalizability of these results needs to be considered. First, the use of a single SOA limits the current findings. Avoidance processes observed in these studies may be specific to the long exposure duration of the emotional stimuli; a brief SOA may have lead to different findings (Stormark et al., 1997; Mogg & Bradley, 1998). Future work in this area should examine spatial cueing effects with different SOAs. Another question of generalizability concerns the use of experimental stress paradigms as models of the psychobiological processes occurring in response to real-life aversive events. There is evidence, for example, that laboratory-induced cortisol elevations correlate poorly with those occurring in daily life (van Eck et al., 1996). A criticism of laboratory stress paradigms is that they do not accurately model the type of stressors that occur in daily life. While acknowledging this limitation, laboratory stressors allow for controlled experimental manipulations that are necessary to test hypotheses. When plausible mechanisms underlying maladaptive stress-related behaviour are identified, naturalistic studies may be designed to test out these hypotheses. In this study, the laboratory stressor incorporated one aspect of a naturalistic encounter; a competitive situation with a peer. This procedure was likely more naturalistic than other types of standard stressors, such as noise stress or mathematical problems.

6. CONCLUSIONS AND FUTURE DIRECTIONS

The present studies are part of a new generation of research aimed at integrating the longstanding gulf between the research literature on emotion and cognition. They examined the unfolding of events when faced with a stressful challenge, from state variables and stressor reactivity, to subsequent cognitive processing of emotional information. The results demonstrated that attentional shifting away from unpleasant stimuli is an important factor in coping with emotional and stress-related neuroendocrine arousal. In addition, this research draws attention to possible mechanisms of dysfunction in psychopathology, by demonstrating how participants with mild symptoms of depression and anxiety exhibit different patterns of response than euthymic subjects. For example, participants who report symptoms of depression show poor attentional flexibility in response to stress and/or emotional pictures, and exhibit subtle abnormalities in baseline and recovery levels of cortisol. Although their functional significance has not yet been determined, these subtle changes in stress-sensitive systems may indicate a vulnerability to clinical depression. In effect, the results of the present studies point to future directions of research in this area which warrant consideration.

The process of avoidance can be viewed as an important component of emotional activation, rarely studied in the literature. It is consistent with theoretical accounts of emotion that postulate an action-readiness or action-tendency function of emotion (Izard, 1993; Ekman, 1992). In this conceptual framework, emotional systems serve to achieve, change, or maintain a particular goal-state. An approach-avoidance view of emotional processes would be an

example of this (Davidson, 1998; Lang et al., 1998). Negative emotions such as fear and sadness are associated with avoidance or defensive-type tendencies (i.e. fleeing danger; avoiding hostile conflicts), and positive emotions such as joy and relief are associated with approach-tendencies (i.e. feeding; performing pleasurable activities). From this perspective, the present studies suggest that attentional shifting away from unpleasant stimuli may represent an avoidance tendency in response to negative affect, similar to an animal withdrawing from aversive food or a human withdrawing from a distressing encounter. This conceptualization is consistent with evidence that participants reporting the greatest distress in response to loss were most likely to avoid unpleasant stimuli in a subsequent attention task. What is novel about these findings is the demonstration of attentional systems as *effectors* of self-regulatory behaviour, a hypothesis described in theory but rarely demonstrated in the literature (for an exception, see Rothbart et al, 1994). The relationship between cortisol regulation and attentional avoidance is an intriguing extension of this idea, and may represent a further advance in understanding the relationship between cognitive factors and HPA function. Future research should examine how attentional response styles prospectively influence stress-coping behaviours and long-term HPA function.

The beneficial effect of stress-induced arousal on cognition, which led to rapid and flexible attentional shifting, warrants further consideration. In contrast to the detrimental role of stress in psychopathology (Benes, 1994) and in physical illness (McEwen & Stellar, 1993), these results suggest that a stressful challenge has beneficial effects on cognition. Whether this occurs through the direct influence of cortisol in the CNS, the locus coeruleus NE system, or some other mechanism is not yet established. Nevertheless, future research should attempt to

delineate when and under what circumstances do stressful events become damaging. It is known that prolonged and chronically elevated glucocorticoids levels can damage and impair hippocampal function (Lupien & Meaney, 2000; McEwen, 1999; Sapolsky, 1992), but less is known about the effects of moderate or intermittent stress on cognition and behaviour. Furthermore, distinctions between stressful challenges, daily hassles and major life events may be critical in understanding the relationship between stress, coping behaviours, and outcome (i.e. resilience versus pathology). It is possible that coping behaviours effective in one situation become maladaptive in other situations. Attentional avoidance, for example, may be effective in coping with hassles and challenging situations, but is probably less effective in coping with a major crisis. For studies assessing major life events, denial and avoidant coping behaviours are generally predictive of poor outcome and psychopathology (Kendler et al., 1991; Rohde et al., 1990).

Future work in this area will need to determine the neural mechanisms by which stress influences attention. There are a number of possibilities. Ledoux (2000) describes two neural pathways for fear conditioning that explain how auditory stimuli with affective significance are processed. In the first circuit, information about a fearful stimulus projects from the thalamus to higher sensory processing areas, and then to the lateral nucleus of the amygdala and hippocampus. The second circuit consists of direct sensory input from the thalamus to the amygdala, where a number of effector systems (HPA, sympathetic, para-sympathetic, etc.) are activated via the central nucleus. The latter circuit rapidly processes the motivational significance of a stimulus (i.e. is it dangerous?), while the former circuit engages in more extensive processing leading to its identification (i.e. what is it?). Of interest, the amygdala receives input only from the later stages of cortical sensory processing, but it projects back to the primary

sensory cortices, an earlier stage of stimulus processing. This circuit (thalamus-amygdala-sensory cortex) may be important in altering cortical processing in response to an emotional stimulus, so that attention can be immediately focused, and resources allocated, to the stimulus for further processing and preparation for action. It is perhaps this type of circuit that underlies the attentional vigilance for negatively-valenced information observed in anxious participants. Other potential circuits include amygdala projections to the brainstem arousal systems, such as the locus coeruleus noradrenergic system or ascending cholinergic systems, both which affect cortical processing and attention (Ledoux, 2000; Robbins, 1997). These types of influences on attention probably reflect stimulus-driven automatic processes that are largely outside of awareness.

In addition to these automatic processes, conscious and goal-directed influences are also important in understanding how stress influences attention, particularly in terms of the avoidance responses observed in the present studies. One hypothesized circuit involves the amygdala, anterior cingulate and orbitofrontal cortex, which has interconnections with the parietal cortex, implicated in spatial attention, and systems of working memory in the dorsolateral prefrontal cortex (Mesulam, 1998; Devinsky et al., 1995; Posner & Dehaene, 1994). This circuit may reflect a top-down influence on attention, where conscious strategies and goal-directed behaviour define attentional functioning. Before attempting to address these neural issues, cognitive experiments of attentional engagement and disengagement using different stimulus exposure durations are needed provide a more precise understanding of the type of processing and mental operations underlying attentional vigilance and avoidance. Once the nature of processing is better understood, different anatomical hypotheses may be examined through imaging techniques and

transcranial magnetic stimulation (TMS). For example, it has recently been shown that low frequency repetitive TMS to the left dorsolateral prefrontal cortex, which disrupts neural processing and decreases activation, elicited an attentional avoidance response to threatening faces relative to neutral ones. Selective attention to threatening faces was observed following TMS to the right prefrontal cortex (D'Alfonso et al., 2000). This type of effect may be considered an experimental induction of a "top-down" bias, where selective attention is altered in response to alterations in prefrontal function. Future work of this kind can begin to identify which structures are involved in various types of attentional operations. Because the attentional avoidance observed in the present studies is not well understood, the type of research proposed here will help further understand the intriguing interaction between stress, attention, and self-regulatory behaviours.

REFERENCES

Aitken, K.G. (1977). Using cloze procedure as an overall language proficiency test. *TESOL Quarterly*, **11**, 59-67.

Al'Absi, M., Bonguard, S., Buchanan, T., Pincomb, G.A., Licinio, J., & Lovallo, W.R. (1997). Cardiovascular and neuroendocrine adjustment to public speaking and mental arithmetic stressors. *Psychophysiology*, **34**, 266-275.

Allen, P.I.M., Batty, K.A., Dodd, C.A.S., Herbert, J., Hugh, C.J., Moore, G.F., Seymore, M.J., Shiers, H.M., Stacey, P.M., & Young, S.K. (1985). Dissociation between emotional and endocrine responses preceding an academic examination in male medical students. *Journal of Endocrinology*, **107**, 163-170.

Aston-Jones, G., Rajkowski, J., & Cohen, J.D. (1999). Role of locus coeruleus in attention and behavioral flexibility. *Biological Psychiatry*, **46**, 1309-1320.

Bargh, J.A. & Pratto, F. (1986). Individual construct accessibility and perceptual selection. *Journal of Experimental Social Psychology*, **22**, 293-311.

Bargh, J.A. & Gollwitzer, P.M. (1994). Environmental control of goal-directed action: Automatic and strategic contingencies between situations and behavior. In W. D. Spaulding (Ed), *Integrative views of motivation, cognition, and emotion. Vol. 41. The Nebraska symposium on motivation* (pp. 71-124). Lincoln: U of Nebraska Press.

Beck, A.T., Ward, C.H., Mendelson, M., Mock, J.E., & Erbaugh, J.K. (1961). An inventory for measuring depression. *Archives of General Psychiatry*, **4**, 561-571.

Benes, F.M. (1994). Developmental changes in stress adaptation in relation to psychopathology. *Development and Psychopathology*, **6**, 723-739.

Benkelfat, C., Ellenbogen, M.A., Dean, P., Palmour, R.M., & Young, S.N. (1994). Mood-lowering effect of tryptophan depletion: Enhanced susceptibility in young men at genetic risk for major affective disorders. *Archives of General Psychiatry*, **51**, 687-697.

Berlucchi, G., Heron, W., Hyman, R., Rizzolatti, G., & Umilta, C. (1971). Simple reaction times of ipsilateral and contralateral hands to lateralized visual stimuli. *Brain*, **94**, 419-430.

Blaney, P.H. (1986). Affect and memory: A review. *Psychological Bulletin*, **99**, 229-246.

Blondin, J.P. & Waked, E. (1991). Cardiovascular responses, performance and mood in heart rate reactive individuals during a challenging cognitive task. *Personality and Individual Differences*, **12**, 825-834.

Bohnen, N., Houx, P., Nicolson, N., & Jolles, J. (1990). Cortisol reactivity and cognitive performance in a continuous mental task paradigm. *Biological Psychology*, **31**, 107-116.

Booth, A., Shelley, G., Mazur, A., Tharp, G., & Kittok, R. (1989). Testosterone, and winning and losing in human competition. *Hormones and Behavior*, **23**, 556-571.

Born, J., Fehm, H.L., & Voight, K.H. (1986). ACTH and attention in humans: A review. *Neuropsychobiology*, **15**, 165-186.

Born, J., Bräuninger, W., Fehm-Wolfsdorf, G., Voight, K.H., Pauschinger, P., & Fehm, H.L. (1987). Dose-dependent influences on electrophysiological signs of attention in humans after neuropeptide ACTH 4-10. *Experimental Brain Research*, **67**, 85-92.

Born, J., Hitzler, V., Pietrowsky, R., Pauschinger, P., & Fehm, H.L. (1988). Influences of cortisol on auditory evoked potentials (AEPs) and mood in humans. *Neuropsychobiology*, **20**, 145-151.

Born, J., Bathelt, B., Pietrowsky, R., Pauschinger, P., & Fehm, H.L. (1990). Influences of peripheral adrenocorticotropin 1-39 (ACTH) and human corticotropin releasing hormone (h-CRH) on human auditory evoked potentials (AEP). *Psychopharmacology*, **101**, 34-38.

Bowers, D., Bauer, R.M., Coslett, H.B., & Heilman, K.M. (1985). Processing of faces by patients with unilateral hemisphere lesions. 1. Dissociation between judgements of facial affect and facial identity. *Brain and Cognition*, **4**, 258-272.

Bradley, B.P., Mogg, K., White, J., & Millar, N. (1995). Selective processing of negative information: Effects of clinical anxiety, concurrent depression, and awareness. *Journal of Abnormal Psychology*, **104**, 532-536.

Bradley, B.P., Cuthbert, B.N., & Lang, P.J. (1996). Picture media and emotion: Effects of a sustained affective context. *Psychophysiology*, **33**, 662-670.

Bradley, B.P., Mogg, K., & Lee, S.C. (1997a). Attentional biases for negative information in induced and naturally occurring dysphoria. *Behaviour Research and Therapy*, **35**, 911-927.

Bradley, B.P., Mogg, K., Millar, N., Bonham-Carter, C., Fergusson, E., Jenkins, J., & Parr, M. (1997b). Attentional biases for emotional faces. *Cognition and Emotion*, **11**, 25-42.

Bradley, B.P., Mogg, K., Falla, S.J., & Hamilton, L.R. (1998). Attentional bias for threatening facial expressions in anxiety: Manipulation of stimulus duration. *Cognition and Emotion*, **12**, 737-753.

Breier, A., Albus, M., Pickar, D., Zahn, T.P., Wolkowitz, O.M., & Paul, S.M. (1987). Controllable and uncontrollable stress in humans: Alterations in mood and neuroendocrine and psychophysiological function. *American Journal of Psychiatry*, **144**, 1419-1425.

Breier, A. (1989). Experimental approaches to human stress research: Assessment of neurobiological mechanisms of stress in volunteers and psychiatric patients. *Biological Psychiatry*, **26**, 438-462.

Broadbent, D.E. (1971). *Decision and stress*. London: Academic Press.

Buchanan, T., Al'Absi, M., & Lovallo, W.R. (1999). Cortisol fluctuates with increases and decreases in negative affect. *Psychoneuroendocrinology*, **24**, 227-241.

Byrne, A. & Eysenck, M. (1995). Trait anxiety, anxious mood, and threat detection. *Cognition and Emotion*, **9**, 549-562.

Cacioppo, J.T., Malarkey, W.B., Kiecolt-Glaser, J.T., Uchio, B.N., Sgoutas-Emch, S.A., Sheridan, J.F., Berntson, G.G., & Glaser, R. (1995). Heterogeneity in neuroendocrine and immune responses to brief psychological stressors as a function of autonomic cardiac activation. *Psychosomatic Medicine*, **57**, 154-164.

Carroll, J.B., Davies, P., & Richman, B. (1971). *Word frequency book*. New York: American Heritage.

Chen, E., Lewin, M.R., & Craske, M.G. (1996). Effects of state anxiety on selective processing of threatening information. *Cognition and Emotion*, **10**, 225-240.

Clark, C.R., Geffen, G.M., & Geffen, L.B. (1989). Catecholamines and the covert orientation of attention in humans. *Neuropsychologia*, **27**, 131-139.

Clore, G.L. & Ortony, A. (2000). Cognition in emotion: Always, sometimes, or never. In R. D. Lane, L. Nadel (Eds), *Cognitive neuroscience of emotion* (pp. 24-61). New York: Oxford University Press.

Constans, J.I., Mathews, A., Brantley, P.J., & James, T. (1999). Attentional reactions to an MI: The impact of mood state, worry, and coping style. *Journal of Psychosomatic Research*, **46**, 415-423.

Coplan, J.D., Andrews, M.W., Rosenblum, L.A., Owens, M.J., Friedman, S., Gorman, J.M., & Nemeroff, C.B. (1996). Persistent elevations of cerebrospinal fluid concentrations of corticotropin-releasing factor in adult nonhuman primate exposed to early-life stressors: Implications for the pathophysiology of mood and anxiety disorders. *Proceedings of the National Academy of Sciences of the USA*, **93**, 1619-1623.

Corbetta, M., Miezin, F.M., Dobmeyer, S., Shulman, G.L., & Petersen, S.E. (1990). Attentional modulation of neural processing of shape, color, and velocity in humans. *Science*, **248**, 1556-1559.

Corbetta, M., Miezin, F.M., Dobmeyer, S., Shulman, G.L., & Petersen, S.E. (1991). Selective and divided attention during visual discriminations of shape, color, and speed: Functional anatomy by Positron Emission Tomography. *Journal of Neuroscience*, **11**, 2383-2402.

Corbetta, M., Miezin, F.M., Shulman, G.L., & Petersen, S.E. (1993). A PET study of visuospatial attention. *Journal of Neuroscience*, **13**, 1202-1226.

Croes, S., Merz, P., & Netter, P. (1993). Cortisol reaction in success and failure condition in endogenous depressed patients and controls. *Psychoneuroendocrinology*, **18**, 23-35.

Czeisler, C.A., Ede, M.C., Regenstein, Q.R., Kisch, E.S., Fang, V.S., & Ehrlich, E.N. (1976). Episodic 24-hour cortisol secretory patterns in patients awaiting elective cardiac surgery. *Journal of Clinical Endocrinology and Metabolism*, **42**, 273-283.

D'Alfonso, A., van Honk, J., Hermans, E., Postma, A., & de Haan, E. (2000). Laterality effects in selective attention to threat after rTMS at the prefrontal cortex. Submitted to *Neuroscience Letters*.

Dalgleish, T. & Watts, F.N. (1990). Biases of attention and memory in disorders of anxiety and depression. *Clinical Psychology Review*, **10**, 589-604.

Danckert, J. & Maruff, P. (1997). Manipulating the disengage operation of covert visual spatial attention. *Perception and Psychophysics*, **59**, 500-508.

Davidson, R.J. (1995). Cerebral asymmetry, emotion, and affective style. In R. J. Davidson, K. Hugdahl (Eds), *Brain asymmetry* (pp. 361-387). Cambridge,MA: MIT Press.

Davidson, R.J. (1998). Affective style and affective disorders: Perspectives from affective neuroscience. *Cognition and Emotion*, **12**, 307-330.

Davidson, R.J., Abercrombie, H., Nitschke, J.B., & Putman, K. (1999). Regional brain function, emotion and disorders of emotion. *Current Opinion in Neurobiology*, **9**, 228-234.

de Boer, S.F., de Beun, R., Slangen, J.L., & Van der Gugten, J. (1990a). Dynamics of plasma catecholamine and corticosterone concentrations during reinforced and extinguished operant behavior in rats. *Physiology and Behavior*, **47**, 691-698.

de Boer, S.F., Slangen, J.L., & Van der Gugten, J. (1990b). Plasma catecholamine and corticosterone levels during active and passive shock-prod avoidance behavior in rats: Effects of chlordiazepoxide. *Physiology and Behavior*, **47**, 1089-1098.

De Kloet, E.R. (1995). Steroids, stability and stress. *Frontiers in Neuroendocrinology*, **16**, 416-425.

De Kloet, E.R., Vreugdenhil, E., Oitzl, M.S., & Joëls, M. (1998). Brain corticosteroid receptor balance in health and disease. *Endocrine Reviews*, **19**, 269-301.

Derryberry, D. (1987). Incentive and feedback effects on target detection: A chronometric analysis of Gray's model of temperament. *Personality and Individual Differences*, **8**, 855-865.

Derryberry, D. (1988). Emotional influences on evaluative judgements: Roles of arousal, attention, and spreading activation. *Motivation and Emotion*, **12**, 23-55.

Derryberry, D. (1989). Effects of goal-related motivational states on the orienting of spatial attention. *Acta Psychologica*, **72**, 199-220.

Derryberry, D. (1991). The immediate effects of positive and negative feedback signals. *Journal of Personality and Social Psychology*, **61**, 267-278.

Derryberry, D. (1993). Attentional consequences of outcome-related motivational states: Congruent, incongruent, and focusing effects. *Motivation and Emotion*, **17**, 65-89.

Derryberry, D. & Reed, M.A. (1994). Temperament and attention: Orienting toward and away from positive and negative signals. *Journal of Personality and Social Psychology*, **66**, 1128-1139.

Derryberry, D. & Tucker, D.M. (1994). Motivating the focus of attention. In P. M. Niedenthal, S. Kitayama (Eds), *The heart's eye: Emotional influences in perception and attention* (pp. 167-196). San Diego: Academic Press.

Dess, N.K., Linwick, D., Patterson, J., Overmier, J.B., & Levine, S. (1983). Immediate and proactive effects of controllability and predictability on plasma cortisol responses to shocks in dogs. *Behavioral Neuroscience*, **97**, 1005-1016.

Devinsky, O., Morell, M.J., & Vogt, B.A. (1995). Contributions of anterior cingulate cortex to behavior. *Brain*, **118**, 279-306.

Diorio, D., Viau, V., & Meaney, M.J. (1993). The role of the medial prefrontal cortex (cingulate gyrus) in the regulation of hypothalamic-pituitary-adrenal responses to stress. *Journal of Neuroscience*, **13**, 3839-3847.

Easterbrook, J.A. (1959). The effects of emotion on cue utilization and the organization of behavior. *Psychological Review*, **66**, 183-201.

Eckhardt, C.I. & Cohen, D.J. (1997). Attention to anger-relevant and irrelevant stimuli following naturalistic insult. *Personality and Individual Differences*, **23**, 619-629.

Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion*, **6**, 169-200.

Elias, M. (1981). Serum cortisol, testosterone, and testosterone-binding globulin responses to competitive fighting in human males. *Aggressive Behavior*, **7**, 215-224.

Ellenbogen, M.A., Young, S.N., Dean, P., Palmour, R.M., & Benkelfat, C. (1996). Mood response to acute tryptophan depletion in healthy volunteers: Sex differences and temporal stability. *Neuropsychopharmacology*, **15**, 465-474.

Epel, E., McEwen, B.S., & Lupien, S.J. (2000). Cortisol reactivity to repeated stress as a function of fat distribution: Effects on cognition. *Psychoneuroendocrinology*, **25 (suppl. 1)**, S32.

Fehm-Wolfsdorf, G., Scheible, G., Zenz, H., Born, J., & Fehm, H.L. (1989). Taste thresholds in man are differentially influenced by hydrocortisone and dexamethasone. *Psychoneuroendocrinology*, **14**, 433-440.

Fehm-Wolfsdorf, G., Soherr, U., Arndt, R., Kern, W., Fehm, H.L., & Nagel, D. (1993). Auditory reflex thresholds elevated by stress-induced cortisol secretion. *Psychoneuroendocrinology*, **18**, 579-589.

Fernandez-Duque, D. & Posner, M.I. (1997). Relating the mechanisms of orienting and alerting. *Neuropsychologia*, **35**, 477-486.

Ferry, B., Roozendaal, B., & McGaugh, J.L. (1999). Role of norepinephrine in mediating stress hormone regulation of long-term memory storage: A critical involvement of the amygdala. *Biological Psychiatry*, **46**, 1140-1152.

First, M., Spitzer, R.L., Gibbon, M., & Williams, J. (1997). *Structured clinical interview for DSM-IV disorders*. New York: Biometrics Research Department.

Fiske, S.T. & Taylor, S.E. (1991). *Social Cognition*. 2nd edition. New York: McGraw-Hill.

Foa, E.B., Feske, U., Murdoch, T.B., Kozak, M.J., & McCarthy, P.R. (1991). Processing of threat-related information in rape victims. *Journal of Abnormal Psychology*, **100**, 156-162.

Foote, S.L., Bloom, F.E., & Aston-Jones, G. (1983). Nucleus locus coeruleus: New evidence of anatomical and physiological specificity. *Physiological Reviews*, **63**, 844-914.

Francis, D.D., Diorio, J., LaPlante, P., Weaver, S., Seckl, J.R., & Meaney, M.J. (1996). The role of early environmental events in regulating neuroendocrine development: Moms, pups, stress, and glucocorticoid receptors. *Annals of the New York Academy of Sciences*, **794**, 136-152.

Gainotti, G., Caltagirone, C., & Zoccolotti, P. (1993). Left/right and cortical/subcortical dichotomies in the neuropsychological study of human emotions. *Cognition and Emotion*, **7**, 71-93.

Gilbert, D.G., Stunkard, M.E., Jensen, R.A., Detwiler, F.R.J., & Martinko, J.M. (1996). Effects of exam stress on mood, cortisol, and immune functioning: Influences of neuroticism and smoker/non-smoker status. *Personality and Individual Differences*, **21**, 235-246.

Gilboa, E. & Gotlib, I.H. (1997). Cognitive biases and affect persistence in previously dysphoric and never-dysphoric individuals. *Cognition and Emotion*, **11**, 517-538.

Gladue, B.A., Boechler, M., & McCaul, K.D. (1989). Hormonal response to competition in human males. *Aggressive Behavior*, **15**, 409-422.

Gold, P.W., Goodwin, F.K., & Churosos, G.P. (1988a). Clinical and biochemical manifestations of depression: Relation to the neurobiology of stress (part 2). *New England Journal of Medicine*, **319**, 413-420.

Gold, P.W., Goodwin, F.K., & Churosos, G.P. (1988b). Clinical and biochemical manifestations of depression: Relation to the neurobiology of stress (part 1). *New England Journal of Medicine*, **319**, 348-353.

Gotlib, I.H. & McCann, C.D. (1984). Construct accessibility and depression: An examination of cognitive and affective factors. *Journal of Personality and Social Psychology*, **47**, 427-429.

Gotlib, I.H., McClachlan, A.L., & Katz, A,N. (1988a). Biases in visual attention in depressed and non-depressed individuals. *Cognition and Emotion*, **2**, 185-200.

Gotlib, I.H., McLachlan, A.L., & Katz, A.N. (1988b). Biases in visual attention in depressed and nondepressed individuals. *Cognition and Emotion*, **2**, 185-200.

Gotthardt, U., Schweiger, U., Fahrenberg, J., Lauer, C.J., Holsboer, F., & Heuser, I. (1995). Cortisol, ACTH and cardiovascular response to a cognitive challenge paradigm in aging and depression. *American Journal of Physiology*, **268**, R865-R873.

Graham, S. & Hudley, C. (1994). Attributions of aggressive and non-aggressive African-American male early adolescents: A study of construct accessibility. *Developmental Psychology*, **30**, 365-373.

Granger, D.A., Weisz, J.R., & Kauneckis, D. (1994). Neuroendocrine reactivity, internalizing behavior problems, and control-related cognitions in clinic-referred children and adolescents. *Journal of Abnormal Psychology*, **103**, 267-276.

Grigoroiu-Serbanescu, M., Christodorescu, D., Magureanu, S., Jipescu, I., Totoescu, A., Marinescu, E., Ardelean, V., & Popa, S. (1991). Adolescent offspring of endogenous unipolar depressive parents and of normal parents. *Journal of Affective Disorders*, **21**, 185-198.

Gunnar, M. (1994). Psychoneuroendocrine studies of temperament and stress in early childhood: Expanding current models. In J. E. Bates, T. D. Wachs (Eds), *Temperament: Individual differences at the interface of biology and behavior* (pp. 175-198). Washington,DC: American Psychological Association.

Gunnar, M., Porter, F.L., Wolf, C.M., Rigatuso, J., & Larson, M.C. (1995). Neonatal stress reactivity: Predictions to later emotional temperament. *Child Development*, **66**, 1-13.

Hansen, C.H. & Hansen, R.D. (1994). Automatic emotion: Attention and facial efference. In P. M. Niedenthal, S. Kitayama (Eds), *The heart's eye: Emotional influences in perception and attention* (pp. 217-243). San Diego: Academic Press.

Hanson, J.D., Larson, M.E., & Snowdon, C.T. (1976). The effects of control over high intensity noise on plasma cortisol levels in rhesus monkeys. *Behavioral Biology*, **16**, 333-340.

Hart, J., Gunnar, M., & Cicchetti, D. (1995). Salivary cortisol in maltreated children: Evidence of relations between neuroendocrine activity and social competence. *Development and Psychopathology*, **7**, 11-26.

Hedlund, S. & Rude, S. (1995). Evidence of latent depressive schemas in formerly depressed individuals. *Journal of Abnormal Psychology*, **104**, 517-525.

Heilman, K.M. (1995). Attentional asymmetries. In R. J. Davidson, K. Hugdahl (Eds), *Brain asymmetry* (pp. 217-234). Cambridge,MA: MIT Press.

Heinze, H.-J., Luck, S.J., Münte, T.F., Gös, A., Mangun, G.R., & Hillyard, S.A. (1994). Attention to adjacent and separate positions in space: An electrophysiological analysis. *Perception and Psychophysics*, **56**, 42-52.

Heller W, Nitschke JB, Etienne MA & Miller GA (1997). Patterns of regional brain activity differentiates types of anxiety. *Journal of Abnormal Psychology,* **106**, 376-385.

Henderson, J.M. (1996). Stimulus discrimination following covert attentional orienting to an exogenous cue. *Journal of Experimental Psychology: Human Perception and Performance*, **17**, 91-106.

Henkin, R.I. (1975). The role of adrenal corticosteroids in sensory processes. In R. O. Greep, E. B. Astwood (Eds), *Handbook of Physiology, Vol. VI* (pp. 209-230). Washington: American Physiological Society.

Henry, J.P. (1992). Biological basis of the stress response. *Integrative Physiological and Behavioral Science*, **27**, 66-83.

Hillyard, S.A., Luck, S.J., Mouloua, M., Downing, C.J., & Woodward, D.P. (1990). Visual attention modulates signal detectability. *Journal of Experimental Psychology: Human Perception and Performance*, **16**, 802-811.

Hillyard, S.A., Vogel, E.K., & Luck, S.J. (1999). Sensory gain control (amplification) as a mechanism of selective attention: Electrophysiological and neuroimaging evidence. In G. W. Humphreys, J. Duncan, A. Treisman (Eds), *Attention, space and action: Studies in cognitive neuroscience* (pp. 31-53). New York: Oxford University Press.

Hirschfeld, R.M.A., Klerman, G.R., Lavori, P.W., Keller, M.B., Griffith, P., & Coryell, W. (1989). Premorbid personality assessments of first onset major depression. *Archives of General Psychiatry*, **46**, 345-350.

Holsboer, F. (1992). The hypothalamic-pituitary-adrenocortical system. In E. S. Paykel (Ed), *Handbook of affective disorders* (pp. 267-287). Edinburgh: Churchill Livingstone.

Holsboer, F. (1995). Neuroendocrinology of mood disorders. In F. E. Bloom, D. J. Kupfer (Eds), *Psychopharmacology: The fourth generation of progress* (pp. 957-969). New York: Raven Press.

Holsboer, F., Lauer, C.J., Schreiber, W., & Krieg, J.C. (1995). Altered hypothalamic-pituitary-adrenocortical regulation in healthy subjects at high familial risk for affective disorders. *Neuroendocrinology*, **62**, 340-347.

Huwe, S., Hennig, J., & Netter, P. (1998). Biological, emotional, behavioral, and coping reactions to examination stress in high and low state anxious subjects. *Anxiety, Stress, and Coping*, **11**, 47-65.

Ilsley, J.E., Moffoot, A.P.R., & O'Carroll, R.E. (1995). An analysis of memory dysfunction in major depression. *Journal of Affective Disorders*, **35**, 1-9.

Ingram, R.E., Bernet, C.Z., & McLaughlin, S.C. (1994). Attentional allocation processes in individuals at risk for depression. *Cognitive Therapy and Research*, **18**, 317-332.

Ishihara, S. (1964). *Test for color blindness*. Tokyo,Japan: Kanehara Shippan Company Ltd.

Izard, C.E. (1993). Four systems for emotion activation: Cognitive and Noncognitive processes. *Psychological Review*, **100**, 68-90.

Jacobson, L. & Sapolsky, R.M. (1991). The role of the hippocampus in feedback regulation of the hypothalamic-pituitary-adrenocortical axis. *Endocrine Reviews*, **12**, 118-134.

Johansson, G., Collins, A., & Collins, V.P. (1983). Male and female psychoneuroendocrine response to examination stress: A case report. *Motivation and Emotion*, **7**, 1-10.

Johnson, D.N., Weingartner, H.J., Andreason, P., & George, D.T. (1995). An effect of triazolam on visual attention and information processing. *Psychopharmacology*, **121**, 145-149.

Johnson, D.N. & Yantis, S. (1995). Allocating visual attention: Tests of a two-process model. *Journal of Experimental Psychology: Human Perception and Performance*, **21**, 1376-1390.

Johnston, W.A., Hawley, K.J., Plewe, S.H., Elliot, J.M.G., & DeWitt, M.J. (1990). Attention capture by novel stimuli. *Journal of Experimental Psychology: General*, **119**, 397-411.

Jonides, J. & Mack, R. (1984). On the cost and benefit of cost and benefit. *Psychological Bulletin*, **96**, 29-44.

Jonides, J. & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception and Psychophysics*, **43**, 346-354.

Jonz, J. (1990). Another turn in the conversation: What does cloze measure? *TESOL Quarterly*, **24**, 61-83.

Kagan, J., Reznick, J.S., & Snidman, N. (1988). Biological bases of childhood shyness. *Science*, **240**, 167-171.

Kalin, N.H., Larson, C., Shelton, S., & Davidson, R.J. (1998). Asymmetric frontal brain activity, cortisol, and behavior associated with fearful temperament in rhesus monkeys. *Behavioral Neuroscience*, **112**, 286-292.

Kehlet, H. & Binder, C. (1973). Alterations in distribution volume and biological half-life of cortisol during major surgery. *Journal of Clinical Endocrinology and Metabolism*, **36**, 330-333.

Kendler, K.S., Kessler, R.C., Heath, A.C., Neale, M.C., & Eaves, L.J. (1991). Coping: A genetic epidemiological investigation. *Psychological Medicine*, **21**, 337-346.

Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. *Acta Psychologica*, **33**, 193-201.

Kirschbaum, C. & Hellhammer, D.H. (1989). Salivary cortisol in psychobiological research. An overview. *Neuropsychobiology*, **22**, 150-169.

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

Kirschbaum, C., Prüssner, J.C., Stone, A.A., Federenko, I., Gaab, J., Lintz, D., Schommer, N., & Hellhammer, D.H. (1995). Persistent high cortisol responses to repeated psychological stress in a subpopulation of healthy men. *Psychosomatic Medicine*, **57**, 468-474.

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

Klaassen, T., Riedel, W.J., van Someren, A., Deutz, N.E.P., Honig, A., & van Praag, H.M. (1999). Mood effects of 24-hour tryptophan depletion in healthy first-degree relatives of patients with affective disorders. *Biological Psychiatry*, **46**, 489-497.

Klein, R. & Hansen, E. (1990). Chronometric analysis of apparent spotlight failure in endogenous visual orienting. *Journal of Experimental Psychology: Human Perception and Performance*, **16**, 790-801.

Kolb, B. & Taylor, L. (2000). Facial expression, emotion, and hemispheric organization. In R. D. Lane, L. Nadel (Eds), *Cognitive neuroscience of emotion* (pp. 62-83). New York: Oxford University Press.

Koolhaas, J.M., Meerlo, P., de Boer, S.F., Strubbe, J.H., & Bohus, B. (1997). The temporal dynamics of the stress response. *Neuroscience and Biobehavioral Reviews*, **21**, 775-782.

Kopell, B.S., Wittner, W.K., Lunde, D., Warrick, G., & Edwards, D. (1970). Cortisol effects on averaged evoked potential, alpha-rhythm, time estimation, and two-flash fusion threshold. *Psychosomatic Medicine*, **32**, 39-49.

Kral, V.A., Grad, B.,, & Berenson, J. (1968). Stress reactions resulting from the relocation of an aged population. *Canadian Psychiatric Association Journal*, **13**, 201-209.

Krey, L.C., Lu, K.H., Butler, W.R., Hotchkiss, J., Piva, F., & Knobil, E. (1975). Surgical disconnection of the medial basal hypothalamus and pituitary function in the rhesus monkey. *Endocrinology*, **96**, 1088-1093.

Krieg, J., Lauer, C.J., Hermle, L., von Bardeleben, U., Pollmächer, T., & Holsboer, F. (1990). Psychometric, polysomnographic, and neuroendocrine measures in subjects at high risk for psychiatric disorders: Preliminary results. *Neuropsychobiology*, **23**, 57-67.

LaBerge, D. & Buchsbaum, M.S. (1990). Positron emission tomographic measurements of pulvinar activity during an attention task. *Journal of Neuroscience*, **10**, 613-619.

LaBerge, D. (1995a). Computational and anatomical models of selective attention in object identification. In M. S. Gazzaniga (Ed), *The Cognitive Neurosciences* (pp. 649-664). Cambridge,MA: MIT Press.

LaBerge, D. (1995b). *Attentional processing: The brain's art of mindfullness.* Cambridge,MA: Harvard U Press.

Lambert, A.J., Beard, C.T., & Thompson, R.J. (1988). Selective attention, visual laterality, awareness, and perceiving the meaning of parafoveally presented words. *Quarterly Journal of Experimental Psychology*, **40A**, 615-652.

Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (1990). Emotion, attention, and the startle reflex. *Psychological Review*, **97**, 377-395.

Lang, P.J., Greenwald, M.K., Bradley, M.M., & Hamm, A.O. (1993). Looking at pictures: Affective, facial, and visceral, and behavioral reactions. *Psychophysiology*, **30**, 261-273.

Lang, P.J. (1995). The emotion probe: Studies of motivation and attention. *American Psychologist*, **50**, 372-385.

Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (1997). *International affective picture system (IAPS): Technical manual and affective ratings.* Gainsville,FL: Centre for the Study of Emotion and Attention.

Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (1998). Emotion, motivation, and anxiety: Brain mechanisms and psychophysiology. *Biological Psychiatry*, **44**, 1248-1263.

Laudat, M.H., Cerdas, S., Fournier, C., Guiban, D., Guilhaume, B., & Luton, J.P (1988). Salivary cortisol measurement: A practical approach to assess pituitary-adrenal function. *Journal of Clinical Endocrinology and Metabolism*, **66**, 343-348.

Lauer, C.J., Bronisch, T., Kainz, M., Schreiber, W., Holsboer, F., & Krieg, J.C. (1997). Pre-morbid psychometric profiles of subjects at high familial risk for affective disorder. *Psychological Medicine*, **27**, 355-362.

Lovallo, W.R., Pincomb, G.A., Brackett, D.J., & Wilson, M.F. (1990). Heart rate reactivity as a predictor of neuroendocrine responses to aversive and appetitive challenges. *Psychosomatic Medicine*, **52**, 17-26.

Lavy, E., van den Hout, M., & Arntz, A. (1993). Attentional bias and spider phobia: Conceptual and clinical issues. *Behaviour Research and Therapy*, **31**, 17-24.

Lazarus, R.S. (1993). From psychological stress to the emotions: A history of changing outlooks. *Annual Review of Psychology*, **44**, 1-21.

Ledoux, J.E. (2000). Cognitive-emotional interactions: Listen to the brain. In R. D. Lane, L. Nadel (Eds), *Cognitive neuroscience of emotion* (pp. 129-155). New York: Oxford University Press.

Ley, R. & Bryden, P. (1979). Hemispheric differences in processing emotions and faces. *Brain and Language*, **7**, 126-130.

Lorr, M., McNair, D.M., & Fisher, S. (1982). Evidence for bipolar mood states. *Journal of Personality Assessment*, **46**, 432-436.

Luck, S.J., Hillyard, S.A., Mouloua, M., Woldorff, M.G., Clark, V.P., & Hawkins, H.L. (1994). Effects of spatial cueing on luminance detectability: Psychophysical and electrophysiological evidence for early selection. *Journal of Experimental Psychology: Human Perception and Performance*, **20**, 887-904.

Luck, S.J. (1995). Multiple mechanisms of visual-spatial attention: Recent evidence from human electrophysiology. *Behavioural Brain Research*, **71**, 113-123.

Lundberg, U. & Frankenhaeuser, M. (1980). Pituitary-adrenal and sympathetic-adrenal correlates of distress and effort. *Journal of Psychosomatic Research*, **24**, 125-130.

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. *Journal of Neuroscience*, **14**, 2893-2903.

Lupien, S.J. & McEwen, B.S. (1997). The acute effects of corticosteroids on cognition: Integration of animal and human model studies. *Brain Research Reviews*, **24**, 1-27.

Lupien, S.J. & Meaney, M.J. (2000). Cognitive dysfunction in the elderly and the HPA axis. *Psychoneuroendocrinology*, **25 (Suppl. 1)**, S19.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, **95**, 15-20.

MacLeod, C. & Mathews, A. (1988). Anxiety and the allocation of attention to threat. *Quarterly Journal of Experimental Psychology*, **40A**, 653-670.

MacLeod, C. & Mathews, A. (1991). Biased cognitive operations in anxiety: Accessibility of information or assignment of processing priorities? *Behaviour Research and Therapy*, **29**, 599-610.

MacLeod, C. & Rutherford, E.M. (1992). Anxiety and the selective processing of emotional information: Mediating roles of awareness, trait and state variables, and personal relevance of stimulus materials. *Behaviour Research and Therapy*, **30**, 479-491.

Maier, W., Lichtermann, D., Minges, J., & Heun, R. (1992). Personality traits in subjects at risk for unipolar major depression: A family study perspective. *Journal of Affective Disorders*, **24**, 153-164.

Malarkey, W.B., Pearl, D.K., Demers, L.M., Kiecolt-Glaser, J.T., & Glaser, R. (1995). Influence of academic stress and season on 24-hour mean concentrations of ACTH, cortisol, and ß-endorphin. *Psychoneuroendocrinology*, **20**, 499-508.

Marrocco, R.T. & Davidson, M.C. (1998). Neurochemistry of attention. In R. Parasuraman (Ed), *The attentive brain* (pp. 35-50). Cambridge,MA: MIT Press.

Mathews, A., May, J., Mogg, K., & Eysenck, M. (1990). Attentional bias in anxiety: Selective search of defective filtering? *Journal of Abnormal Psychology*, **99**, 166-173.

Mathews, A. & Klug, F. (1993). Emotionality and interference with color-naming in anxiety. *Behaviour Research and Therapy*, **31**, 57-62.

Mathews, A. & Sebastien, S. (1993). Suppression of emotional Stroop effects by fear arousal. *Cognition and Emotion*, **7**, 517-530.

Mathews, A. & MacLeod, C. (1994). Cognitive approaches to emotion and emotional disorders. *Annual Review of Psychology*, **45**, 25-50.

Mathews, A., Ridgeway, V., & Williamson, D.A. (1996). Evidence for attention to threatening stimuli in depression. *Behaviour Research and Therapy*, **34**, 695-705.

Matthews, G., Jones, D.M., & Chamberlain, A.G. (1989). Interactive effects of extraversion and arousal on attentional task performance: Multiple resources or encoding processes? *Journal of Personality and Social Psychology*, **56**, 629-639.

Matthews, G., Davies, D.R., & Less, J.L. (1990). Arousal, extraversion, and individual differences in resource availability. *Journal of Personality and Social Psychology*, **59**, 150-168.

Mazur, A., Susman, E.J., & Edelbrock, S. (1997). Sex differences in testosterone response to a video game contest. *Evolution and Human Behavior*, **18**, 317-326.

McCabe, S.B. & Gotlib, I.H. (1993). Attentional processing in clinically depressed subjects: A longitudinal investigation. *Cognitive Therapy and Research*, **17**, 359-377.

McCabe, S.B. & Gotlib, I.H. (1995). Selective attention and clinical depression: Performance on a deployment-of-attention task. *Journal of Abnormal Psychology*, **104**, 241-245.

McCann, R., Folk, C.L., & Johnston, J.C. (1992). The role of spatial attention in visual word processing. *Journal of Experimental Psychology: Human Perception and Performance*, **18**, 1015-1029.

McCaul, K.D., Gladue, B.A., & Joppa, M. (1992). Winning, losing, and mood and testosterone. *Hormones and Behavior*, **26**, 486-504.

McCormick, P.A. (1997). Orienting attention without awareness. *Journal of Experimental Psychology: Human Perception and Performance*, **23**, 168-180.

McEwen, B.S. & Stellar, E. (1993). Stress and the individual: Mechanisms leading to disease. *Archives of Internal Medicine*, **153**, 2093-2101.

McEwen, B.S. (1999). Stress and hippocampal plasticity. *Annual Review of Neuroscience*, **22**, 105-122.

McNair, D.M., Lorr, M., & Droppleman, L.F. (1988). *Manual for the Profile of Mood States*. San Diego: Educational and Industrial Testing Service.

McNally, R.J., Riemann, B.C., Louro, C.E., Lukach, B.M., & Kim, E. (1992). Cognitive processing of emotional information in panic disorder. *Behaviour Research and Therapy*, **30**, 143-149.

Mesulam, M.-M. (1998). From sensation to cognition. *Brain*, **121**, 1013-1052.

Mogg, K., Mathews, A., Bird, C., & Macgregor-Morris, R. (1990). Effects of stress and anxiety on the processing of threat stimuli. *Journal of Personality and Social Psychology*, **59**, 1230-1237.

Mogg, K., Mathews, A., & Eysenck, M. (1992). Attentional bias to threat in clinical anxiety. *Cognition and Emotion*, **6**, 149-159.

Mogg, K., Bradley, B.P., Williams, R., & Mathews, A. (1993a). Subliminal processing of emotional information in anxiety and depression. *Journal of Abnormal Psychology*, **102**, 304-311.

Mogg, K., Kentish, J., & Bradley, B.P. (1993b). Effects of anxiety and awareness on colour-identification latencies for emotional words. *Behaviour Research and Therapy*, **31**, 559-567.

Mogg, K., Bradley, B.P., & Hallowell, N. (1994). Attentional bias to threat: Roles of trait anxiety, stressful events, and awareness. *Quarterly Journal of Experimental Psychology*, **47A**, 841-864.

Mogg, K., Bradley, B.P., & Williams, R. (1995). Attentional bias in anxiety and depression: The role of awareness. *British Journal of Clinical Psychology*, **34**, 17-36.

Mogg, K. & Bradley, B.P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy*, **36**, 809-848.

Mogg, K., Bradley, B.P., Hyare, H., & Lee, S. (1998). Selective attention to food-related stimuli in hunger: Are attentional biases specific to emotional and psychopathological states, or are they also found in normal drive states? *Behaviour Research and Therapy*, **36**, 227-237.

Mogg, K. & Bradley, B.P. (1999). Some methodological issues in assessing attentional biases for threatening faces in anxiety: A replication study using a modified version of the probe detection task. *Behaviour Research and Therapy*, **37**, 595-604.

Moss, H.B., Vanyukov, M.M., & Martin, C.S. (1995). Salivary cortisol responses and the risk for substance abuse in prepubertal boys. *Biological Psychiatry*, **38**, 547-555.

Munck, A., Guyre, P.M., & Holbrook, N.J. (1984). Physiological functions of glucocorticoids in stress and their relation to pharmacological actions. *Endocrine Reviews*, **5**, 24-44.

Murphy, F.C., Sahakian, B.J., Rubinsztein, J.S., Michael, A., Rogers, R.D., Robbins, T.W., & Paykel, E.S. (1999). Emotional bias and inhibitory control processes in mania and depression. *Psychological Medicine*, **29**, 1307-1321.

Mölle, M., Albrecht, C., Marshall, L., Fehm, H.L., & Born, J. (1997). Adrenocorticotropin widens the focus of attention in humans. A nonlinear electroencephalographic analysis. *Psychosomatic Medicine*, **59**, 497-502.

Nachmias, M., Gunnar, M., Mangelsdorf, S., Parritz, R.H., & Buss, K. (1996). Behavioral inhibition and stress reactivity: The moderating role of attachment security. *Child Development*, **67**, 508-522.

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

Nicolson, N.A. (1992). Stress, coping and cortisol dynamics in daily life. In M. W. deVries (Ed), *The experience of psychopathology: Investigating mental disorders in their natural settings* (pp. 219-232). Cambridge,UK: Cambridge University Press.

Nitschke, J.B., Heller, W., Palmieri, P.A., & Miller, G.A. (1999). Contrasting patterns of brain activity in anxious apprehension and anxious arousal. *Psychophysiology*, **36**, 628-637.

Nolen-Hoeksema, S. (1987). Sex differences in unipolar depression: Evidence and theory. *Psychological Bulletin*, **101**, 259-282.

Öhman, A., Flykt, A., & Lundqvist, D. (2000). Unconscious emotion: Evolutionary perspectives, psychophysiological data, and neuropsychological mechanisms. In R. D. Lane, L. Nadel (Eds), *Cognitive neuroscience of emotion* (pp. 296-327). New York: Oxford University Press.

Parasuraman, R., Warm, J.S., & See, J.E. (1998). Brain systems of vigilance. In R. Parasuraman (Ed), *The attentive brain* (pp. 221-256). Cambridge: MIT Press.

Pardo, J.V., Pardo, P.J., Janer, K.W., & Raichle, M.E. (1990). The anterior cingulate cortex mediates processing selection in the Stroop attentional conflict paradigm. *Proceedings of the National Academy of Sciences of the USA*, **87**, 256-259.

Parrott, W.G. & Sabini, J. (1990). Mood and memory under natural conditions: Evidence for mood-incongruent recall. *Journal of Personality and Social Psychology*, **59**, 321-336.

Petersen, S.E., Corbetta, M., Miezin, F., & Raichle, M.E. (1993). The effects of selective attention on visual processing measured with performance and positron emission tomography. In T. Ono, L. Squire, M. Raichle, D. Perrett, M. Fuicuda (Eds), *Brain mechanisms of perception and memory* (pp. 413-425). New York: Oxford Press.

Plihal, W., Pietrowsky, R., & Born, J. (1999). Dexamethasone blocks sleep induced improvement of declarative memory. *Psychoneuroendocrinology*, **24**, 313-331.

Posner, M.I. (1978). *Chronometric explorations of mind.* Hillsdale,NJ: Erlbaum.

Posner, M.I., Nissen, M.J., & Ogden, W.C. (1978). Attended and unattended processing modes: The role of set for spatial location. In H. L. Jr. Pick, E. Saltzman (Eds), *Modes of perceiving and processing information* (pp. 137-157). Hillsdale, NJ: Erlbaum.

Posner, M.I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, **32**, 3-25.

Posner, M.I., Snyder, C.R.R., & Davidson, B.J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General*, **109**, 160-174.

Posner, M.I., Walker, J.A., Friedrich, F.J., & Rafal, R.D. (1984). Effects of parietal lobe injury on covert orienting of visual attention. *Journal of Neuroscience*, **4**, 1863-1874.

Posner, M.I., Inhoff, A.W., & Friedrich, F.J. (1987). Isolating attentional systems: A cognitive-anatomical analysis. *Psychobiology*, **15**, 107-121.

Posner, M.I. & Presti, D.E. (1987). Selective attention and cognitive control. *Trends in Neuroscience*, **10**, 13-17.

Posner, M.I. (1988). Structures and functions of selective attention. In T. Boll, B. K. Bryant (Eds), *Clinical Neuropsychology and Brain Function: The Master lecture Series, vol. 7* (pp. 173-202). Washington,DC: American Psychological Association.

Posner, M.I. & Petersen, S.E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, **13**, 25-42.

Posner, M.I. (1993). Interaction of arousal and selection in the posterior attention network. In A. Baddeley, L. Weiskrantz (Eds), *Attention: Selection, awareness, and control. A tribute to Donald Broadbent* (pp. 390-405). Oxford: Clarendon Press.

Posner, M.I. & Dehaene, S. (1994). Attentional networks. *Trends in Neuroscience*, **17**, 75-79.

Post, R.M. (1992). Transduction of psychosocial stress into the neurobiology of recurrent affective disorder. *American Journal of Psychiatry*, **149**, 999-1010.

Pratto, F. (1994). Consciousness and automatic evaluation. In P. M. Niedenthal, S. Kitayama (Eds), *The Heart's Eye: Emotional Influences in Perception and Attention* (pp. 115-143). San Diego: Academic Press.

Purcell, R., Maruff, P., Kyrios, M., & Pantelis, C. (1997). Neuropsychological function in young patients with unipolar major depression. *Psychological Medicine*, **27**, 1277-1285.

Rajkowski, J., Kubiak, P., & Aston-Jones, G. (1994). Locus Coeruleus activity in monkey: Phasic and tonic changes are associated with altered vigilance. *Brain Research Bulletin*, **35**, 607-616.

Redmond, D.E.Jr. (1987). Studies of the nucleus locus-coereleus in monkeys and hypotheses for neuropsychopharmacology. In H. Y. Meltzer (Ed), *Psychopharmacology: The third generation of progress* (pp. 867-875). New York: Raven Press.

Reed, M.A. & Derryberry, D. (1995). Temperament and attention to positive and negative trait information. *Personality and Individual Differences*, **18**, 135-147.

Renaud, P. & Blondin, J.-P. (1997). The stress of Stroop performance: Physiological and emotional responses to color-word interference, task pacing, and pacing speed. *International Journal of Psychophysiology*, **27**, 87-97.

Reuter-Lorenz, P.A., Kinsbourne, M., & Moscovitch, M. (1990). Hemispheric control of spatial attention. *Brain and Cognition*, **12**, 240-266.

Revelle, W. (1993). Individual differences in personality and motivation: "non-cognitive" determinants of cognitive performance. In A. Baddeley, L. Weiskrantz (Eds), *Attention: Selection, awareness, and control. A tribute to Donald Broadbent* (pp. 346-373). Oxford: Clarendon Press.

Richards, A., French, C.C., Johnson, W., Naparstek, J., & Williams, J. (1992). Effects of mood manipulation and anxiety on performance of an emotional Stroop task. *British Journal of Psychology*, **83**, 479-491.

Rinck, M., Glowalla, U., & Schneider, K. (1992). Mood-congruent and mood-incongruent learning. *Memory and Cognition*, **20**, 29-39.

Robbins, T.W. (1997). Arousal systems and attentional processes. *Biological Psychology*, **45**, 57-71.

Robertson, I.H. & Manly, T. (1999). Sustained attention deficits in time and space. In G. W. Humphreys, J. Duncan, A. Treisman (Eds), *Attention, space and action: Studies in cognitive neuroscience* (pp. 297-310). Oxford: Oxford University Press.

Robinson, D.L. & Petersen, S.E. (1992). The pulvinar and visual saliency. *Trends in Neuroscience*, **15**, 127-132.

Rohde, P., Lewinsohn, P.M., Tilson, M., & Seely, J.R. (1990). Dimensionality of coping and its relation to depression. *Journal of Personality and Social Psychology*, **58**, 499-511.

Ross, E.D. (1984). Right hemisphere's role in language, affective behavior and emotion. *Trends in Neuroscience*, **7**, 343-346.

Rothbart, M.K., Posner, M.I., & Rosicky, J. (1994). Orienting in normal and pathological development. *Development and Psychopathology*, **6**, 635-652.

Rothbart, M.K., Posner, M.I., & Hershey, K.L. (1995). Temperament, attention, and developmental psychopathology. In D. Cicchetti, D. J. Cohen (Eds), *Developmental psychopathology: Vol. 1. Theory and method* (pp. 315-340). New York: Wiley.

Rugg, M.D., Milner, A.D., Lines, C.R., & Phalp, R. (1987). Modulation of visual event-related potentials by spatial and non-spatial visual selective attention. *Neuropsychologia*, **15**, 85-96.

Sapolsky, R.M. (1990). Adrenocortical function, social rank, and personality among wild baboons. *Biological Psychiatry*, **28**, 862-878.

Sapolsky, R.M. (1992). *Stress, the aging brain, and the mechanisms of neuron death*. Cambridge,MA: MIT Press.

Schmidt, L.A., Fox, N.A., Goldberg, M.C., Smith, C.C., & Schulkin, J. (1999). Effects of acute prednisone administration on memory, attention and emotion in healthy human adults. *Psychoneuroendocrinology*, **24**, 461-483.

Schwartzman, A.E. & Austin, E.T. (1998). Aggression et retrait social durant l'enfance, stress et efficacité dans la façon de faire face comme jeune adulte. In G. M. Tarabulsy, R. Tessier (Eds), *Dimension du tempérament de l'enfant* (pp. 24-53). St-Foy,PQ: Presse de L'Université du Québec.

Sedikides, C. (1994). Incongruent effects of sad mood on self-conception valence: It's a matter of time. *European Journal of Social Psychology*, **24**, 161-172.

Seeman, T.E. & McEwen, B.S. (1996). Impact of social environment characteristics on neuroendocrine regulation. *Psychosomatic Medicine*, **58**, 459-471.

Sergent, J. (1995). Hemispheric contributions to face processing: Patterns of convergence and divergence. In R. J. Davidson, K. Hugdahl (Eds), *Brain asymmetry* (pp. 157-181). Cambridge, MA: MIT Press.

Sheppard, M. & Müller, H.J. (1989). Movement versus focusing of visual attention. *Perception and Psychophysics*, **46**, 146-154.

Skosnik, P.D., Chatterton Jr., R.T., Swisher, T., & Park, S. (2000). Modulation of attentional inhibition by norepinephrine and cortisol after psychological stress. *International Journal of Psychophysiology*, **36**, 59-68.

Smith, A. & Nutt, D. (1996). Noradrenaline and attention lapses. *Nature*, **380**, 291.

Smith, S.M. & Petty, R.E. (1995). Personality moderators of mood congruency effects on cognition: The role of self-esteem and negative mood regulation. *Journal of Personality and Social Psychology*, **68**, 1092-1107.

Smyth, J., Ockenfels, M.C., Porter, L., Kirschbaum, C., Hellhammer, D.H., & Stone, A.A. (1998). Stressors and mood measured on a momentary basis are associated with salivary cortisol secretion. *Psychoneuroendocrinology*, **23**, 353-370.

Spielberger, C., Gorsuch, R., Lushene, R., Vagg, P.R., & Jacobs, G.A. (1983). *Manual for the stait-trait anxiety inventory*. Palo Alto, CA: Consulting Psychologists Press.

Spitzer, H., Desimone, R., & Moran, J. (1988). Increased attention enhances both behavioral and neuronal performance. *Science*, **240**, 338-340.

Stahl, F. & Dorner, G. (1982). Response of salivary cortisol levels to stress-situations. *Endokrinologie*, **80**, 158-162.

Steinmetz, M.A. (1998). Contributions of posterior parietal cortex to cognitive functions in primates. *Psychobiology*, **26**, 109-118.

Steptoe, A. (1991). The links between stress and illness. *Journal of Psychosomatic Research*, **35**, 633-644.

Stewart, S.H., Conrod, P.J., Gignac, M.L., & Pihl, R.O. (1998). Selective processing biases in anxiety-sensitive men and women. *Cognition and Emotion*, **12**, 105-133.

Stokes, P.E. & Sikes, C.R. (1987). Hypothalamic-pituitary-adrenal axis in affective disorders. In H. Y. Meltzer (Ed), *Psychopharmacology: The third generation of progress* (pp. 589-607). New York: Raven Press.

Stormark, K.M., Nordby, H., & Hugdahl, K. (1995). Attentional shifts to emotionally charged cues: Behavioural and ERP data. *Cognition and Emotion*, **9**, 507-523.

Stormark, K.M., Field, N.P., Hugdahl, K., & Horowitz, M. (1997). Selective processing of visual alcohol cues in abstinent alcoholics: An approach-avoidance conflict? *Addictive Behaviours*, **22**, 509-519.

Stroop, J.R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, **18**, 643-662.

Suay, F., Salvador, A., González-Bono, E., Sanchís, C., Martínez, M., Martínez-Sanchís, S., Simón, V.M., & Montoro, J.B. (1999). Effects of competition and its outcome on serum testosterone, cortisol and prolactin. *Psychoneuroendocrinology*, **24**, 551-566.

Svensson, T., Bunney, B., & Aghajanian, G.K. (1975). Inhibition of both noradrenergic and serotonergic neurons in brain by alpha-adrenergic agonist clonidine. *Brain Research*, **92**, 291-306.

Tallarida, R.J. & Murray, R.B. (1981). *Manual of Pharmacologic Calculations*. New York: Springer-Verlag.

Thoits, P.A. (1983). Dimensions of life events that influence psychological distress: An evaluation and synthesis of the literature. In H. B. Kaplan (Ed), *Psychosocial stress: Trends in theory and research* (pp. 33-103). New York: Academic Press.

Tomarken, A.J. & Davidson, R.J. (1994). Frontal brain activation in repressors and non-repressors. *Journal of Abnormal Psychology*, **103**, 339-349.

Tomarken, A.J. & Keener, A.D. (1998). Frontal brain asymmetry and depression: A self-regulatory perspective. *Cognition and Emotion*, **12**, 387-420.

Trestman, R.L., Coccaro, E.F., Bernstein, D., Lawrence, T., Gabriel, S.M., Horvath, T.B., & Siever, L.J. (1991). Cortisol responses to mental arithmetic in acute and remitted depression. *Biological Psychiatry*, **29**, 1051-1054.

Tucker, D.M. & Williamson, P.A. (1984). Asymmetric neural control systems in human self-regulation. *Psychological Review*, **91**, 185-215.

Ursin, H., Baade, E., & Levine, S. (1978). *Psychobiology of stress: A study of coping men*. New York: Academic Press.

van Eck, M.M. & Nicolson, N.A. (1994). Perceived stress and salivary cortisol in daily life. *Annals of Behavioral Medicine*, **16**, 221-227.

van Eck, M.M., Nicolson, N.A., Berkhof, H., & Sulon, J. (1996). Individual differences in cortisol responses to a laboratory speech task and their relationship to responses to stressful daily events. *Biological Psychology*, **43**, 69-84.

van Honk, J., Tuiten, A., van den Hout, M., Koppeschaar, H., Thijssen, J., de Haan, E., & Verbaten, R. (1998). Baseline salivary cortisol levels and preconscious selective attention for threat: A pilot study. *Psychoneuroendocrinology*, **23**, 741-747.

van Honk, J., Tuiten, A., van den Hout, M., Koppeschaar, H., Thijssen, J., de Haan, E., & Verbaten, R. (2000). Conscious and preconscious selective attention to social threat: Different neuroendocrine response patterns. Submitted to *Psychoneuroendocrinology.*

Virkkunen, M. (1985). Urinary free cortisol secretion in habitually violent offenders. *Acta Psychiatrica Scandinavica*, **72**, 40-44.

von Grünau, M. & Iordanova, M. (1997). Visual selection: Facilitation due to stimulus saliency. *Proceedings of the II Workshop on Cybernetic Vision,* São Carlos, Brazil, pp. 15-20.

Wheeler, R.E., Davidson, R.J., & Tomarken, A.J. (1993). Frontal brain asymmetry and emotional reactivity: A biological substrate of affective style. *Psychophysiology*, **30**, 82-89.

Whitehead, R. (1991). Right hemisphere processing superiority during sustained visual attention. *Journal of Cognitive Neuroscience*, **3**, 329-334.

Wiedenfeld, S.A., O'Leary, A., Bandura, A., Brown, S., Levine, S., & Raska, K. (1990). Impact of perceived self-efficacy in coping with stressors on components of the immune system. *Journal of Personality and Social Psychology*, **59**, 1082-1094.

Williams, J.M.G., Mathews, A., & MacLeod, C. (1996). The emotional stroop task and psychopathology. *Psychological Bulletin*, **120**, 3-24.

Wittling, W. & Pflüger, M. (1990). Neuroendocrine hemisphere asymmetries: Salivary cortisol secretion during lateralized viewing of emotion-related and neutral films. *Brain and Cognition*, **14**, 243-265.

Wittling, W. (1995). Brain asymmetry in the control of autonomic-physiologic activity. In R. J. Davidson, K. Hugdahl (Eds), *Brain asymmetry* (pp. 305-357). Cambridge,MA: MIT Press.

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

Wolkowitz, O.M. (1994). Prospective controlled studies of the behavioral and biological effects of exogenous corticosteroids. *Psychoneuroendocrinology*, **19**, 233-255.

Woodman, D.D., Hinton, J.W., & O'Neill, M.T (1978). Cortisol secretion and stress in maximum security hospital patients. *Journal of Psychosomatic Research*, **22**, 133-136.

Yantis, S. & Johnson, D.N. (1990). Mechanisms of attentional priority. *Journal of Experimental Psychology: Human Perception and Performance*, **16**, 812-835.

Yerkes, R.M. & Dobson, J.D. (1908). The relation of strength of stimuli to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, **18**, 459-482.

Zahn, T.P., Nurnberger, J.I., & Berrettini, W.H. (1989). Electrodermal activity in young adults at genetic risk for affective disorder. *Archives of General Psychiatry*, **46**, 1120-1124.

APPENDIX 1

Stimuli used in modified spatial cueing task

Words used in spatial cueing task for study 1:

Positive	Negative	Neutral
1. Glory	17. Loser	33. Chair
2. Success	18. Gloomy	34. Yearly
3. Winner	19. Misery	35. Period
4. Strong	20. Beaten	36. Moment
5. Gifted	21. Ruined	37. Annual
6. Victory	22. Flunked	38. Passage
7. Triumph	23. Useless	39. Kitchen
8. Dynamic	24. Failure	40. Cabinet
9. Prosper	25. Pitiful	41. Section
10. Talented	26. Inferior	42. Interval
11. Champion	27. Helpless	43. Segment
12. Honoured	28. Pathetic	44. Kilogram
13. Superior	29. Defeated	45. Duration
14. Inspired	30. Disaster	46. Category
15. Conquest	31. Hopeless	47. Corridor
16. Flourish	32. Disgrace	48. Assembly

Pictures used in spatial cueing task for study 2 (reference numbers from the International Affective Picture System; Lang et al, 1997):

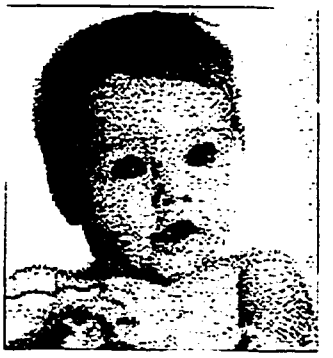
Positive	Negative	Neutral
1. 1440	19. 2750	37. 2190
2. 1463	20. 2800	38. 2200
3. 1610	21. 2900	39. 2440
4. 1710	22. 3030	40. 2480
5. 1750	23. 3180	41. 2570
6. 1920	24. 3300	42. 2840
7. 2050	25. 3350	43. 2850
8. 2070	26. 3550	44. 2890
9. 2160	27. 6242	45. 6150
10. 2165	28. 6243	46. 7004
11. 2260	29. 6250	47. 7009
12. 2311	30. 6570	48. 7034
13. 2550	31. 9181	49. 7050
14. 7200	32. 9300	50. 7090
15. 8200	33. 9410	51. 7235
16. 8380	34. 9421	52. 7550
17. 8470	35. 9433	53. 9070
18. 8496	36. 9571	54. 9210

Examples of pictures used in the spatial cueing task for study 2:

Negative pictures:



Positive pictures:


Neutral pictures:



Note: Pictures are the actual size as those used in the spatial cueing task. However, pictures were presented in colour during the task

APPENDIX 2

Mood ratings at each time point during the experiment

Table 1

Bipolar Profile of Mood States (POMS) by time in each of the experimental conditions for study 1

	Negative stressor		Positive stressor		Neutral condition		F(2,132)	P
POMS:	M	SD	M	SD	M	SD		
depressed-elated								
pre-stress	26.09	5.54	25.29	5.15	25.30	6.18	0.3	NS
post-stress	21.47	6.45	26.62	5.11	23.65	6.35	8.52	0.001
post-attention task	22.64	5.78	23.58	6.00	22.05	6.50	0.71	NS
end of experiment	23.77	5.72	23.96	4.95	23.98	5.65	0.02	NS
anxious -composed								
pre-stress	30.13	4.16	28.27	5.41	30.21	4.50	2.44	NS
post-stress	22.04	7.86	23.71	6.38	24.23	6.80	1.2	NS
post-attention task	27.87	5.41	26.69	5.30	27.49	5.80	0.55	NS
end of experiment	30.60	4.67	29.44	4.43	30.28	5.06	0.72	NS
hostile-aggreable								
pre-stress	29.55	3.74	28.73	4.90	29.44	4.71	0.45	NS
post-stress	23.19	7.47	28.11	5.15	26.67	5.94	7.47	0.001
post-attention task	26.40	5.27	26.58	5.84	26.02	6.15	0.11	NS
end of experiment	27.21	5.16	27.16	5.24	27.26	5.17	0	NS
unsure-confident								
pre-stress	25.81	4.43	25.11	5.41	25.86	5.11	0.32	NS
post-stress	22.89	5.71	27.98	5.27	24.81	6.42	8.95	0.001
post-attention task	23.79	5.32	24.04	5.69	25.00	5.98	0.56	NS
end of experiment	24.51	5.09	24.69	5.45	25.35	5.52	0.3	NS
confused-clearheaded								
pre-stress	30.70	3.36	28.98	4.14	30.56	4.53	2.56	NS
post-stress	26.45	5.85	29.33	4.89	28.42	4.98	3.61	0.05
post-attention task	26.72	5.46	26.00	5.25	27.23	6.56	0.51	NS
end of experiment	28.15	4.63	26.91	5.48	28.49	5.60	1.12	NS
tired-energetic								
pre-stress	24.34	6.02	23.31	6.55	24.56	6.72	0.47	NS
post-stress	22.75	7.19	26.73	5.67	23.44	6.57	4.85	0.01
post-attention task	17.15	8.15	18.13	8.70	18.86	8.33	0.47	NS
end of experiment	19.34	7.60	18.87	7.60	21.58	7.21	1.65	NS

Note. n=135

Table 2

Bipolar Profile of Mood States (POMS) by time in each of the experimental conditions for study 2

	Negative stressor		Positive stressor		Neutral condition		F (2, 63)	P
POMS	M	SD	M	SD	M	SD		
depressed-elated								
pre-stress	27.1	5.2	24.9	4.8	26.0	4.3	.1.1	NS
post-stress	23.3	7.1	25.7	4.8	23.0	5.2	1.4	NS
post-attention task	23.8	6.7	26.1	5.5	24.5	5.1	0.9	NS
end of experiment	24.3	5.8	25.4	5.2	24.3	5.0	0.3	NS
anxious -composed								
pre-stress	28.1	5.4	29.6	5.0	29.5	3.6	0.7	NS
post-stress	20.7	6.6	22.4	8.7	22.0	6.1	0.3	NS
post-attention task	25.2	8.1	25.8	8.2	26.4	5.4	0.1	NS
end of experiment	29.7	5.4	31.8	4.3	30.2	4.9	1.1	NS
hostile-aggreable								
pre-stress	29.5	4.7	30.9	2.8	30.0	3.5	0.8	NS
post-stress	24.3	7.5	29.0	4.8	25.3	6.5	3.3	0.05
post-attention task	25.6	7.9	28.9	5.2	26.8	5.6	1.5	NS
end of experiment	27.5	6.4	29.0	5.2	27.4	6.2	0.5	NS
unsure-confident								
pre-stress	25.7	4.5	24.7	4.6	25.8	4.1	0.4	NS
post-stress	22.0	6.7	26.5	5.5	23.3	6.0	3.1	0.05
post-attention task	21.9	7.2	27.0	6.0	25.3	5.1	3.9	0.05
end of experiment	24.0	6.2	26.9	5.4	26.2	4.2	1.8	NS
confused-clearheaded								
pre-stress	28.7	3.9	30.3	4.3	31.0	3.2	2.2	NS
post-stress	24.8	4.8	30.5	4.4	26.7	4.3	8.9	0
post-attention task	25.0	6.8	30.5	6.1	28.5	3.6	5.3	0.01
end of experiment	27.0	4.8	31.0	4.7	27.8	4.9	4.1	0.05
tired-energetic								
pre-stress	24.9	5.8	25.9	5.3	25.8	5.3	0.2	NS
post-stress	24.3	7.2	27.1	6.5	23.6	6.6	1.6	NS
post-attention task	21.8	8.1	25.9	6.7	21.0	7.5	2.7	NS
end of experiment	21.8	7.4	25.5	7.3	21.8	6.6	2.0	NS

Note. n=66

APPENDIX 3

Sources tables for study 1

Table 1

Multivariate Analysis of Variance of POMS change scores

Multivariate tests of Significance

Source of variance	Wilks Lambda	df	error df	Approx F
Stressor condition	0.66	12	254	4.8**

Univariate F-tests (df: 2, 132)

Source of variance	SS	Error SS	MS	Error MS	F
Relaxed-anxious	291	5540	145	42	3.5*
Elated-depressed	814	3057	407	23	17.6**
Energetic-tired	693	3795	347	29	12.1**
Agreeable-hostile	775	3445	388	26	14.9**
Confident-unsure	795	2543	398	19	20.**
Clearheaded-confused	489	2458	245	19	13.1**

* $p < .05$ ** $p < .01$

Table 2

Multivariate Analysis of Variance of VAS change scores

Multivariate tests of Significance

Source of variance	Wilks Lambda	df	error df	Approx F
Stressor conditions	0.71	10	256	4.7**

Univariate F-tests (df: 2, 132)

Source of variance	SS	Error SS	MS	Error MS	F
Stressed	999	72889	499	552	0.9
Discouraged	12634	61414	6317	465	13.6**
Confident	11812	67281	5906	510	11.6**
Determined	3590	74968	1795	568	3.2*
Negative Thinking	5725	64581	2863	489	5.9**

* $p < .05$ ** $p < .01$

Table 3

Mixed design Analysis of Variance of mean cortisol

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	0.08	2	0.04	0.26
Within-group error	20.7	130	0.16	
		Within Subjects		
Time (T)	0.15	3	0.05	3.27*
C x T	0.05	6	0.01	0.55
Within-group error	5.91	390	0.02	

* p <.05 ** p <.01

Table 4

Mixed design Analysis of Variance of peak cortisol

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	0.09	2	0.04	0.26
Within-group error	21.36	130	0.16	
		Within Subjects		
Time (T)	10.24	3	3.41	177.54**
C x T	0.06	6	0.01	0.48
Within-group error	7.5	390	0.02	

* p <.05 ** p <.01

Table 5

Mixed design Analysis of Variance of reaction time for invalid trials

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	0.18	2	0.09	0.11
Within-group error	106.66	132	0.81	
		Within Subjects		
Wordtype (W)	0	2	0	0.01
C x W	0.02	4	0	0.23
Within-group error	4.83	264	0.02	
Hemifield (H)	0.89	1	0.89	31.82**
C X H	0.03	2	0.02	0.54
Within-group error	3.7	132	0.03	
W X H	0.04	2	0.02	2.16
C x W x H	0.09	4	0.02	2.23†
Within-group error	2.75	264	0.01	

† p<.07 * p <.05 ** p <.01

Table 6

Mixed design Analysis of Variance of reaction time for invalid trials in "happy winners" and "sad losers"

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	2.15	1	2.15	2.6
Within-group error	38.81	47	0.83	
		Within Subjects		
Wordtype (W)	0.07	2	0.04	1.7
C x W	0.02	2	0.01	0.5
Within-group error	2.02	94	0.02	
Hemifield (H)	0.32	1	0.32	14.29**
C X H	0	1	0	0.01
Within-group error	1.05	47	0.02	
W X H	0.03	2	0.01	1.23
C x W x H	0.14	2	0.07	6.23**
Within-group error	1.04	94	0.01	

* $p < .05$ ** $p < .01$

Table 7

Mixed design Analysis of Variance of recognition memory

Source of variance	SS	df	MS	F
	Between Subjects			
Stressor condition (C)	59.98	2	29.99	0.85
Within-group error	4659.35	132	35.3	
	Within Subjects			
Wordtype (W)	1225.09	2	612.54	78.16**
C x W	9.65	4	2.41	0.31
Within-group error	2069.11	264	7.84	

* $p < .05$ ** $p < .01$

Table 8

Mixed design Analysis of Variance of reaction time for invalid trials in dysphoric and non-dysphoric participants

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	0.17	2	0.08	0.11
Group (G)	0.48	1	0.48	0.61
C x G	4.91	2	2.45	3.13*
Within-group error	101.14	129	0.78	
		Within Subjects		
Wordtype (W)	0	2	0	0.02
C x W	0.02	4	0	0.25
G x W	0.02	2	0.01	0.49
C x G x W	0.02	4	0.01	0.34
Within-group error	4.78	258	0.02	
Hemifield (H)	0.85	1	0.85	29.71**
C x H	0.03	2	0.01	0.46
G x H	0	1	0	0.01
C x G x H	0.03	2	0.01	0.5
Within-group error	3.67	129	0.03	
W x H	0.05	2	0.02	2.27
C x W x H	0.09	4	0.02	2.14
G x W x H	0	2	0	0.03
C x G x W x H	0.03	4	0.01	0.74
Within-group error	2.71	258	0.01	

* $p < .05$ ** $p < .01$

Table 9

Dysphoria X Condition mixed design Analysis of Variance of mean cortisol

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	0.12	2	0.06	0.38
Dyphoria Group (G)	0.18	1	0.18	1.13
C x G	0.07	2	0.03	0.21
Within-group error	20.44	127	0.16	
		Within Subjects		
Time (T)	0.12	3	0.04	2.59†
C x T	0.05	6	0.01	0.53
G x T	0.11	3	0.04	2.46†
C x G x T	0.09	6	0.02	1.03
Within-group error	5.71	381	0.01	

† p <.065 * p <.05 ** p <.01

Table 10

Mixed design Analysis of Variance of reaction time for invalid trials in cortisol responders and non-responders

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	0.04	2	0.02	0.03
Group (G)	3.52	1	3.52	4.53*
C x G	0.52	2	0.26	0.34
Within-group error	98.63	127	0.78	
		Within Subjects		
Wordtype (W)	0	2	0	0.01
C x W	0.01	4	0	0.16
G x W	0.03	2	0.01	0.77
C x G x W	0.15	4	0.04	2.06
Within-group error	4.57	254	0.02	
Hemifield (H)	0.9	1	0.9	32.63**
C x H	0.02	2	0.01	0.33
G x H	0.11	1	0.11	3.98*
C x G x H	0.05	2	0.02	0.87
Within-group error	3.52	127	0.03	
W x H	0.05	2	0.02	2.33
C x W x H	0.09	4	0.02	2.2
G x W x H	0.01	2	0	0.33
C x G x W x H	0.02	4	0.01	0.53
Within-group error	2.71	254	0.01	

* $p < .05$ ** $p < .01$

APPENDIX 4

Sources tables for study 2

Table 1

Multivariate Analysis of Variance of POMS change scores

Multivariate tests of Significance

Source of variance	Wilks Lambda	df	error df	Approx F
Stressor condition	0.58	12	116	3.1**

Univariate F-tests (df: 2, 63)

Source of variance	SS	Error SS	MS	Error MS	F
Relaxed-anxious	1	1977	0	31	0.0
Elated-depressed	262	1068	131	17	7.7**
Energetic-tired	121	1463	61	23	2.6
Agreeable-hostile	139	1365	70	22	3.2*
Confident-unsure	371	983	186	16	11.9**
Clearheaded-confused	270	855	135	14	10.0**

* $p < .05$ ** $p < .01$

Table 2

Mixed design Analysis of Variance of mean cortisol

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	0.32	2	0.16	0.68
Within-group error	14.96	63	0.24	
		Within Subjects		
Time (T)	0.03	4	0.01	0.36
C x T	0.06	8	0.01	0.33
Within-group error	5.67	252	0.02	

* p <.05 ** p <.01

Table 3

Mixed design Analysis of Variance of peak cortisol

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	0.38	2	0.19	0.84
Within-group error	14.29	63	0.23	
		Within Subjects		
Time (T)	9.2	4	2.3	65.82**
C x T	0.11	8	0.01	0.38
Within-group error	8.81	252	0.03	

* p <.05 ** p <.01

Table 4

Mixed design Analysis of Variance of reaction time for valid trials

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	4.46	2	2.23	3.15*
Within-group error	44.62	63	0.71	
		Within Subjects		
Picture valence (P)	0.22	2	0.11	7.19**
C x P	0.05	4	0.01	0.81
Within-group error	1.9	126	0.02	
Hemifield (H)	0.58	1	0.58	31.32**
C X H	0.02	2	0.01	0.43
Within-group error	1.16	63	0.02	
P X H	0.11	2	0.05	10.65**
C x P x H	0.03	4	0.01	1.62
Within-group error	0.62	126	0	

* $p < .05$ ** $p < .01$

Table 5

Mixed design Analysis of Variance of reaction time for invalid trials

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	2.98	2	1.49	2.22
Within-group error	42.36	63	0.67	
		Within Subjects		
Picture valence (P)	0.17	2	0.09	3
C x P	0.02	4	0	0.14
Within-group error	3.57	126	0.03	
Hemifield (H)	0.66	1	0.66	23.3**
C X H	0	2	0	0.03
Within-group error	1.8	63	0.03	
P X H	0.27	2	0.14	8.52**
C x P x H	0.11	4	0.03	1.76
Within-group error	2	126	0.02	

* $p < .05$ ** $p < .01$

Table 6

Mixed design Analysis of Variance of recognition memory

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	0.18	2	0.09	0.1
Within-group error	56.56	63	0.9	
		Within Subjects		
Picture Valence (P)	25.59	2	12.8	65.71**
C x P	0.28	4	0.07	0.35
Within-group error	24.54	126	0.19	

* $p < .05$ ** $p < .01$

Table 7

Mixed design Analysis of Variance of reaction time for invalid trials in dysphoric and non-dysphoric participants

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	4.09	2	2.05	3.42*
Group (G)	0.08	1	0.08	0.13
C x G	6.35	2	3.18	5.31**
Within-group error	35.91	60	0.6	
		Within Subjects		
Picture valence (P)	0.21	2	0.11	4.02*
C x P	0.01	4	0	0.08
G x P	0.13	2	0.06	2.4
C x G x P	0.28	4	0.07	2.63*
Within-group error	3.17	120	0.03	
Hemifield (H)	0.65	1	0.65	21.92**
C x H	0	2	0	0.02
G x H	0	1	0	0
C x G x H	0.01	2	0	0.13
Within-group error	1.79	60	0.03	
P x H	0.27	2	0.14	8.86**
C x P x H	0.12	4	0.03	1.9
G x P x H	0.07	2	0.04	2.3
C x G x P x H	0.07	4	0.02	1.1
Within-group error	1.86	120	0.02	

* $p < .05$ ** $p < .01$

Table 8

Mixed design Analysis of Variance of reaction time for invalid trials in high and low anxious participants

Source of variance	SS	df	MS	F
		Between Subjects		
Stressor condition (C)	2.63	2	1.32	1.97
Group (G)	1.56	1	1.56	2.33
C x G	0.66	2	0.33	0.5
Within-group error	40.13	60	0.67	
		Within Subjects		
Picture valence (P)	0.15	2	0.08	2.73
C x P	0.01	4	0	0.09
G x P	0.11	2	0.06	2.04
C x G x P	0.15	4	0.04	1.35
Within-group error	3.31	120	0.03	
Hemifield (H)	0.68	1	0.68	23.76**
C x H	0	2	0	0.05
G x H	0	1	0	0
C x G x H	0.07	2	0.03	1.2
Within-group error	1.73	60	0.03	
P x H	0.28	2	0.14	9.5**
C x P x H	0.1	4	0.02	1.67
G x P x H	0.09	2	0.05	3.23*
C x G x P x H	0.16	4	0.04	2.75*
Within-group error	1.74	120	0.01	

* $p < .05$ ** $p < .01$