COGNITIVE BIASES IN HEALTHY PARTICIPANTS WITH SYMPTOMS OF DEPRESSION OR SEASONAL AFFECTIVE DISORDER

by

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ABSTRACT

Exaggerated cognitive bias is observed in affective disorder patients, and is often probed using the Emotional Stroop (eStroop) task. Few studies of the eStroop have employed Event-Related Potentials (ERPs). Here, High-density ERPs were recorded while healthy subjects with and without sub-syndromal Depression and Seasonal Affective Disorder (SAD) performed eStroop variations containing disorder-congruent words. RTs did not reliably differentiate between groups. Emotional relative to neutral words elicited either a P1 or a new component with anterior frontal topography, the Early Anterior Positivity (EAP), maximal 200-400ms post-onset. In study 1, an EAP was elicited by depression words in subjects with and without depression, while amplitude of the Late Posterior Positivity (LPP) was greater in the depression group. In study 2, an EAP to winter-related words was observed in SAD participants during the winter, while only a P1 occurred in the summer. The EAP may index automatic processing of aversive self-relevant stimuli.

Keywords: Emotion; Stroop; Depression; SAD; Event-Related Potentials
DEDICATION

To my parents,

Peter and Valerie Jaspers-Fayer,

for their love, support and guidance.
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CHAPTER 1
GENERAL INTRODUCTION
AND LITERATURE REVIEW

1.1 Introduction: Cognitive Bias for Emotional Stimuli

Cognitive theories of the pathogenesis and maintenance of affective disorders, such as the schema model of depression (Beck, Rush, Shaw, Emery, 1979) propose that affective disorders are provoked and maintained by dysfunctional attitudes or schemas. Schemas are defined as a stored body of knowledge that interacts with incoming information by shaping selective attention and memory (Williams, Watts, MacLeod, & Mathews, 1997). These underlying dysfunctional schemas result in altered cognitive biases for stimuli that are negatively valence, and self-descriptive (Segal, Gemar, Truchon, & Guirguis, 1995), causing these stimuli to be: (1) selectively attended, (2) elaborated and interpreted, and (3) stored in memory, preferentially over information that is neutrally or positively valenced (Williams, Mathews & MacLeod, 1996).

A dysfunctional cognitive bias reflects the extreme end of the continuum of normal cognitive biases that can influence the effect of emotion on cognition. In healthy participants, cognitive biases for threatening stimuli allow for the quick allocation of cognitive resources to arousing signals of potential danger (Williams et al., 1996). Patients with affective disorders, however, respond to disorder or mood-congruent stimuli in an exaggerated manner. For example, content-specific cognitive biases have now been shown in generalized anxiety disorder to body-threat words (e.g. “sweating”), a variety of phobias (e.g. “crawling” presented to people with spider phobia), obsessive-compulsive
disorder (OCD; e.g. "germs"), post-traumatic stress disorder (PTSD; e.g. "explosion"), and depressive disorder (e.g. "sad"), but these concern-specific cognitive biases do not occur in healthy controls (for review see Williams et al., 1996). It is theorized that healthy participants can override cognitive biases for some types of arousing stimuli in some situations by increasing the top-down control of cognitive processing, but patients cannot, and therefore cannot keep arousing stimuli from being selectively processed (Williams et al., 1996).

Cognitive biases are thought to play a major role in the maintenance of affective disorders: A vicious cycle is built-up whereby the selective processing of mood-congruent (negative) stimuli is reinforced, and thus these stimuli become more salient and arousing, increasing the likelihood that they will be selectively processed in the future (Williams et al., 1996).

Cognitive biases in affective disorders have been experimentally investigated using three main paradigms: The emotional Stroop task, the visual dot-probe task, and the dichotic listening task (for a review see MacLeod & Mathews, 1991). Since the emotional Stroop paradigm (eStroop) has been used most extensively and has produced the most consistent results in demonstrating cognitive biases (Williams et al., 1996), variations of the eStroop task were used in this series of experiments.

1.2 Review of the Emotional Stroop Task

The eStroop evolved from the cognitive Stroop Task (cStroop), which was first developed by Stroop himself in 1935. In a typical cStroop, lists of colour words (red, green, yellow and blue), printed in four different ink colours (red, green, yellow or blue) are given to the participant to read out loud. In the congruent condition, the colour word
matches the ink colour (e.g., red written in red), and in the incongruent condition the
colour word does not match the ink colour (e.g., red might be written in green). Stroop
demonstrated that it takes longer to name colours in the incongruent compared to the
congruent condition, an effect typically referred to as Stroop interference or more plainly
the Stroop effect.

The most prominent explanation for the cStroop effect is grounded in Cohen’s
connectionist model (Cohen, Dunbar, & McClelland, 1990). This model suggests that as
word reading occurs automatically (Posner & Snyder, 1975), the response associated with
the task-irrelevant word meaning will conflict with the selection of the task-relevant
response to the colour of the word in the incongruent trials (Cohen, et al., 1990).

In 1964, Klein extended the original cStroop paradigm to include non-colour
words. Klein found that when he presented words that were associated with the ink
colour (e.g., grass written in green) the reaction time (RT) was longer than if the words
were unrelated to the colour (e.g., take written in yellow). Klein suggested that words
with meaning have the capacity to produce arousal, which in turn results in attention-
catching or attensive power. Klein went on to posit that the interference non-colour
words create in the Stroop task is directly related to their attensive power.

Gotlib and McCann (1984) where the first researchers to use emotional words in a
Stroop task, and therefore can be credited with creating the first true emotional Stroop
(eStroop) experiment. They selected participants that scored high (over 9) or low (under
4) on the first version of the Beck Depression Inventory (Beck, Ward, Mendleson, Mock
& Erbaugh, 1961), and asked participants to name the ink colour of 50 neutral, 50
depressive and 50 manic words presented on a tachistoscope. They found that the
valence of the word did not affect the control group, but participants with mild depression were significantly slower (23 ms) to respond to the colour of negative words than to positive or neutral words. These results have since been replicated in a number of depression studies (Gotlib & McCann, 1984; Hill & Knowles, 1991; Klieger & Cordner, 1990; Segal & Vella, 1990; Segal et al., 1995; Williams & Nulty, 1986), with negative words generally causing more interference than neutral words, and self-descriptive, mood-congruent (negative) words showing the greatest amount of interference.

There are a number of theories to explain why interference occurs in the eStroop. As discussed above, Beck (1979) suggests that emotional stimuli attract disproportionately more processing resources due to the activation of schemas for personally-threatening stimuli. In line with this theory, recent researchers suggest that the emotional word captures attention, diverting attention from the task-relevant attribute (Bishop, Duncan, Brett, & Lawrence, 2004; Whalen, et al., 1998), that the eStroop causes interference by activating a task-irrelevant processing stream that then ‘consumes’ some of the processing resources (Dawkins & Furnham, 1989), and, ultimately, that late stage processing is affected when two potential responses are received (Cohen, Dunbar & McClelland, 1990).

1.3 fMRI studies of the Emotional Stroop Task

Recently there has been interest in applying neuroimaging techniques, such as functional Magnetic Resonance Imaging (fMRI), to finding the neural correlates of the eStroop in healthy individuals and people with affective disorders (for review see Bush, Luu & Posner, 2000).
Bush and colleagues (2000) conducted a meta-analysis of neuroimaging studies involving variations of the cStroop and eStroop tasks, and found evidence for differential involvement of the dorsal division of the Anterior Cingulate Cortex (dACC) in the cStroop, and the ventral (or rostral) division of the ACC (rACC) in the eStroop. The dACC includes Brodmann areas (BA) 24b'-c' and 32 and has connections with the prefrontal cortex, particularly the dorsolateral prefrontal cortex (DLPFC, BA 46/9), as well as the primary, pre-motor and supplementary motor areas (Vogt, Finch, & Olson, 1992). The rACC, including BA 24a-c, 32, 25 and 33, projects to limbic structures, such as the amygdala, nucleus accumbens, hypothalamus, hippocampus and orbitofrontal cortex (Vogt et al., 1992).

Due to these interconnections, it has been hypothesized that the dACC is involved in resolving cognitive conflict (Bush et al., 2000), while the rACC is activated in instances of emotional conflict, such as in studies using task-irrelevant fearful faces and negative-valence words (Bishop, et al., 2004; Vuilleumeir, Armony, Driver, & Dolan, 2001; Whalen, et al., 1998).

1.4 The Temporal Course of the cStroop and eStroop

The temporal course of the cStroop has been studied extensively (Duncan-Johnson & Kopell 1981; Liotti, Woldorff, Perez III, & Mayberg, 2000; Rabai, Bernard, & Lannou, 1997; West, 2003; West & Alain, 1999), but only minimal work has been done on the eStroop (Kolasska, Musial, Mohr, Trippe, & Miltner, 2005; Metzger, Orr, Lasko, McNally, & Pitman, 1997; Perez-Edgar & Fox, 2003; Thomas, Johnstone, & Gonsalvez, 2007). According to Liotti and colleagues (2000), the congruent and incongruent words in the original cStroop elicited ERPs that diverged between 350-500 ms, with the
incongruent condition eliciting a negative wave (peaking at 410 ms) that is reduced in amplitude in the congruent condition. This negativity had an anterior medial focus when participants responded verbally, and a broader medial-dorsal distribution when they responded manually. Dipole source localization in this and other studies suggested that the dACC was the main brain generator, which is in line with the fMRI evidence cited previously in this work (see Bush et al., 2000 for review). Other paradigms involving cognitive conflict, such as the Eriksen Flanker Task (van Veen & Carter, 2002) and Go-NoGo tasks (Nieuwenhuis, Yeung, Wildenberg & Ridderinkhof, 2003), have reported similar medial frontocentral negativities, generally referred to as N2 components.

The first EEG study of the eStroop was reported by Metzger and colleagues (Metzger, Orr, Lasko, McNally, & Pitman, 1997), and involved an experiment with individuals who had developed post-traumatic stress disorder (PTSD). They found a general slowing in PTSD patients, but also an interference effect particularly for threat words. In the ERP data they only reported a significantly delayed and reduced P3 component to threat words.

Perez-Edgar and Fox (2003) studied the eStroop in 11-year-old children. Using negative, neutral and positive words, presented in red, green, or blue on a computer screen, they found that the eStroop produced an N1 (50-150 ms), at frontal sites that was significantly smaller for negative compared to neutral words, and an N2 (250-350 ms) at frontal, central, and occipital cites that was attenuated for negative versus positive words. A prominent positive slow wave (600-1000 ms), was reported, that showed the largest mean amplitudes for negative words, particularly over the left hemisphere. By splitting their sample into groups, they also found that children who experienced more eStroop
interference had shorter latencies to negative words than to positive words for the P2
(150-250 ms) at frontal and parietal sites, and a larger mean amplitude for the positive
slow wave at parietal sites for the group that experienced less eStroop interference.

Thomas and colleagues (Thomas, Johnstone, & Gonsalvez, 2007) looked at
individually rated words that healthy participants found personally disturbing versus
neutral words, but failed to find eStroop RT interference for concern-specific words.
They did find however, an interaction between threat and laterality in P2 amplitude, in
which threat words caused significantly larger P2 amplitudes in the right hemisphere. In
contrast to Metzger et al. (1997), they found an enhanced P3 to threat words.

Kolasska and colleagues (Kolasska, Musial, Mohr, Trippe, & Miltner, 2005) used
a pictorial eStroop with spider phobic, social phobic and non-phobic individuals.
Participants identified the colour of either red or blue pictures of spiders, birds or flowers.
No RT emotional interference effects were found, but parietal P300 and P400 amplitudes
were enhanced in people with spider phobia to spider-related stimuli.

In conclusion, unlike the cStroop and similar studies, which consistently implicate
a frontocentral negativity, the available studies of the eStroop fail to report consistent
findings both in terms of latency and topography. This variability may be caused by
sampling from different populations (children vs. adults, patients vs. controls), different
varieties of the eStroop (word vs. picture and phobia-specific vs. PTSD-specific content),
and the limited number of electrodes employed.

### 1.5 Rational for using ERPs for this Work

There are many benefits to using event-related potentials (ERPs) over other
imaging methods: ERPs measures provide a non-invasive measure of neural activity, with
high temporal resolution. To date, although the eStroop is the main research tool for
demonstrating cognitive biases, only one ERP study has been done in a clinical
population (Metzger et al., 1997). The purpose of this work was to expand upon the RT
research done on the eStroop in groups with symptoms of affective disorders, as well as
matched comparison groups.

1.6 General Hypotheses

The first goal of this work was to explore the temporal course and spatial
distribution of emotional interference effects during the eStroop, and clarify the
inconsistencies found in previous studies. In line with fMRI research, we hypothesized
that emotional conflict would produce a more anterior ERP scalp topography than
cognitive conflict, reflecting a shift from dorsal to rostral ACC involvement.
Additionally, it was hypothesized that participants who had symptoms of affective
disorders would show a significant emotional RT interference effect, and greater ERP
correlates of emotional conflict.

To this goal, the present set of experiments investigated cognitive biases for
emotionally salient words in two studies, both of which employed healthy volunteers
with high scores on affective disorder scales, as well as matched comparison groups.

In the first experiment, we measured cognitive bias using a depression and neutral
word eStroop in healthy individuals. Participants scored in the normal or the mild to
moderate range on the second version of the Beck Depression Inventory (Beck, Steer, &
Ranieri, 1996). RTs and electrical brain activity were recorded in response to depression
and neutral word types. We expected to find greater emotional RT interference in the
high-BDI group, relative to the low-BDI comparison group. Additionally, we
hypothesized that frontal modulations of the evoked response to depression words would be stronger in the High BDI group, and less pronounced or absent in the low BDI comparison group.

In the second study, RT and EEG were recorded in 29 healthy participants with high \( n = 15 \) and low \( n = 14 \) Seasonal Affective Disorder (SAD) symptoms, as assessed with the Seasonal Pattern Affective Questionnaire (SPAQ; Lam, Zis, Grewal, Delgado, Charney, & Krystal, 1996) during a variation of the eStroop task that used winter-related and depression-related words.

Participants were tested twice, first in the winter and then again in the summer, to create a within-subjects design. We hypothesized that the seasonal and non-seasonal groups would respond differently to the winter eStroop, with highly seasonal individuals showing a cognitive bias, with RT slowing to winter-related words in the winter, and greater ERP correlates of emotional conflict. We then explored whether these highly seasonal subjects continued to exhibit a cognitive bias for winter words in the summer (which would suggest that they have a SAD-trait effect), or whether the winter-related interference would disappear in the summer (suggesting a SAD-state effect). Depression eStroop results were gathered to address the content-specificity of the emotional interference effects in the SAD group, and as a localizer task to elicit reliable ERP frontal activity associated with emotional processing.
1.7 Reference List


CHAPTER 2 COGNITIVE BIAS IN HEALTHY PARTICIPANTS WITH SYMPTOMS OF DEPRESSION

The following paper is in preparation under the co-authorship of F. Jaspers-Fayer, I. Taake, L. Bucy, & M. Liotti.

2.1 Abstract

Cognitive biases cause selective processing of emotional over non-emotional stimuli. Seen in healthy participants for threatening stimuli and in people with affective disorders for disorder-congruent stimuli, cognitive biases are often studied through the emotional Stroop (eStroop) task. There is little literature on the temporal course of cognitive biases in this paradigm. The present study recorded ERPs in a version of the eStroop with depression-related words, in participants with symptoms of depression and a comparison group. RT interference approached significance for the high group. ERPs to emotional versus neutral words elicited an early anterior positivity (EAP) over the frontal scalp (200-400 ms post-stimulus onset) for all participants. This new ERP component may only occur when emotion is task-irrelevant, as in the eStroop, and might index an automatic orientating to emotionally salient stimuli. Traditional LPPs (300ms post-stimulus onset) to emotional words were also elicited over the posterior scalp, and differentiated the groups.

Keywords: Emotion; Stroop; Cognitive Bias; Depression; Event-Related Potentials
2.2 Introduction

Depression is a serious mental illness with changes in mood (e.g., sadness, anhedonia, or irritability), basic drives, (e.g., sleep, or hunger), and cognition (e.g., ruminations, guilt, or suicidal thoughts; American Psychiatric Association, 2000). Recent data suggests that one and a half million Canadians, or 12% of the population, will experience an episode of major depression at some point in their lives (Gilmour & Pattern, 2007). Two-thirds of the people affected are women, and depression is usually chronic with periods of relapse and remission (Mayberg, 2004).

Due to its prevalence and impact on society, researchers are looking for new ways to conceptualize, diagnose and treat depression. As depression does not cause consistent structural changes in the brain, we are looking for functional changes that occur while patients perform well-developed neuropsychological tasks (Liotti & Mayberg, 2001). The ultimate goal is to identify non-invasive neural markers of depression, and perhaps improve diagnosis and treatment.

One of the psychological markers of an affective disorder is a cognitive bias for disorder-specific stimuli. Cognitive biases occur because underlying dysfunctional schemas (Beck, Rush, Shaw, & Emery, 1979) or attitudes shape selective attention and memory for incoming information (Williams, Watts, MacLeod, & Mathews, 1997). Cognitive biases in depression cause the preferential processing of disorder-congruent stimuli, often related to sadness and past losses (Williams, Mathews & MacLeod, 1996). These biases then maintain a cycle, where the selective processing of mood-congruent (negative) stimuli is reinforced, causing these stimuli to become more salient and arousing, increasing the likelihood that they will be selectively processed in the future.
The principle research tool for demonstrating cognitive biases is the emotional Stroop (eStroop) task (Williams et al., 1996).

In the eStroop task, emotional and neutral words are shown in four possible colours (blue, red, green, or yellow) and the task is to respond to the colour of the word, while ignoring the meaning. Both patients with affective disorders and healthy participants have slower reaction times to colour words when they are highly arousing threat words, or concern-congruent (Williams, et al., 1996). There are a number of theories to explain why interference occurs in the eStroop. As discussed above, Beck and colleagues (1979) suggests that emotional stimuli attract processing resources due to the activation of schemas for personally threatening stimuli. In line with this theory, recent researchers have suggested that the emotional word captures attention diverting attention from the task-relevant attribute (Bishop, Duncan, Brett, & Lawrence, 2004; Whalen et al., 1998), that the eStroop causes interference by activating a task-irrelevant processing stream that then ‘consumes’ some of the processing resources (Dawkins & Furnham, 1989), and ultimately, that later stages of processing are affected when two potential responses are received simultaneously (Cohen, Dunbar & McClelland, 1990).

Recently, there has been interest in imaging the neural correlates of the eStroop in healthy individuals and people with affective disorders (Bush, Luu & Posner, 2000). Bush and colleagues conducted a meta-analysis of neuroimaging studies involving variations of the cStroop and eStroop tasks, and found evidence for differential involvement of the dorsal division of the Anterior Cingulate Cortex (dACC) in the cStroop, and the ventral (or rostral) division of the ACC (rACC) in the eStroop. The dACC includes Brodmann areas (BA) 24b’-c’ and 32 and has connections with the
prefrontal and motor cortex, while the rACC (BA 24a-c, 32, 25 and 33), projects to limbic structures (Vogt, Finch, & Olson, 1992). Based on these interconnections, the dACC is thought to be involved in resolving cognitive conflict (Bush et al., 2000), while the rACC is activated in instances of emotional conflict, such as in studies using task-irrelevant fearful faces and negative-valence words (Bishop, Duncan, Brett & Lawrence, 2004; Vuilleumeir, Armony, Driver, & Dolan, 2001; Whalen et al., 1998).

No study has looked at the temporal course of the eStroop in depressed individuals, despite the clinical relevance of cognitive bias in the provocation and maintenance of this disorder. In fact, there are only a handful of studies that report recording ERPs while participants performed an eStroop task (Metzger, Orr, Lasko, McNally, & Pitman, 1997; Perez-Edgar & Fox, 2003; Thomas, Johnstone, & Gonsalvez, 2007; Kolasska, Musial, Mohr, Trippe, & Miltner, 2005). These studies however, failed to report consistent findings, both in terms of latency and topography. This variability may have been caused by: (1) differing samples, for instance Metzger and colleagues (1997) used adults with PTSD while Perez-Edgar and Fox (2003) used healthy children; (2) different varieties of the eStroop, for example Thomas and colleagues used words while Kolasska et al. (2005) used pictures, and (3) a limited number of electrodes.

The first goal of study was to further explore the temporal course and spatial distribution of emotional interference during the eStroop. To this goal, we used depression and neutral words in a modified version of the eStroop, in healthy individuals who scored in the mild to moderate depression range (BDI≥9; n = 18) on the Beck Depression Inventory version 2 (BDI; Beck, Steer, & Ranieri, 1996) and a comparison
group with BDI scores below that cut-off (BDI<9; n = 27), and simultaneously recorded both RTs and electrical brain activity.

We hypothesized that emotional conflict would produce a more anterior ERP scalp topography than cognitive conflict, reflecting a shift from dorsal to rostral ACC involvement. Additionally, we hypothesized that there would be greater emotional RT interference in the high BDI group, relative to the low BDI comparison group, and that frontal modulations of the evoked response to depression words would be stronger in the High BDI group, and less pronounced or absent in the low BDI comparison group.

2.3 Methods

The Simon Fraser University Research Ethics Board approved this experiment. All participants read and signed a consent form before participating and received either course credit or a monetary incentive for their involvement.

2.3.1 Participants

Participants were recruited from the SFU subject pool. A total of 27 comparison participants (15 females, age = 21.19 ± 3.78, BDI = 3.83 ± 2.94) and 18 high BDI subjects (15 females, age = 19.61 ± 1.98, BDI = 15.31 ± 6.80) were tested, but one high BDI female, three control males, and two control females could not be used in the ERP analysis due to excessive artifacts. This allowed a final sample of 22 control participants (13 females, age = 21.4 ± 4.0, BDI = 3.6 ± 2.8) and 17 participants with high BDI scores (14 females, age = 19.7 ± 2.0, BDI = 14.32 ± 5.5) (see Table 2.1). The BDI was administered approximately 1 week before testing and again soon after the completion of the ERP study. Codes were used to associate personal information (e.g., name and
contact information) with the questionnaires, and were not written on the questionnaires themselves to ensure anonymity.

2.3.2 Questionnaire Measures

2.3.2.1 Medical Screening Questionnaire

A self-administered medical screening questionnaire was completed at the beginning of the experiment to screen for the present or past history of neurological or psychiatric disorders, sleeping habits, alcohol and medication consumption, and previous participation in electrical brain recording/imaging (See Questionnaire 2.1 and Table 2.2).

2.3.2.2 The Beck Depression Inventory

The Beck Depression Inventory version 2 (BDI-II) was administered approximately 1 week before testing, and again after the completion of the ERP component of the study. The BDI is a 21-item self-report questionnaire that assesses the existence and severity of symptoms of depression. Items relate to the constructs of sadness, pessimism, failure, dissatisfaction, and guilt. A Likert scale is used to score items, from zero, “I do not feel sad,” to three, “I am so sad or unhappy that I can't stand it.” The scores sum to give a single total score from 0-63 (Beck, et al., 1996; see Questionnaire 2.2).

2.3.3 Stimuli and Apparatus

The experiment was conducted in a sound-attenuated room. Stimuli were displayed on a 19-inch computer monitor and responses were made using the shoulder buttons of a game-pad (Logitech, Romanel-sur-Morges, Switzerland). The modified eStroop Task consisted of single colour words written in blue, red, green, or yellow that
flashed for 300 ms just above a central fixation cross (Presentation software version 9.70, Neurobehavioural Systems, Davis, USA). Half of the stimuli were emotional words with depression-related content. The remaining half were emotionally neutral words, individually matched with the emotion stimuli for word length and Kucera-Francis written frequency in the English language, using an online database (Wilson, 1988; see Figure 2.1 and Table 2.3). Emotional and Neutral words were randomly interspersed.

Stimuli length varied from 2.77° (cup) to 11.94° (typewriter), and had a standard height of 1.39°. The inter-stimulus interval was randomly jittered from 1700 to 2300ms. There were nine words of each type, and each word was presented three times in each of the four colours. Therefore, in total there were a total of 108 trials per condition. The entire behavioural experiment took approximately 35 minutes.

2.3.4 Procedure

Subjects were seated 60 cm from the screen and were instructed to maintain their gaze on the central fixation at all times, while trying to avoid or minimize eye blinks, motion, and muscle tension. They were told that while different types of words were flashed on the screen, they had to pay attention and respond to the colour of the word, by pressing one of four designated buttons on a game-pad that corresponded to the colour. The index and middle finger of both hands were used to response. Participants were asked to respond as quickly as possible to the colour of the word, while ignoring the meaning of the word itself. All participants were asked to practice to an 80% criterion on the practice block before beginning the experiment. The software allowed us to record and separately bin the correct reaction times (RTs) and errors, and save the data in log files for offline behavioural analysis.
2.3.5 Electrophysiological Recording

EEG was recorded from 63 tin electrodes positioned at FP1, FPz, FP2, AF3, AF4, F7, F5, F3, F1, Fz, F2, F4, F6, F8, FC5, FC3, FC1, FCz, FC2, FC4, FC6, T7, C5, C3, C1, Cz, C2, C4, C6, T8, CP5, CP3, CP1, CPz, CP2, CP4, CP6, P9, P7, P5, P3, P1, Pz, P2, P4, P6, P8, P10, PO7, PO3, POz, PO4, PO8, O1, Oz, O2, Iz, and M1 (American Electroencephalographic Society, 1994) as well as five non-standard sites inferior to the standard occipital locations. Electrodes were mounted in an elastic cap (Electrocap Inc.) All EEG signals were referenced to the right-mastoid. The horizontal electrooculogram (HEOG) was recorded with two electrodes, positioned lateral to the external canthi. Electrode impedances were kept below 10 kΩ. All signals were recorded with a band-pass of 0.1–100 Hz (-3 dB point; -12 dB per octave). EEG data were recorded with a modern amplifier (SA Instrumentation, San Diego, CA) at a sampling rate of 500 Hz and a gain of 20,000. Artifact reject was performed to remove trials with horizontal eye movements, blinks and amplifier blocking. Stimulus presentation and data acquisition were controlled by Presentation (Neurobehavioural Systems, Albany, CA) and Aquire! (HEL, Burnaby, BC), respectively.

2.3.6 Behavioural Statistics

Repeated measures analyses of variance (ANOVA) F-statistics were used to compare the behavioural performance of the Groups (high vs. low BDI), across Emotion (emotional vs. neutral).

Analyses of both the RTs and the proportion of errors [p (errors)] in each condition was conducted on the entire sample of participants (n = 45). Only correct trials, where responses were made 150-1500 ms after stimulus onset were used in the RT and
ERP analyses. For each subject, mean RTs were calculated for both emotion conditions (emotional vs. neutral), and the p (errors) was calculated by dividing the correct trials by the total number of trials.

2.3.7 ERP Statistics

Distinct ERP averages were obtained for depression and neutral words, time-locked to word onset (200 ms pre-stimulus baseline and 800 ms post-stimulus). All channels were re-referenced to the average of the two mastoid electrodes, and smoothed twice using a 7-point running average filter. ERP amplitudes were aligned to a 100 ms pre-stimulus baseline period. Grand averages were calculated across subjects for each Emotion (depression or neutral word) and Group (high or low BDI). To help isolate effects of interest, within-group difference waves were calculated. To facilitate visualization, scalp voltage topographic distribution maps were obtained using spherical spline interpolation (Perrin, Pernier, Bertrand, Giard, Echallier, 1987).

After inspection of grand-average waveforms and scalp topography distribution maps for each Emotion and various difference waves, two effects of interest were identified. First, the ERPs to emotional words were characterized by greater amplitude of a slow positive wave (which we named the Early Anterior Positivity or EAP) with a focal scalp distribution over bilateral frontal scalp, peaking over bilateral frontal poles, although more right lateralized in the High BDI group (see Figure 2.3). This wave diverged as early as 150 ms, and the effect extended for several hundred milliseconds, its voltage difference peaking between 200-400 ms from onset of the depression word.

Later on in the epoch, depression words elicited a greater amplitude slow wave (see Figure 2.3) similar in timing (400-600ms) and scalp distribution (midline and dorsal
posterior scalp) to the Late Positive Potential (LPP), which has been reported in several other studies of emotion (e.g., Cuthbert, Schugpp, Bradley, Birbaumer & Lang, 2000; Fischler & Bradley, 2006; Huang & Luo, 2006; Ito, Larson, Smith & Cacioppo, 1998; Schupp, Cuthbert, Bradley, Cacioppo, Ito, & Lang, 2000). Critically, an emotion-related LPP modulation was present only in the high BDI subjects (see Figure 2.3 for waveform plots and scalp topographies).

For the EAP and LPP, regions of interest (ROIs) were selected, by averaging together four neighbouring electrode sites where the voltage difference appeared to peak. For the EAP (200-400 ms), four ROIs were chosen, two for each hemisphere. There were two anterior-lateral ROIs (sites F1, F3, AF3, CF5 and F2, F4, AF4, CF6) and two dorsal-posterior (sites P1, P3, P03, P05 and P2, P4, P04, P06). For the later LPP window, a posterior midline ROI was chosen, collapsing sites Pz, POz and Oz.

For the EAP analysis, a mixed design Repeated Measures ANOVA was used, with voltage as the dependent variable and Group (high BDI vs. low BDI) as the between-subjects factor. The within-subjects factors used included: Emotion (depression vs. neutral word), Topography (anterior vs. posterior) and Hemisphere (right vs. left).

For the LPP analysis, a similar ANOVA was carried out, but the topography factor was omitted. Restricted within-group ANOVAs were planned to help in the interpretation of significant Emotion x Group interactions. For both analyses, the critical p-value was set at $\alpha = .05$ (degrees of freedom were corrected with the Greenhouse-Geisser epsilon method; Greenhouse & Geisser, 1954).
A BESA (version 5.1) dipole analysis was also performed on the difference wave (depression-neutral) for the entire group, and then this solution was applied to the high BDI and low BDI groups separately.

2.4 Results

The results of the demographic questionnaire are published in Table 2.1. The results of the medical questionnaire are published in Table 2.2

2.4.1 Behavioural Results

In the RT analysis, the global ANOVA found a significant interaction of Emotion x Group, \( F (42) = 4.39, p < .05 \). This was explained by a marginally significant Emotion effect in the high BDI group, \( F (17) = 4.04, p = 0.06 \), while the difference was far from significant for the low BDI group, \( F (25) = .516, p<.05 \). High BDI subjects were 19.38 ms slower to respond to depression words than neutral words, while the low BDI group was (RT difference = -5.07 ms; See Table 2.4 and Figure 2.2).

The analysis of p (errors) found no significant differences for Emotion \( F (1, 43) = .017, p>.05 \), or Group \( F (1,43) = .058, p>.05 \), and no interaction between Emotion and Group \( F (1,43) = .017, p>.05 \) in either the entire sample (n = 44), or the subgroup used in the ERP analysis (see Table 2.5).

2.4.2 ERP Results

For the Early Anterior Positivity (200-400 ms) there were main effects of Emotion \( F (1, 37) = 21.75, p = 0.000 \), and Topography \( F (1, 37) = 31.85, p = .000 \), but both were qualified by the significant Emotion x Topography interaction \( F (1, 37) = \)
9.62, p= 0.004]. For the anterior ROI, there was a significant effect of Emotion \([F (1, 37) = 39.37, p = 0.000]\). Additionally, for the posterior ROI, the effect of Emotion was also significant \([F (1, 37) = 4.92, p = 0.033]\). There were no main effects for Group and no Interactions involving Group, with the exception of the Group x Hemisphere, \([F (1.37) = 4.36, p = 0.044]\). This significant interaction was caused by the tendency of the high BDI group to show greater amplitude LPPs over the right hemisphere. (Please see Figure 2.3).

The late posterior potential (LPP 400-600 ms) showed a main effect of Emotion, \([F (1,37) = 6.35, p = 0.016]\), qualified by the significant interaction of Emotion x Group, \([F (1,37) = 7.22, p = 0.011]\). The interaction was explained by greater amplitude LPP for depression than neutral words in the High BDI group, \([F (1, 16) = 13.81, p = 0.002]\), and lack of such emotional modulation on LPP amplitude in the Low BDI group, \([F (1, 21) = .014, p<.05]\). (Please see Figures 2.3).

### 2.4.3 Source Dipole Modelling (BESA) of the EAP

According to research by Bush (2000) and Whalen (1998) and their colleagues, the eStroop is accompanied by activation of the affective/rostral division of the Anterior Cingulate Cortex (rACC). Accordingly, we applied source dipole modelling (BESA) to the grand-average depression versus neutral difference waves for the entire sample of subjects, and then to the high and low BDI groups individually. We used the following approach. First, we seeded BESA by constraining the location of the dipole to the Talairach coordinates of the rACC \((x = +5; y = +35; z = +5)\) in the time window 200-400 ms, with the orientation left to vary. When applied to the entire sample, the rACC yielded a solution with a residual variance of 25.3%. We then applied the same solution.
to the high and low BDI groups. In the high group, a rACC source accounted for all but 28.6% of the variance in the EAPs, while in the low group this dipole accounted for all but 39.2% of the variance.

We then proceeded to add a symmetric pair of dipoles; with the reasoning that residual activity in the 200-400 ms window may reflect sources in the fusiform gyrus, an area which has been implicated in emotional processing in fMRI research (Whalen et al., 1998). First working with the entire group we added a symmetric pair of dipoles that were constrained in the z-plane ($z = -20.9$). The x and y co-ordinates and the orientation were left to vary. Notably, the dipoles’ best fit was in anterior-lateral ventral occipital cortex, within 5 mm of the fusiform activations reported for the emotional processing of aversive stimuli in fMRI studies ($x = \pm 38, y = -50, z = -20$). This three-dipole model yielded an improved solution, with only 18.28% residual variance for the entire group over the 200-400ms time window. We then applied this new model to the high and low BDI groups separately, obtaining improved solutions of 22.12% for the high group and 30.14% residual variance for the low group.

In summary, a three-dipole solution with sources in rACC and bilateral fusiform gyri explained most of the variance in the scalp EAP, agreeing nicely with evidence of rACC and fusiform gyri involvement in the processing of negative emotional information.

As for the scalp voltage data, from this source modelling of the EAP there was no clear indication that EAP was different between high and low BDI groups. We therefore did not pursue further modelling of the data.
2.5 Discussion

High BDI participants responded more slowly to depression words relative to neutral words, compared to the comparison group. This finding is consistent with previous studies done on the eStroop effect for depression-related stimuli in samples of participants with symptoms of depression (Gotlib & McCann, 1984; Hill & Knowles, 1991; Klieger & Cordner, 1990; Segal & Vella, 1990; Segal et al., 1995; Williams & Nulty, 1986). In previous studies, Stroop interference has generally been thought to index biases for negative information in people with dysfunctional underlying schemas. Once these schemas are activated, features of depression, such as rumination, self-blame and predictions of future failure, can recruit increasingly amounts of the brain’s processing capacity and maintain the depressive state (Segal et al., 1995). This study adds to the previous literature by recording ERPs while participants completed the eStroop task. We found two strong effects, an early anterior potential (EAP, 200-400 ms post stimulus onset), and a late posterior potential (LPP, 400-600 ms post stimulus onset) in response to depression words. These two effects are discussed separately in the following sections.

2.5.1 The EAP (200-400 ms)

Depression words elicited an early positive deflection of the waveform (200-400 ms post-stimulus onset) with a frontal scalp topography that was more anterior than the distribution seen in previous ERP studies looking at cognitive conflict (Liotti, Woldorff, Perez, & Mayberg, 2000; Nieuwenhuis, Yeung, Wildenberg & Ridderinkhof, 2003; van Veen & Carter, 2002). Interestingly, this effect was seen independent of BDI status.
There was a trend toward a greater right hemisphere distribution in the high BDI group, but this effect was not significant.

The majority of studies exploring the impact of negative versus neutral stimuli on brain potentials have focused on the LPP (Cacioppo, Crites, & Gardner, 1996; Cacioppo, Crites, Gardner, & Berntson, 1994; Crites & Cacioppo, 1995; Smith, Larsen, Chartrand, & Cacioppo, 2006). Only a few ERP studies have reported an anterior P2 to negative versus neutral words, and they are reviewed below. Using a healthy sample, Bernat, Bunce and Shevrin (2001) recorded ERPs while pleasant and unpleasant words were presented using a tachistoscope, supraliminally (40ms) and subliminally (unmasked, 1 ms). Participants were not required to respond in anyway. They found a P2 (80s-190 ms supraliminal; 100-210 ms subliminal) at frontal sites to negative words relative to neutral words and, as the P2 for subliminal words was much higher in amplitude, hypothesized that the P2 was associated with the process by which affective responses are given conscious attention.

Pauli, Amrhein, Muhlberger, Dengler and Wiedemann (2005), found a frontal positivity (200-400 ms) to emotional versus neutral words when they were presented at perception threshold to participants with panic disorder (PD). Participants were asked to read each word aloud after a 3 second delay. Like Bernat et al. (2001), the researchers theorized that brain activity in the P2 time window plays a significant role in the process by which affective responses are given conscious attention.

Mercado, Carretie, Tapia and Gomez-Jarabo (2006), looked at participants with high trait anxiety scores and recorded ERPs while using an oddball paradigm. Pictures were negatively arousing, positively arousing, neutral and relaxing. Auditory stimulation
began 10 s after visual stimuli onset, and participants were asked to mentally count the
deviant auditory stimuli in the auditory trains. They found that in participants with high
trait anxiety a P2 component (150-210 ms) at frontal and central cites (Fz, F4 and Cz) to
negative stimuli. They interpreted this component as a reflection of the increase in
attentional resources dedicated to negative stimuli in people with trait anxiety. They
further suggest that this process might be schema driven, where people with high trait
anxiety experience “hyper-vigilance” for negative stimuli and are quick to activate a
“threat-detection system.”

Given the reviewed literature, there are two important points of interest to be
made about our study: (1) Our study elicited an EAP to negative words relative to neutral
words in both the depressed and comparison groups, (2) studies that elicit an EAP all use
paradigms that present emotional implicitly, such that the emotion is task-irrelevant.

In reference to the first point, like Bernat et al. (2001), an EAP to negative stimuli
was elicited in healthy participants. We suspect that this result was obtained because
highly salient, negative-valence stimuli were employed (e.g., misery). In principle,
cognitive biases for highly arousing, negative stimuli should exist in everyone, as they
are of considerable value for survival and give an adaptive advantage to the organism by
letting it detect and react rapidly to danger in the environment (Bernat et al., 2001). The
existence of a threat-detection system has often been hypothesized, in which the
amygdala signals to the prefrontal cortex that incoming information needs to be evaluated
(Vuilleumier, Armony, Driver, & Dolan, 2001; Phelps, 2002).

In reference to the second point, it is important to emphasize that of the studies
reviewed in this paper, the EAP effects found for negative emotional information were all
elicited by paradigms where emotion was implicit. The great majority of the published ERP studies of emotion (e.g., Cacioppo, et al., 1996; Cacioppo, et al., 1994; Crites & Cacioppo, 1995; Smith, et al., 2006) all ask subjects to overtly categorize the emotional stimulus, asking the participant, "Is this positive or negative?" or "Does this word describe you?" and such task-relevance may have yielded LPP effects rather than an EAP. Furthermore, many studies either only focused on reporting LPP effects, or employed only a few electrodes. This fits well with the theory that the EAP indexes the activation of a threat-detection system. This hypothesis needs to be formally tested in future studies.

2.5.2 The LPP (400-600ms)

In the 400-600ms time window, there was a significant late posterior positivity (LPP) for depression words compared to neutral words. These results are consistent with the LPP literature (e.g., Cuthbert, et al., 2000; Fischler & Bradley, 2006; Huang & Luo, 2006; Ito, et al., 1998; Schupp, et al., 2000), which has repeatedly found an effect for arousing visual stimuli (words and faces) over neutral or positive stimuli (see Fischer & Bradley, 2006 for a review). It is interesting to note that in our study the LPP was modulated by emotion only in the high BDI group. Previous studies (Fischler & Bradley, 2006) have found that the LPP is attenuated or eliminated when the task does not involve semantic evaluation. As reading is automatic (Posner & Snyder, 1975), and people with depression preferentially process mood-congruent information, perhaps the participants with high BDI could not help but process the semantic meaning of the stimuli.

This result supports the existence of a depression-related feedback cycle, where people with symptoms of depression are more likely to allocate cognitive processing to
mood-congruent stimuli, reinforcing an underlying dysfunctional schema. It also suggests that the underlying schema in depression, unlike anxiety, has a larger effect on the late, conscious and sustained processing of negative information (Williams Mathews, & MacLeod, 1996; Williams, Kemp, Felmingham, Liddell, Palmer & Bryant, in press). We hypothesize that this late effect occurs when negative stimuli are matched against the negative schemas present in depressed individuals. The LPP is identical in timing and posterior scalp topography to the P3b wave, which is obtained in response to salient, task-relevant stimuli, and it’s thought to reflect matching of a current stimulus against a template of the task-relevant stimulus (Demiralp, Ademoglu, Comerchero, & Polich, 2001).

2.6 Conclusion

The goal of this study was to explore the temporal course and scalp distribution of the eStroop task, and evaluate the effect of depression status on the behavioural and electrophysiological correlates of the eStroop. We found two robust effects, the modulation of an early anterior potential (200-400 ms post stimulus onset) in all of our participants, and the enhancement of a late posterior potential (LPP, 400-600 ms post stimulus onset) in the high BDI group in response to depression words. We suggest that these effects reflect the temporal course of cognitive biases, as they occur in healthy people with and without symptoms of depression.

A limitation of this study was that we did not use clinically diagnosed depression patients. Stronger results distinguishing depression and non-depressed participants may be acquired using a clinical group. However, studying healthy subjects with sub-
syndromal depression has the advantage that other confounding factors, such as disease, co-morbidity, and medications, are not concomitantly at play.

In future work we hope to continue exploring the effect of task-relevance on the processing of emotion on the EAP, and use clinically diagnosed depressed patients so that we can elicit stronger effects.
2.7 Figures

Figure 2.1 Study 1 - The Depression Stroop task
Figure 2.2 Study 1 - RTs to Depression words and Neutral words across High and Low BDI groups
Figure 2.3 Study 1- ERP Waveforms and Scalp Topographies

High Depression

Low Depression

Note. EAP (200-400ms) and LPP (400-600ms) effects in the high and low BDI groups. A = early effects; B = late effects
### 2.8 Tables

**Table 2.1 Study 1- Demographics**

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<th>Characteristic</th>
<th>All Participants</th>
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</tr>
<tr>
<td>n</td>
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<tr>
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<td>Handedness</td>
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<td></td>
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<tr>
<td>(right)</td>
<td>16 (88.9)</td>
<td>26 (96.3)</td>
</tr>
<tr>
<td>M</td>
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<tr>
<td>Age (years)</td>
<td>19.61 (1.98)</td>
<td>21.19 (3.78)</td>
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<tr>
<td>BDI</td>
<td>15.31 (6.80)</td>
<td>3.83 (2.94)</td>
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Table 2.2  Study 1 Medical Screening Questionnaire by Groups.

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<td>Low BDI</td>
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<td>Sleep Disorder</td>
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<td>Migraines</td>
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<td>Previous Scans</td>
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Table 2.3  Study 1- Frequency Rating for Words used in the dStroop

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<th>Neutral Words</th>
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<td><strong>Frequency</strong></td>
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<td>SAD</td>
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<tr>
<td>LONELY</td>
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<tr>
<td>MISERY</td>
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</tr>
<tr>
<td>FAILURE</td>
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<td>HOPELESS</td>
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<tr>
<td>MISFORTUNE</td>
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<tr>
<td>GRIEF</td>
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Table 2.4  Study 1- dStroop RT for depression and neutral words by High and Low BDI groups

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<tr>
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<th>SErr</th>
<th>Comparison Group Mean RT (ms)</th>
<th>SErr</th>
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<td>5.41</td>
<td>690.98</td>
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<tr>
<td>Depression Words</td>
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### Table 2.5  Study 1 Analysis of Errors

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<th>EEG Participants</th>
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<td>Low BDI</td>
<td>High BDI</td>
<td>Low BDI</td>
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<td>P (error)</td>
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<td>P (error)</td>
<td>SD</td>
<td>P (error)</td>
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<tr>
<td>Neutral words</td>
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<td>0.61</td>
<td>0.06</td>
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2.9 Questionnaires

Questionnaire 2.1 Medical Screening Questionnaire

Date …………..

Subject #: ………….. Age: ………….. Years of Education: …………..

1) Do you wear glasses or contacts? ……………………………..

2) Is your vision nearly normal when using glasses/contacts? ……………………………..

3) Are you Right Handed or Left Handed? ……………………………..

4) How you ever seen a psychiatrist or have been treated for any of the following problems:
   a) Depression YES NO
   b) Anxiety YES NO
   c) Attention-Deficit Disorder YES NO
   d) Thought disorder YES NO
   e) Other (specify)…………………………………………………..

5) Have you ever seen a neurologist or been in an emergency room for:
   a) loss of motor or sensory function YES NO
   b) loss of consciousness YES NO
   c) Head concussion YES NO
   d) sleep disorder YES NO
   e) Migraines YES NO

f) Have you ever had a CT scan, MRI scan or Electroencephalogram YES NO

6) Have you been told you have a learning disorder such as dyslexia?

   YES NO
7) **Have you had/do you have any serious medical condition?**

   YES  NO

   If yes, explain which .............................................

6) **Are you currently taking any prescription medication?**

   YES  NO

   If yes, explain which .............................................

7) **How many hours do you typically sleep?** .............................................

8) **How many hours did you sleep last night?** .............................................

9) **Please describe which and how many alcoholic beverages you typically have in a week:**

   ........................................................................

10) **Do you use non-prescription drugs frequently (optional).** ..............................

Please rate, on a scale from 0 (not at all) to 9 (very much so) how sleepy you have been feeling during the past week:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not sleepy</td>
<td>Very sleepy</td>
<td>Great effort to fight sleep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please rate, on a scale from 0 (not at all) to 9 (very much so) how sleepy you feel now:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Alert</td>
<td>Very Sleepy</td>
<td>Great effort to stay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wide Awake</td>
<td>Awake</td>
<td>Great effort to fight sleep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How tired-fatigued have you been feeling during the **past week**:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very little</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>No fatigue</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Extreme fatigue interferes with work, duties &amp; social activities</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Please rate, on a scale from 0 (*not at all*) to 10 (*very much so*) the way you are feeling **now**:

<table>
<thead>
<tr>
<th>Sad</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxious</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Tired</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Relaxed</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Energetic</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Upset</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Happy</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>
Questionnaire 2.2  Beck Depression Inventory (BDI)

On this questionnaire are groups of statements. Please read each group of statements carefully. Then pick out the statement in each group which best describes the way you have been feeling in the PAST WEEK, including TODAY! If several statements in the group seem to apply equally well, circle each one. Be sure to read all the statements in each group before making your choice.

1  
I do not feel sad.  
I feel sad.  
I am sad all the time and can't snap out of it.  
I am so sad or unhappy that I can't stand it.

2  
I am not particularly discouraged about the future.  
I feel discouraged about the future.  
I feel I have nothing to look forward to.  
I feel that the future is hopeless and that things cannot improve.

3  
I do not feel like a failure.  
I feel I have failed more than the average person.  
I feel I have nothing to look forward to.  
I feel I am a complete failure as a person.

4  
I get as much satisfaction out of things as I used to.  
I don't enjoy things the way I used to.  
I don't get real satisfaction out of anything anymore.  
I am dissatisfied or bored with everything.

5  
I don't feel particularly guilty.  
I feel guilty a good part of the time.  
I feel quite guilty most of the time.  
I feel guilty all of the time.

6  
I don't feel I am being punished.  
I feel I may be punished.  
I expect to be punished.  
I feel I am being punished.

7  
I don't feel disappointed in myself.  
I am disappointed in myself.  
I am disgusted with myself.  
I hate myself.

8  
I don't feel I am worse than anybody else.  
I am critical of myself for my weaknesses or mistakes.  
I blame myself all the time for my faults.  
I blame myself for everything bad that happens.

9  
I don't have any thoughts of killing myself.
I have thoughts of killing myself, but I would not carry them out.
I would like to kill myself.
I would kill myself if I had the chance.

10 I don't cry anymore than usual.
I cry more now than I used to.
I cry all the time now.
I used to be able to cry, but now I can't cry even though I want to.

11 I am no more irritated than I ever was.
I get annoyed or irritated more easily than I used to.
I feel irritated all the time now.
I don't get irritated at all by the things that used to irritate me.

12 I have not lost interest in other people.
I am less interested in other people than I used to be.
I have lost most of my interest in other people.
I have lost all of my interest in other people.

13 I make decisions about as well as I ever could.
I put off making decisions more than I used to.
I have greater difficulty in making decisions than before.
I can't make decisions at all anymore.

14 I don't feel I look worse than I used to.
I am worried that I am looking old or unattractive.
I feel that there are permanent changes in my appearance that make me look unattractive.
I feel that I am ugly or repulsive looking.

15 I can work about as well as before.
It takes an extra effort to get started at doing something.
I have to push myself very hard to do anything.
I can't do any work at all.

16 I can sleep as well as usual.
I don't sleep as well as I used to.
I wake up 1-2 hours earlier than usual and find it hard to get back to sleep.
I wake up several hours earlier than I used to and cannot go back to sleep.

17 I don't get more tired than usual.
I get tired more easily than I used to.
I get tired from doing almost anything.
I am too tired to do anything.

18 My appetite is no worse than usual.
My appetite is not as good as it used to be.
My appetite is much worse now.
I have no appetite at all anymore.

19 I haven't lost much weight, if any, lately.
I have lost more than 5 pounds.
I have lost more than 10 pounds.
I have lost more than 15 pounds.
(Please ALSO ANSWER: I am trying to lose weight via dieting? Yes ___ No ___)

20  I am no more worried about my health than usual.
I am worried about physical problems such as aches and pains or upset stomach or constipation
I am very worried about physical problems and it's hard to think of much else.
I am so worried about my physical problems that I cannot think of much else.

21  I have not noticed any recent changes in my interest in sex.
I am less interested in sex than I used to be.
I am much less interested in sex now.
I have lost interest in sex completely.
2.10 Reference List


CHAPTER 3
COGNITIVE BIAS IN PARTICIPANTS WITH
SYMPTOMS OF SEASONAL AFFECTIVE DISORDER

The following paper is in preparation under the co-authorship of F. Jaspers-Fayer.

L. Buchy, I. Taake, & M. Liotti.

3.1 Abstract

To study the electrophysiological correlates of cognitive bias in Seasonal Affective Disorder (SAD), high-density EEG was recorded in 15 sub-syndromal SAD (s-SAD) and 14 comparison participants while they performed winter and depression versions of the emotional Stroop task (eStroop). There were two sessions, the first in the winter (when s-SAD participants were symptomatic) the second in the summer (when they were symptom-free). RT interference was observed only for depression words in the winter for the s-SAD group. Winter words elicited an early anterior positivity (EAP, 200-400 ms post-stimulus), in s-SAD participants in the winter, which dissipated in the summer, and did not occur in either season for the comparison group. Furthermore, P1 modulations over occipital cortex varied as a function of season and group. Interestingly, EAP and P1 effects were mutually exclusive. The results are discussed in the context of direct and indirect amygdalar pathways for processing threat signals.

Keywords: Stroop; Seasonal Affective Disorder; P1; EAP; LPP
3.2 Introduction

Seasonal affective disorder (SAD) was first described by Rosenthal and colleagues in 1984 as: (1) a regular recurring depression in the fall and winter, with full remission in the spring or summer, with (2) at least one prior depressive episode that met criteria for major depressive disorder (MDD), that is (3) unexplained by other psychosocial events that might cause mood shifts (Rosenthal, Sacks, Gillian, Lewy, Goodwin, Davenport, et al., 1984). The current DSM-V-IV-TR criteria propose a similar constellation of symptoms (American Psychiatric Association, 2000). SAD can also be thought of as the extreme end of a seasonality continuum in healthy people, with a variable degree of symptoms from mild to severe. People who have moderate symptoms of SAD, yet do not meet criteria for full-fledged clinical SAD, are categorized as sub-syndromal SAD (s-SAD; Rohan, 2004). Depressive episodes last an average of 5 months starting in the fall and peaking in January and February (Rosenthal et al., 1984).

Currently SAD is considered a distinct subtype of major depressive disorder (MDD), with a characteristic symptom profile (Tam, Lam, Robertson, Stewart, Yatham, Zis, 1997). In presentation, SAD shares some features with MDD such as decreased activity, sadness and anxiety, but there are also atypical reverse vegetative symptoms, the most defining of which are hypersomnia (i.e., excessive sleeping) and hyperphagia (i.e., excessive eating, particularly a pronounced craving for carbohydrates; Rosenthal et al., 1984).
3.2.1 Neuroimaging in SAD Studies

Four neuroimaging studies have been done on participants with SAD. Cohen, Gross, Nordahl, Semple, Oren and Rosenthal (1992) were the first to conduct a neuroimaging study in SAD patients and used single photon emission computed tomography (SPECT). They employed seven participants with SAD and 38 controls. While SAD patients had a lower global metabolic rate both before and after light therapy compared to controls, the contrast between post- and pre-light therapy showed an increase in regional metabolism in the occipital cortex. Vasile, Sachs, Anderson, Lafer, Matthews, and Hill (1997) also used SPECT to measure regional cerebral blood flow (rCBF) before and after light therapy. No pre-treatment abnormalities distinguished light responders from non-responders. Post-treatment responders however, showed an increase in rCBF in all brain areas relative to the cerebellum when compared to the non-responders. The strongest effects were found in frontal and cingulate cortex, and the thalamus. The other two imaging studies in SAD subjects focused on sub-cortical structures, Willeit and colleagues (2000) used SPECT to find that serotonin transporter 5-HTT was less available in the thalamus/hypothalamus region in patients, and Schwartz et al. (1997), used structural MRI to measured differences in the pituitary gland across seasons, but found no significant differences. In summary, there is a paucity of studies, and variability in regional effects, but there is a suggestion that some of the effects found in SAD patients are similar to those found in resting state PET studies of major unipolar depression, particularly those implicating dorsal prefrontal cortex, cingulate cortex, and the thalamus (Mayberg, 2004). It is clear that more studies are required to shed light on the neural correlates of SAD.
3.2.2 Cognitive Bias and Seasonality

One aspect of SAD that has received academic attention concerns the distinct cognitive structure of patients with clinical manifestations of SAD. Not unlike other patients with affective disorders, for which content-specific cognitive bias has been demonstrated, SAD patients appear to have more negative thoughts, perceptions and memories, particularly in the winter season (Golden, Dalgleish & Spinks, 2006) for words related to the winter (Spinks & Dalgleish, 2001). As mentioned in chapter two, cognitive bias has been successfully investigated in anxiety and depression by using the emotional Stroop (eStroop) task, particularly when the Stroop has been tailor to use symptom-specific stimuli.

The eStroop is similar to the original cognitive Stroop (cStroop), in that words are presented in different colours (e.g. red, green, yellow, and blue), and participants are asked to respond to the colour of the word. Unlike the cStroop however, which uses incongruent colour words to create cognitive conflict (i.e., red written in blue), the eStroop creates emotional conflict by using highly emotional and arousing stimuli (i.e., the word murder written in blue). In both versions, response time slowing is caused by the processing of the task-irrelevant word meaning (reading is automatic, Posner & Snyder, 1975) interfering with the processing of the task-relevant word colour (Bishop, Duncan, Brett, & Lawrence, 2004; Cohen, Dunbar, & McClelland, 1990; Whalen et al., 1998).

Bush and colleagues (2000) conducted a quantitative meta-analysis of neuroimaging studies involving cStroop and eStroop tasks, and found that the cStroop activated the dorsal (or caudal) division of the ACC (dACC), while the eStroop activated the ventral (or rostral) division of the ACC (rACC). Broadly speaking, the affective division of the
ACC, including Brodmann areas 24a-c, 32, 25 and 33, projects to limbic structures, such as the amygdala, nucleus accumbens, hypothalamus, hippocampus and orbitofrontal cortex (Vogt, Finch, & Olson, 1992). In contrast, dACC has reciprocal connections with DLPFC, parietal cortex, and the hippocampus, which support neocortical cognitive processes such as working memory and attention. Since the eStroop appears to activate limbic areas which have been found to be dysfunctional in affective disorders, it’s unsurprising that researchers have use the eStroop to probe reactivity to emotional conflict in normal and abnormal emotional states.

Similar to other affective disorders, people experiencing depression exhibit the strongest emotional interference effects when probed with content-specific, symptom-related and often self-descriptive depression words (Williams et al., 1996), for example words that are congruent with feelings of sadness and loneliness (Gotlib & McCann, 1984, 1987; Hill & Knowles, 1991; Klieger & Cordner, 1990; Segal & Vella, 1990; Segal et al., 1995; Williams & Nulty, 1986). People with SAD are also susceptible to words related to their disorder, for instance words related to the winter, such as “rain”, “winter”, and “ice”. Spinks and colleagues (2001) found that emotional conflict could be caused in people with SAD using eStroop tasks containing either depression or winter words. This study was the first foundation of the present project.

There are only a few published studies investigating the temporal course of the eStroop. Looking at those studies (Metzger, Orr, Lasko, McNally, & Pitman, 1997; Perez-Edgar & Fox, 2003; Thomas, Johnstone, & Gonsalvez, 2007; Kolasska, Musial, Mohr, Trippe, & Miltner, 2005), as a whole they fail to report consistent findings, both in terms of latency and topography.
Previous work in our laboratory has identified a novel ERP effect, which might index an early selective bias for emotionally salient, negative words in the eStroop task, in healthy controls with and without symptoms of depression (see Study 1). That study used an adaptation of the eStroop, which used self-descriptive depression words, and will be referred to in this study as the dStroop. Based on its distribution over anterior frontal scalp, we have named this effect the Early Anterior Positivity (EAP, 200-400 ms), and hypothesize that it reflects automatic orienting towards salient negative stimuli during early stages of cognitive processing. In line with previous fMRI work, and supported by our dipole source analysis, we have proposed that the EAP might originate in the rACC and adjacent ventromedial PFC (Bush et al., 2000).

This ERP work (study 1) was the second foundation of the present project. We reasoned that winter words (e.g., rain, winter and ice) related to SAD symptoms, and which have been used in adaptations of the eStroop in SAD patients (Spinks et al, 2001) should elicit similar EAP modulations selectively in individuals who experience SAD symptoms, while healthy subjects without SAD symptoms should not find the same words aversive and self-relevant, and therefore should not show an EAP modulation. We refer to this new version of the eStroop as the winter word Stroop, or wStroop. An advantage of using SAD as a model of cognitive bias is that SAD symptoms are typically restricted to the winter, and subside in the summer, which allowed us to test for winter-summer differences both in behavioural and electrophysiological responses to emotional trigger words.

This replication would have three important benefits: (1) it would support our initial EAP findings, and (2) it would extend our previous results using the dStroop in
participants with and without depression symptoms, and finally (3) a study using s-SAD participants allows us to create a within-subjects design by including a longitudinal component. Participants with winter SAD are on a predictable cycle of relapse and remission: By testing participants once in the winter and then again in the summer, we can look at how the EAP is affected by relapse and remission.

To this goal, two experiments were conducted. In the first experiment, we studied a group of highly seasonal individuals in the winter, to test the hypothesis that s-SAD participants would exhibit an eStroop interference effect (such as in Spinks et al, 2001) and an EAP to the winter words in the wStroop. We also included a dStroop as a localizer task for the EAP discovered in study 1, which was observed in both groups independent of depression status.

We posit that if an EAP occurs it will show similar features as the EAP to depression words, but that the EAP for winter words will occur selectively for s-SAD participants, because these words are salient and aversive for these participants, but not for a comparison group with low seasonality. In the second experiment, we re-tested the same groups to explore whether or not these effects continued to be seen in the summer, when s-SAD participants were presumably in remission. If emotional interference and EAP effects continued to be seen in the summer, it would suggest that these effects may be a disease or trait marker in SAD, which is always present in people with s-SAD regardless of their symptom severity. Conversely, if the effects disappear in the summer, it would suggest that they might be related to symptom severity (state markers) rather than to a persistent latent dysfunction possibly associated to the neurobiology of SAD.
3.2.3 Hypotheses

The main hypotheses of the present study are as follows: (1) The s-SAD group will exhibit interference to winter words and show an EAP effect during the winter session, while no such effects will be present in the comparison group. This hypothesis is tested in Experiment 1 (winter session). (2) We will test the null hypothesis that the behavioural and EAP effects observed in the winter session will dissipate during testing in the summer session in parallel with expected symptom remission. This hypothesis is tested in Experiment 2 (comparison of winter and summer sessions).

3.3 Experiment 1

3.3.1 Methods

This experiment involved a screening phase and an experimental phase conducted in the winter. The Simon Fraser University Research Ethics Board approved both phases. All participants read and signed a consent form before participating and received either course credit or a monetary incentive for their involvement.

3.3.1.1 Participants

Over two semesters, 964 undergraduate students (607 women) enrolled in either introductory or second year psychology courses at Simon Fraser University were screened using the Seasonal Pattern Assessment Questionnaire (SPAQ; Lam, Zis, Grewal, Delgado, Charney, & Krystal, 1996). The average age was 18.07 ± 2.34 years. The SPAQ was administered as part of a much larger battery of tests, and the tests were counter-balanced. Participants filled out a demographics sheet (see Questionnaire 3.1) in addition to the battery, and in total testing took 40 minutes. Screening occurred in large
auditoriums and participants were asked to sit in every other seat to ensure confidentiality. Codes were used to associate personal information (e.g., name and contact information) with the questionnaires, and were not written on the questionnaires themselves. Over 80 participants were contacted, and over one half of these were scheduled, but seven could not be run because they did not speak English as their first language. Seventeen participants where found to meet the criteria for s-SAD on the SPAQ (the most important criteria are a Global Seasonality Score, or GSS of more than 11, and moderate to severe symptoms). At screening the s-SAD averaged a GSS of 13.87 ± 2.45. The s-SAD the sample (n = 17) included 12 females, and the average age was 19.9 ± 3.9. The comparison group (n = 17, 9 females, age = 21.5, ± 3.2) had SPAQ scores in the normal range (normal GSS range = 5, comparison group GSS = 3.11 ± 1.76 at the time of screening,), with no SAD symptoms. Of these participants, the ERP data for two s-SAD and three comparison participants had to be discarded due to excessive EEG artifacts. This left a total winter sample of 15 SAD participants (GSS = 12.80 ± 3.17 at the time of EEG testing, 10 females, age = 19.9 ± 4.0 years old) and 14 comparison participants with a GSS in the average range, (GSS = 4.43 ± 2.82 at time of EEG testing, 8 females, age = 21.9 ± 3.3) for ERP analysis (see Table 31 for demographics).

3.3.1.2 Questionnaire Measures

3.3.1.2.1 Medical Screening Questionnaire

A medical screening questionnaire was administered at the beginning of the experiment to screen for possible neurological deficits resulting from previous medical problems or accidents, previously diagnosed mental problems/disorders, sleeping habits,
alcohol and medication consumption, and previous participation in electrical brain recording/imaging studies (See Table 3.2 and Questionnaire 2.1).

3.3.1.2.2 **Seasonal Pattern Affective Questionnaire**

The SPAQ uses 6 items with a 5-point Likert scale to assess how much mood, activity, and sleep length change over the year. The extremes of the Likert scale are “No change,” and “Extremely marked change.” These items are then summed to give a total Global Seasonality Score (GSS) that can range from 0 (no seasonality) to 24 (extreme seasonality). The average GSS in community samples is approximately five (Lam et al., 1996). The screening criteria for a “diagnosis” of sub-syndromal SAD are based on three criteria: (1) a GSS of 11 or higher, (2) depressive mood evident in the winter months of January and February, and (3) an indication that these changes are considered to be a moderate to severe problem (Lam et al., 1996). All high SPAQ scorers used in this study met all three of the criteria for s-SAD. Participants with little seasonality (GSS ~ 5), no depression in the winter months, and no problem with seasonal mood changes were considered low scorers and were used in the comparison group (as recommended by Lam, et al., 1996) (See Questionnaire 3.2).

3.3.1.2.3 **The Beck Depression Inventory (BDI)**

The Beck Depression Inventory version 2 (BDI-II) was administered upon completion of the ERP component of the study. The BDI-II is a 21-item self-report questionnaire that assesses the existence and severity of symptoms of depression. Items relate to the constructs of sadness, pessimism, failure, dissatisfaction, and guilt. A Likert scale is used to score items, from zero, “I do not feel sad,” to three, “I am so sad or
unhappy that I can’t stand it.” The scores sum to give a single total score from 0-63 (Beck, et al., 1996; see Questionnaire 2.2).

3.3.1.3 Stimuli and Apparatus

The experiment was conducted in a sound-attenuated room. Stimuli were displayed on a 19-inch computer monitor and responses were made using the four shoulder buttons of a game-pad (Logitech, Romanel-sur-Morges, Switzerland). The index and middle fingers of both hands were used to make responses. The modified eStroop tasks consisted of single colour words written in either blue, red, green or yellow and flashed for 300ms just above a central fixation cross (Presentation software version 9.70, Neurobehavioural Systems, Davis, USA). Half of the stimuli were emotional words with content related to either the winter season (see Figure 3.1) or depression (see Figure 3.2). The remaining half were emotionally neutral words, individually matched with the emotional stimuli for word length and Kucera-Francis written frequency in the English language, using an online database (Wilson, 1988; see Table 3.3). Emotional and neutral words were randomly interspersed, but the winter-words and depression words were presented in separate wStroop and dStroop blocks. Block order was randomized. Stimuli length varied from 2.77° (“cup”) to 11.94° (“typewriter”), and had a standard height of 1.39°, measured by visual angle. The inter-stimulus interval was randomly jittered between 1700-2300ms. There were nine words of each type, and each word was presented three times in each of the four colours. Therefore, in total there were a total of 108 trials per condition. The entire behavioural experiment took approximately 35 minutes.
3.3.1.4 Procedure

ERP recordings were collected during the winter (January-early March). Participants were seated 60 cm from the screen and were instructed to maintain their gaze on the central fixation at all times, while trying to avoid or minimize eye blinks, motion, and muscle tension. They were told that while different types of words were flashed on the screen, they had to pay attention and respond to only the colour of the word, by pressing one of the four designated buttons. All participants were asked to practice to an 80% criterion on the practice block before beginning the experiment. The software allowed us to record and separately bin the correct reaction times (RTs) and errors, and save the data in log files for offline behavioural analysis.

3.3.1.5 Electrophysiological Recording

EEG was recorded from 63 tin electrodes positioned at FP1, FPz, FP2, AF3, AF4, F7, F5, F3, F1, Fz, F2, F4, F6, F8, FC5, FC3, FC1, FCz, FC2, FC4, FC6, T7, C5, C3, C1, C2, C4, C6, T8, CP5, CP3, CP1, CPz, CP2, CP4, CP6, P9, P7, P5, P3, P1, Pz, P2, P4, P6, P8, P10, PO7, PO3, POz, PO4, PO8, O1, Oz, O2, Iz, and M1 (American Electroencephalographic Society, 1994) as well as five non-standard sites inferior to the standard occipital locations. Electrodes were mounted in an elastic cap (Electrocap Inc.). All EEG signals were referenced to the right-mastoid. The horizontal electrooculogram (HEOG) was recorded with two electrodes, positioned lateral to the external canthi. Electrode impedances were kept below 10 kΩ. All signals were recorded with a bandpass of 0.1–100 Hz (-3 dB point; -12 dB per octave). EEG data were recorded with a modern amplifier (SA Instrumentation, San Diego, CA) at a sampling rate of 500 Hz and a gain of 20,000. Artifact rejection was performed to remove trials with horizontal eye
movements, blinks and amplifier blocking. Stimulus presentation and data acquisition were controlled by Presentation (Neurobehavioural Systems, Albany, CA) and Aquire! (HEL, Burnaby, BC), respectively.

3.3.1.6 Behavioural Statistics

Repeated measures analysis of variance (ANOVA) analyses were used to compare the behavioural performance of the Groups (s-SAD vs. comparison) on both eStroops, across Emotion (emotional vs. neutral). When we had a priori hypotheses, or when the global ANOVA was significant, post-hoc repeated measures ANOVAs were performed within-groups to further explore the effects.

Analyses of both the RTs and the proportion of errors [p (errors)] in each condition were only conducted on participants that could be used in the ERP analyses (n = 29). Please note that in the winter season, BDI scores were significantly higher in the s-SAD compared to the comparison group [s-SAD = 10.77 ± 1.5; Comparison = 3.0 ± 1.5, F (1, 28) = 13.35, p = 0.001], but this was not used as a covariate because the BDI and SPAQ both tap into the construct of depression; in other words, depression is a criteria for s-SAD.

3.3.1.7 ERP Statistics

ERP averages were obtained for winter and neutral words, time-locking to word onset (200 ms pre-stimulus baseline and 800 ms post-stimulus). All channels were re-referenced to the average of the two mastoid electrodes, and smoothed twice using a 7-point running average filter. ERP amplitudes were aligned to a 100 ms pre-stimulus baseline period. Grand averages were calculated across subjects for each Emotion word-
type (winter and winter-matched-neutral, depression and depression-matched-neutral) and Group (s-SAD vs. comparison). To help isolate effects of interest, within-group difference waves were calculated. Then, to facilitate visualization, scalp voltage topographic distribution maps were obtained using spherical spline interpolation (Perrin, Pernier, Bertrand, Giard, Echallier, 1987).

3.3.1.8 Regions of Interest

After inspection of grand-average waveforms and scalp topography distributions for each emotion, as well as various difference waves, our effect of interest was identified. ERPs to emotional words were characterized by greater amplitude of a slow positive wave (referred to as the Early Anterior Positivity or the EAP) with a focal scalp distribution over bilateral frontal scalp, similar to the EAP found in study 1 of this project.

Regions of interest (ROIs) were selected by averaging together neighbouring electrode sites where the voltage difference appeared to peak. For the EAP (200-300 ms) the following sensors were collapsed to create two frontal ROIs: F3-F4, AF3-AF4, F5-F6, C3-C4 and FC5-FC6. For all analyses, the critical p-value was set at .05 (degrees of freedom were corrected with the Greenhouse-Geisser epsilon method; Greenhouse & Geisser, 1954).

Repeated measures ANOVAs F-statistics were calculated to compare the voltage amplitudes across Groups (s-SAD vs. comparison) on both eStroops, across Emotion (emotional vs. neutral), and Hemisphere (right vs. left). When we had a priori hypotheses, or when the global ANOVA was significant, post-hoc repeated measures ANOVAs were used to explore effects within each Group or Hemisphere.
3.3.2 Results

3.3.2.1 Behavioural Results for the wStroop

For the wStroop in the winter season there were no significant RT differences for Emotion \( F(1, 27) = 0.20, p > .05 \), or Group \( F(1, 27) = .020, p > .05 \), and no Emotion x Group interaction \( F(1,27) = .054, p > .05 \). (Please see Figure 3.3).

In the p (errors) analysis of the wStroop no effects of Emotion \( F(1,27) = .024, p > .05 \), or Group \( F(1,27) = .001, p > .05 \) where found, and no interaction \( F(1,27) = .516, p > .05 \).

3.3.2.2 Behavioural Results for the dStroop

For the dStroop RT analysis the repeated measures ANOVA also showed no significant effects, Emotion \( F(1,27) = .824, p > .05 \), or Group \( F(1,27) = .003, p > .05 \), and no Emotion x Group interaction \( F(1,27) = 2.44, p > .05 \) (Please see Figure 3.4).

In the p (errors) analysis of the dStroop however, although no main effects reached significance \( \text{Emotion} = F(1, 27) = .324, p > .05; \text{Group} = F(1, 27) = .028, p > .05 \), showed a significant interaction of Emotion x Group, \( F(1, 27) = 4.495, p < .05 \). The s-SAD group made marginally more errors in the depression word \( p \) (errors) = .064] than the neutral condition \[p \) (errors) = .048], \( F(14) = 3.92, p = .068 \), compared to the comparison group, who did not \[\text{depression} p \) (errors) = .054; neutral [p \) (errors) = .063], \( F(13) = 1.11, p > .05 \). (See Table 3.4).

3.3.2.3 ERP results for the wStroop

In the wStroop EAP (200-300 ms) analysis we found no main effects, but the interaction of Emotion x Group was significant, \( F(1,28) = 4.956, p = .035 \), and the
interaction of Emotion x Hemisphere approached significance, [F (1, 28) = 3.42, p = .076]. We therefore broke the analysis down by Group and Hemisphere and found that in the s-SAD group the main effect of Emotion was significant, [F (1, 14) = 5.67, p = .032, winter word = 6.05 μV, neutral words = 4.19 μV], while the Emotion x Hemisphere interaction was non-significant, [F (1, 14) = 2.73, p = .12]. Based on the scalp topography in the s-SAD group we ran exploratory analyses within each hemisphere. Within hemispheres, the effect was more robust over the left hemisphere, [F (1,14) = 7.09, p = .019], and marginally significant over the right hemisphere, [F (1,14) = 3.89, p = .069]. (See Figure 3.5).

These results differ greatly from the comparison group, where the main effect of Emotion was far from significant, [F (1,13) = 0.44, p<.05], and the main effect of Hemisphere and the interaction of Emotion x Hemisphere did not approach significance. Since no effect was close to significance in the comparison group, the effects were not analyzed further. (See Figure 3.5).

3.3.2.4 ERP results for the dStroop

In the global analysis the main factor of Emotion was highly significant, [F (1, 28) = 27.06, p<.0001], with depression words eliciting more positive activity than neutral words across both groups. There was no Group main effect, but there was a 3-way significant interaction of Emotion x Hemisphere x Group, [F (1, 28) = 8.32, p = .008]. In light of the significant 3-way interaction, more restricted ANOVAs were carried out within Hemispheres and within Groups. The main effect of Emotion was greatest over the right hemisphere, [F (1, 28) = 32.91, p = .0000], but was also significant over the left hemisphere, [F (1,28) = 17.62, p<.0001].
In the s-SAD group the restricted ANOVA showed a Main effect of Emotion \( [F (1, 14) = 14.48, p = .002] \), and there was a significant Emotion x Hemisphere interaction, \( [F (1, 14) = 5.63, p = .033] \). In the breakdown of this interaction, the emotion effect was strongest over the right hemisphere \((\text{depression words} = 8.00\mu V, \text{neutral} = 4.65\mu V, F (1,14) = 29.8, p = .000, \text{see Figure 3.6})\) while it was marginally significant over the left hemisphere \((6.95\mu V \text{ vs.} 5.09\mu V, F (1, 14) = 4.54, p = .051, \text{see Figure 3.6})\).

In the comparison group, the main effect of Emotion was significant, \( [F (1, 13) = 12.63, p = .004] \), with more positive voltage for depression than neutral words, and the Emotion x Hemisphere interaction approached significance, \( [F (1, 13) = 3.43, p = .087] \). When the analysis was repeated within each hemisphere, there was a stronger effect of Emotion over the left hemisphere, \( [F (1, 13) = 16.21, p = .001, \text{depression} = 7.77\mu V \text{ vs. neutral} = 4.80\mu V, \text{see Figure 3.6}] \) than the right hemisphere, \( [F (1, 13) = 8.90, p = .011, \text{depression} = 7.93\mu V \text{ vs. neutral} = 5.41\mu V, \text{see Figure 3.6}] \).

### 3.3.3 Discussion

To summarize, the main hypotheses of this study were largely supported. The s-SAD group had a higher error rate for depression words in the dStroop relative to neutral words, suggesting an interference effect occurred in this group. No RT or error rate differences were present in the comparison group. More importantly, as anticipated, we found large amplitude EAPs to winter words in the s-SAD group but not in the comparison group. These findings confirm the prediction that s-SAD participants, tested during the winter season, display larger amplitude ERPs to winter than neutral words, while this effect was absent in the comparison group.
In the behavioural analysis, we found only a difference in the proportion of errors made in the dStroop, while we did not obtain an emotional RT interference effect in either Stroop tasks. We can only speculate that depression words may have been a more powerful trigger to precipitate a performance difference in s-SAD group, because these words were highly salient, aversive and self-relevant to the s-SAD group. Only two previous studies used eStroop tasks with concern-specific stimuli in seasonal populations. Spinks and colleagues (2001) used a winter-word related eStroop in a clinical population and found significant RT interference effects in both the winter and summer. Rohan and colleagues (2004) used an eStroop with words related to light and dark. Interestingly, they used a sub-syndromal sample and did not find a Stroop RT interference effect. It is possible that these differences occurred because by using a sub-syndromal sample, which experiences less severe symptoms in the winter, both Rohan and colleagues and the present study attained a smaller effect size.

In the wStroop the s-SAD participants showed a bilateral EAP effect over the frontal electrode sites which appeared to peak between 200-300 ms. This effect was absent in the comparison group. Our results in the dStroop confirmed the results in a previous study run in our laboratory (study 1), in that the EAP was elicited to depression words in both the s-SAD and comparison groups. As discussed in chapter 2, we believe that the EAP occurs in all of our participants because of the high salience and the negative valence of the words we used, which is why these words can even elicit a response in comparison subjects. Interestingly, in another study in our laboratory, no EAPs were elicited by positive versus neutral valence words (Taake et al, in prep). One interesting aspect of the results is the hemispheric difference in scalp topography of the
EAP to depression words in the s-SAD and comparison group. The effect was strongest over the right frontal regions in the s-SAD group, while it was greatest over the left hemisphere in the comparison group. A large body of literature reports right hemisphere dominance for emotional processing, particularly as it pertains to depression (reviewed in Liotti & Panksepp, 2004). We can only speculate that for the s-SAD subjects who currently exhibit affective symptoms (including a cognitive bias), the depression word may be self-relevant and also mood-congruent, and this would engage the right hemisphere to a greater degree than the left. In contrast, the left frontal focus in the comparison group could represent a response to a salient threat stimulus that is not inherently mood-congruent. In support of the latter hypothesis, we have observed a left-lateralization of the EAP employing physical threat words in a parallel study (Taake et al, in prep). Therefore, we think EAP reflects a response to salient, negative, mood-congruent or self-relevant words when it occurs on the right, and that it may represent the processing of words that are self-relevant, and threatening when it appears on the left.

Very few studies have reported an effect similar to the EAP. We think that this is because early frontal positivities only occur when a paradigm presents emotional material to participants in such a way as to make emotion task-irrelevant or implicit. The great majority of the published ERP studies on emotional stimuli ask subjects to overtly categorize the emotional stimulus (i.e., “Is this positive or negative?”), and this creates a large LPP effect (Fischer & Bradley, year) rather than an EAP. The idea that the EAP only occurs when emotion is implicit fits well with the theory that the EAP indexes the activation of a threat-detection system. This hypothesis needs to be formally tested in future studies.
As we found evidence confirming our first hypothesis that the s-SAD group will exhibit an EAP effect during the winter session to winter and depression words, we went on to test our second hypothesis: that the behavioural and EAP effects observed in the winter session would dissipate during the summer session in parallel with expected symptom remission. The longitudinal component of this study, Experiment 2, was conducting during the summer and early fall.

### 3.4 Experiment 2

#### 3.4.1 Methods

This experiment was conducted in the summer from early June to early September, and was approved by the Simon Fraser University Research Ethics Board. All participants read and signed a consent form before participating and received either course credit or a monetary incentive for their involvement.

#### 3.4.1.1 Participants

Participants we contacted by electronic mail and asked to take part in the second part of our study in early June. Testing occurred from early June through early September. Of the 15 s-SAD and 14 comparison individuals that participated in the first experiment, 9 s-SAD (GSS = 12.22 ± 1.48, 6 females, age = 18.56 ± 0.88) and 11 comparison participants (GSS = 4.55 ± 3.11, 6 females, age = 21.09 ± 3.3) took part in the longitudinal component of the project, (i.e., were able to return for a second full session; see Table 1 for demographics).

BDI scores continued to be higher in the summer for s-SAD participants [F (1, 18) = 66.51, p<.001], but did not change significantly between sessions [winter BDI =
8.56 ± 4.82; summer BDI = 7.33 ± 4.36, F (1, 8) = 0.34, p>.05]. It is worth noting, that of the 5 s-SAD subjects who did not return for the summer session, 4 were high BDI scorers (with three having a BDI > 18). This may have contributed to the lack of significant BDI differences between seasons.

3.4.1.2 Questionnaires

All of the questionnaires used in experiment 1 were re-administered to the participants in experiment 2. For specific information on the questionnaires, please refer to experiment 1 (Please see Questionnaires 2.1, 2.2, 3.1, and 3.2). Results for the Medical Questionnaire are reported in Table 3.2.

3.4.1.3 Stimuli and Apparatus

The stimuli and apparatus remained the same between experiments. For detailed information about the stimuli and apparatus, please refer to experiment 1 (For examples of the eStroop tasks please see again Figures 3.1 and 3.2).

3.4.1.4 Procedure

The stimuli and apparatus remained the same between experiments. For detailed information about the stimuli and apparatus, please refer to experiment 1.

3.4.1.5 Electrophysiological Recording

The same equipment and filtering procedures were used to collect EEG during Experiment 1 and Experiment 2 (for detailed descriptions please see Experiment 1).
3.4.1.6 Behavioural Statistics

ANOVA's were used to compare the behavioural performance of the Groups (s-SAD vs. comparison) on both eStroop tasks, across Emotion (emotional vs. neutral) and Season (winter vs. summer). When we had *a priori* hypotheses, or when the global ANOVA was significant, post-hoc repeated measures ANOVA's were performed within-groups to further explore the effects.

Analyses on both the RTs and the proportion of errors [p(errors)] were only conducted on participants that were used in the ERP analyses (n = 20).

3.4.1.7 ERP Statistics

Timing locking, averaging, re-referencing and filtering procedures did not change between experiment 1 and experiment 2. Grand averages were calculated across subjects for each Emotion (i.e., winter and winter-matched-neutral, depression and depression-matched-neutral), Group (s-SAD vs. comparison) and Season (winter vs. summer). To help isolate effects of interest, within-group difference waves were calculated. Then, to facilitate visualization, scalp voltage topographic distribution maps were obtained using spherical spline interpolation (Perrin, et al., 1987).

After inspection of grand-average waveforms and scalp topography distributions a focal scalp distribution over bilateral frontal scalp, 200-300 ms after the onset of emotional words was identified. Additionally, between season contrasts showed P1 (100-150 ms) modulations and a Late Posterior Positivity (LPP; 300-500 ms). These additional effects have been treated as exploratory in this study.
3.4.1.8 Regions of Interest

Regions of interest (ROIs) were selected by averaging together neighbouring electrode sites where the voltage difference appeared to peak. For the EAP (200-300 ms) the following sensors were collapsed to create two frontal ROIs: Right = F4, AF4,F6,C4 and FC6; Left: F3, AF3, F5, C3 and FC5. Additionally, based on visual inspection of the grand-average waveforms and seasonal difference waves, P1 differences could be seen for winter words. Two occipital ROIs were selected, collapsing 4 neighbouring sensors, a left ROI (PO3, PO7, O1 and O3) and a right ROI (PO4, PO8, O2 and O4). Finally, for a later LPP window, a posterior midline ROI was chosen, collapsing sites Pz, POz and Oz. Again, for all analyses, the critical p-value was set at .05 (degrees of freedom were corrected with the Greenhouse-Geisser epsilon method, 1954).

Repeated measures ANOVAs F-statistics were calculated to compare the voltage amplitudes across Groups (s-SAD vs. comparison) on both eStroops, across Emotion (emotional vs. neutral), Season (winter vs. summer) and Hemisphere (right vs. left). When we had an a priori hypothesis or when the global ANOVA was significant, post-hoc repeated measures ANOVAs were used to explore within Group, Season and Hemisphere.

3.4.2 Results

3.4.2.1 Behavioural Results for the wStroop

Analyzing the RT to wStroop words, we found no significant effect of Season [F (1, 18) = 2.46, p>.05], or of Emotion [F (1, 18) = .256, p>.05], or of Group [F (1, 18) = .036, p>.05], and no significant interactions. (Please see Figure 3.3). There was a trend for a block effect, which looked similar to the dStroop results.
Looking at the p (errors), we found no significant difference in errors between Season [F (1, 18) = .346, p >.05], Emotion [F (1, 18) = .014, p >.05] or Group [F (1, 18) = 1.46, p >.05], and no significant interactions.

3.4.2.2 Behavioural Results for the dStroop

In the dStroop, the RT analysis showed no significant difference across Season [F (1, 18) = 1.52, p >.05], Emotion [F (1, 18) = .55, p >.05], or Group [F (1, 18) = .084, p >.05], but a significant three-way interaction, Season x Emotion x Group, [F (1, 18) = 4.60, p <.05]. (Please see Figure 3.4).

Using repeated measures ANOVAs within groups did not elucidate the effects, p >.05 for all contrasts. Using paired-sampled t-tests however, we found a marginally significant effect in the s-SAD group for depression vs. neutral words, such that they were 24 ms faster to respond to depression words in the summer [t(8) = -2.06, p = .074] than during the winter season. This effect did not hold for the comparison group, [t(10) = .638, p >.05]. Interestingly, S-SAD participants also showed a trend to respond more slowly to depression words in the winter than the summer season (difference = 38.5 ms, t(8) = 1.937, p = .089), while there no significant seasonal differences in the comparison group [winter RT = 688.6 ms ± 81.0; summer RT = 675.9 ms ± 95.0, t(10) = .516, p >.5].

In the analysis of the p (errors) made during the dStroop, no main effects or interactions approached significance, but a highly significant three-way interaction of Season x Emotion x Group, [F (1, 18) = 9.614, p <.01] occurred. Looking within-groups there was a significant Season x Emotion interaction in the comparison group [F (10) = 14.76, p <.01], with 1.94% more errors on neutral words in the winter and 1.43% fewer
errors on neutral words in the summer. The paired-sample t-tests did not reach significance (please see Table 3.4).

3.4.2.3 ERP Effects for the wStroop

3.4.2.3.1 EAP (200-300ms)

Based on our hypotheses, repeated Measures ANOVAs were run within each Group (s-SAD = 9; comparison n = 11), with Season (winter vs. summer), and Emotion (winter vs. neutral word) as within subject factors. As well, inspection of the grand-average waveforms and difference waves suggested a right lateralization of the effects; therefore analyses were carried out on each hemisphere separately.

In the s-SAD group, over the right frontal ROI, there was no main effect of Season, \( F(1, 8) = 0.99, p<.05 \), nor Emotion, \( F(1, 8) = 0.17, p<.05 \), but the interaction of Season x Emotion was highly significant, \( F(1, 8) = 19.49, p = 0.002 \). This effect was due to opposite emotion effects on the EAP in the winter and summer seasons [winter-winter word = 6.27 ± 2.26μV vs. winter-neutral word = 4.00 ± 2.17μV, \( F(1, 8) = 8.56, p = .019 \); summer-winter word = 2.36 ± 2.74 μV vs. summer-neutral word = 4.10 ± 2.43 μV, \( F(1, 8) = 5.41, p = .048 \), See Figure 3.7]. Over the left frontal ROI, there was a main effect of Emotion, \( F(1, 8) = 5.75, p = 0.043 \), with the Season x Emotion interaction only approaching significance, \( F(1, 8) = 4.12, p = 0.077 \).

The comparison group in the summer, showed no main effects in the right hemisphere (for all, \( p>.17 \)), and the interaction of Season x Emotion did not approach significance, \( F(1, 11) = 3.02, p = .11 \). In the winter season, there was no difference between winter and neutral words [winter words = 5.91 ± 2.39 μV; neutral words = 5.34 ± 2.13 μV, \( F(1, 10) = 0.47, p<.05 \); in the summer season, there was a trend for winter
words being less positive than neutral words [winter words = 3.06 ± 2.35 μV; neutral words = 5.07 ± 1.96 μV, F (1, 10) = 3.74, p= .082] (see Figure 3.7). Over the left hemisphere, main effects and the interaction of Season x Emotion were far from significant (for all, p>.44).

In summary, the comparison group only showed a trend toward a reduced EAP to winter words in the summer. The s-SAD group exhibited a selective enhancement of the early-evoked response to winter words relative to neutral words over anterior frontolateral scalp in the winter. This effect disappeared in the summer, when an opposite trend was observed- a reduced EAP to winter words.

3.4.2.3.2 P1 (100-150ms)

Upon visual inspection of the grand-average waveforms and difference waves, we noticed P1 differences for winter words across seasons. Therefore we conducted an exploratory analysis and found a significant interaction of Season x Hemisphere x Group [F (1, 18) = 8.27, p = 0.01]. Restricted ANOVAs were carried out in each group separately.

In the s-SAD group the interaction Season x Hemisphere was highly significant, F (1, 8) = 12.8, p = 0.007. Over the right hemisphere P1 amplitudes to all winter block words in the summer season were on average twice the amplitude of the P1s to the same words in the winter season (winter = 5.48 ± 0.87 μV; summer = 10.60 ± 2.52μV), F (1, 8) = 8.8, p = 0.022, and the summer effect was significantly greater over the right than the left ROI [left ROI = 5.81 ± 2.04 μV, right ROI = 10.60 ± 2.52 μV, F (1.8) = 5.56, p = 0.046, see Figure 3.8].
In the comparison group, the interaction Season x Emotion was significant, $F(1,10) = 5.52, p = 0.04$. Over the left ROI, the effect was more robust, $F(1,10) = 7.50, p = .021$, while it was marginally significant on the right ($p = .086$). During the Winter season, there was a P1 enhancement in response to winter words relative to neutral words, $F(1,10) = 7.19, p = .023$ (winter words = 13.04 ± 2.78 μV; neutral words = 11.26 ± 2.70 μV), while there was a non-significant trend in the opposite direction during the summer (winter words = 12.87 ± 2.22 μV; neutral words = 12.22 ± 1.93 μV, see Figure 3.9).

3.4.2.3 LPP (300-500ms)

Visual inspection of the grand-average waveforms and difference waves, suggested that waves diverged 300-500 ms post stimulus, with words to emotional words eliciting a positivity. In a global ANOVA, only the interaction Hemisphere x Group was significant, $F(1,18) = 5.14, p = .036$. No pair-wise contrasts reached significance. No other main effects or interactions involving Emotion, Season or Group approached significance (for all, $p>.13$).

3.4.2.4 ERP effects for the dStroop

3.4.2.4.1 EAP (200-300ms)

As in the winter words, because we had a priori hypothesis about the s-SAD group, repeated measures ANOVAs were run within each group (s-SAD vs. comparison), with Season (winter vs. summer), Emotion (depression vs. neutral) and Hemisphere (Left vs. Right ROI) as the within group factors.

In the comparison group, the main effect of emotion on EAP amplitude was highly significant, $[F(1,10) = 16.30, p = .002]$, with greater amplitudes for depression
than neutral words. Interestingly, the main effect of Season was also marginally significant, \( F(1, 10) = 4.16, p = .069 \), with greater EAPs in the winter than summer sessions. There was a significant Emotion x Hemisphere interaction, \( F(1, 10) = 5.87, p = .036 \), and a marginally significant Season x Emotion x Hemisphere interaction \( F(1, 10) = 4.45, p = .061 \). Looking within season in the comparison group in the winter session, there was a highly significant main effect of Emotion, \( F(1, 10) = 20.55, p = .001 \), with greater EAPs to depression than neutral words (depression = 8.08 ± 1.91 μV, neutral = 5.73 ± 1.83 μV). There was no significant Emotion x Hemisphere interaction, \( F(1, 10) = 1.58, p < .05 \). In the summer session, there was a main effect of Emotion, \( F(1, 10) = 7.03, p = .024 \), and an interaction of Emotion x Hemisphere, \( F(1, 10) = 7.88, p = .019 \). The Emotion effect was significant over the right ROI, \( F(1, 10) = 9.29, p = .012 \) (depression = 6.63 ± 1.91 μV, neutral = 3.20 ± 1.87 μV) while it was only marginally significant over the left ROI, \( F(1, 10) = 4.58, p = .058 \). In summary, an effect of emotion on the EAP was present for both winter and summer sessions in the comparison group (Figure 3.10).

Conversely, in the s-SAD group, the main effect of Emotion was marginally significant, \( F(1, 8) = 4.98, p = .056 \), and the interaction of Season x Hemisphere was significant, \( F(1, 8) = 6.35, p = .036 \). In the winter session, the effect of Emotion was significant, \( F(1, 8) = 7.12, p = .028 \), with higher amplitude EAPs for depression than neutral words (depression = 6.35 ± 2.65 μV, neutral = 3.76 ± 2.00 μV). The effect was stronger over the right hemisphere, \( F(1, 10) = 8.69, p = .018 \), while it was marginally significant over the left ROI \( F(1, 10) = 4.42, p = .069 \). In contrast, in the summer season there was no hint of a main effect for Emotion, \( F(1, 8) = .02, p < .05 \), depression =
4.06 ± 2.61 μV, neutral = 3.90 ± 2.61 μV)] or for the Emotion x Hemisphere, interaction [F (1, 8) = 1.33, p<.05].

In summary, depression words elicited significantly greater EAP over anterior frontolateral scalp during both winter and summer sessions in the comparison group. In contrast, in the s-SAD group depression words elicited greater EAP in the winter session, but not in the summer session (See Figure 3.10).

3.4.2.5 P1 (100-150ms)

Upon visual inspection of the grand-average waveforms and difference waves, we discovered P1 differences for depression words across the two sessions. In the global ANOVA, there was a significant interaction of Season x Hemisphere x Group, F (1, 18) = 12.40, p = 0.002. Restricted ANOVAs were therefore carried out in each group separately.

In the comparison, there were no trends for significant main effects or interactions neither in the global analysis (for all, p>.15), or when the two ROIs were analyzed separately [for all effects, p>.26 (Right ROI) and p>.42 (Left ROI)]. No P1 modulations were present for the comparison group in the dStroop as a function of Season or Emotion.

Conversely, in the s-SAD group, the interaction of Season x Hemisphere was significant, [F (1, 8) = 10.62, p = 0.012]. Over the right hemisphere, P1 amplitudes to all depression block words in the summer season were on average twice the amplitude of the P1s to the same words in the winter season [winter = 5.06 ± 1.04 μV; summer = 8.81 ± 1.78 μV], F (1, 8) = 6.5, p = 0.038], and there was a marginally hemispheric difference for the summer effect [left ROI = 5.35 ± 1.48 μV; right ROI = 8.81 ± 1.78 μV, F (1,8) = 5.04, p = 0.055], such that depression words caused more positivity over the right ROI.
3.4.2.5.1 LPP (300-500ms)

This analysis used the same ROIs used for the wStroop of the LPP. In a global ANOVA, only the main effect of Emotion was significant, $F(1, 18) = 7.04, p = 0.016$. LPP amplitude to depression was greater than for neutral words (depression $= 12.73 \pm 1.17 \mu V$; neutral $= 11.57 \pm 1.04 \mu V$). No main effects or interactions involving Group, Season and Emotion approached significance (for all, $p > .15$). In summary, LPP amplitude was greater for depression words than neutral words independent of SAD status.

3.4.2.5 Influence of BDI score on the Winter and Depression Word EAPs

Since there was no significant change in BDI score in the s-SAD group between seasons, the strong EAP effects across seasons cannot be explained by changes in overall depression symptoms as reflected by the BDI. However, within seasons, when BDI score was entered as a covariate factor, the significance of the effects of emotion dropped to non-significant levels. In the winter (for the larger sample, $n = 29$), the winter BDI score was inversely correlated to the EAP for winter words in the s-SAD group ($r = -.70, p = .004$ for the L ROI; $r = -.64, p = .01$ for the right ROI). Similarly, in the winter session, the EAP to depression words was inversely correlated to BDI scores in the s-SAD group ($r = -.53, p = .041$ over the right ROI; $r = -.627, p = .012$ for the left ROI). However, in the comparison group the EAP to depression words was not correlated to BDI score ($r = .13, n.s$ for left ROI; $r = .33, p < .05$, for the right ROI).
3.4.3 Discussion

The main prediction of Experiment 2, that the behavioural and ERP effects observed during the winter in the s-SAD group would disappear during the summer, was supported. Behavioural differences were observed in the dStroop task, with longer RTs and more errors to emotional words during the winter than summer in the s-SAD group. Our main prediction that the EAP effect in the s-SAD group would be absent in the summer was also upheld, supporting the state account, i.e., that the EAP occurs only while s-SAD participants experience symptoms. In addition to the EAP, the experiment revealed an interesting and unexpected finding— a differential PI amplitude modulation over occipital areas elicited by emotional words as a function of s-SAD status and season.

3.4.3.1 Behavioural results

As in the first experiment no RT differences were found in the wStroop. The s-SAD group however, was slower to respond to the depression words in the winter, and was faster to respond to depression words in the summer. This is an unanticipated finding; previous studies using an emotional version of the Stroop found no difference across seasons (Spinks & Dalgleish, 2001). As RT is not a precise measure of cognition we can only speculate, but perhaps the RT interference effect is the outcome of two or more modulations of the processing stream. At one stage the emotionality of the stimulus might hinder processing, while at another stage of processing emotionality facilitates RT. Perhaps during the winter highly salient emotional stimuli influence the first stage, while in the summer they affect the latter.
3.4.3.2 EAP (200-300ms)

The most plausible interpretation of the presence of the EAP in the winter and the absence of the EAP in the summer is that in s-SAD participants the perceived salience or emotional value of the winter word is reduced at a time when s-SAD symptoms are in remission. Unlike words with that are self-relevant and threatening to everyone (i.e., “loneliness” in the dStroop), winter words are not inherently self-relevant or threatening. What characterizes winter words is that, like words tailored to be content-specific for anxiety disorders (i.e. “crawling” for spider phobia), they act as selective symptom “triggers”, perhaps tapping into an underlying dysfunctional cognitive structure. Previous work in anxiety disorder patients has shown that cognitive therapy, which addresses the negative bias in the cognitive structure of people with affective disorders, also reduces the Stroop interference effect (Mogg, Bradley, Millar, & White, 1995). We speculate that the EAP is a correlate of negative bias in s-SAD, and that its disappearance in the summer may reflect a parallel normalization of their negative cognitions. Studies using a direct index of cognitive structure (the Dysfunctional Attitudes Scale, or DAS; Golden, Dalgleish & Spinks, 2006) confirm that SAD patients show less abnormally negative cognitive appraisals when SAD symptoms remit or partially remit in the summer.

It is of interest here that there is no hint of an EAP effect to depression words in the s-SAD participants in the summer. This is, in our experience, the first time that such words have not elicited a robust EAP (see study 1; Taake et al., submitted). We believe that this is a further demonstration that the cognitive outlook of the s-SAD participants is improved in the summer. To some extent even the depression words appear to be less aversive and self-relevant in the summer. A possible mechanism to explain this effect is suggested by evidence that baseline amygdala activity is increased during episodes of
unipolar MDD, and can be reduced or normalized by treatment-induced symptom remission (Sheline, Barch, Donnelly, Ollinger, Synder, & Mintun, 2001). We proposed in Study 1 that the EAP is generated in ventromedial PFC (particularly the rACC, see source analysis in study 1), a region that is reciprocally connected to the amygdala. Transient changes in the amygdala in response to emotional or threatening stimuli may therefore rapidly produce changes in activity in the rACC. This structure in turn would initiate behavioural responses to the source of threat. In other words, the rACC may be an integral part of a system to detect and quickly respond to threat (Williams et al., in preparation; Phelps, 2002). There is ample fMRI evidence that reciprocal sign changes in amygdala and PFC, as well as other neocortical regions, take place during emotion regulation, for example during cognitive control of emotion where participants are asked to “suppress” or “facilitate” emotion (Beauregard, Levesque, & Bourgouin, 2001) or during implicit versus explicit processing of fearful faces or other negative-valence stimuli (Bishop, Duncan, Brett & Lawrence, 2004; Vuilleumier, Armony, Driver, & Dolan, 2001; Whalen et al., 1998).

The reader should note that this interpretation of the amygdala’s role in emotion extends to our findings of EAP effects for implicit emotional processing (see below).

3.4.3.3 P1 (100-150ms)

An unexpected finding of this experiment was the P1 modulations across groups and seasons. In the s-SAD group, a P1 modulation during both the wStroop and dStroop was present only in the summer. Interestingly, this is when the EAP effects were absent.

In contrast, in the comparison group, a P1 modulation for the wStroop occurred only in the winter. Once more, there was no EAP effect for winter words in the wStroop for
the comparison group. The fact that the EAP and P1 effects do not coexist suggests a double dissociation of the ERP effects in both the wStroop and dStroop, and across the two groups. While the exact mechanisms are not known at this time, a possible interpretation is that the brain may have two different mechanisms to signal salience and vigilance to threat. The first system could be an ‘affective’ stream directly activating the amygdala/rACC to rapidly process emotionally salient, threatening stimuli in order to initiate immediate behavioural responses of survival value (also called direct pathway, Phelps, 2002). The second system might be more ‘cognitive’ and involve the facilitation of processing in visual areas of stimuli of potential consequence (in particular the fusiform gyrus). This second stream of processing would reach the amygdala indirectly, after full categorization of the stimulus through the “what” pathway (Phelps, 2002). It is possible that in this second, indirect pathway allows the amygdala to exert top-down control on the visual cortex causing the up-regulation of a gain control mechanism (Pourtois & Vuillermeier, 2006; Phelps, 2002). It has previously been theorized that healthy participants can override cognitive biases for some types of arousing stimuli in some situations by increasing the top-down control of emotional processing, but patients cannot, and therefore cannot keep arousing stimuli from being selectively processed (Williams et al, 1996). As mentioned in the introduction, the first neuroimaging study of SAD participants also found increased activity in the occipital lobe during remission (Cohen, et al., 1992). Perhaps during remission s-SAD participants increase processing of stimuli in the extrastriate cortex, reflected by P1 enhancement, and allows them to process emotionally laden stimuli in a different way than when they are experiencing affective symptoms. Note however that normal controls show no P1 effects in the
summer—therefore the summer P1 modulations likely represent a compensatory mechanism for dealing with symptom-specific stimuli, rather than normalization of processing.

Future research should explore whether or not there is a causal relationship between decreased activity in the amygdala and increased activity in the occipital lobe in MDD subtypes. Previous theories, developed in healthy participants, suggest that the amygdala is involved in triggering visual orientation to threatening locations (Vuilleumeir, 2005).

3.4.3.4 LPP effects (300-500ms)

Finally a third component was noted, a traditional LPP to negative words compared to neutral words. The LPP effect was limited to the dStroop. LPPs have been consistently elicited by arousing visual stimuli (words and faces) over neutral or positive stimuli (see Fischer & Bradley, 2006 for a review), and seems to reflect a later stage of cognitive processing where the stimulus is matched against existing semantic representations. Importantly, an LPP is typically elicited in studies of explicit emotion processing, such as when people are asked to categorize stimuli as emotional or not emotional, or whether a given attribute applies to them (Fischer & Bradley, 2006). Therefore the LPP typically reflects task-relevant processing of negative valence stimuli. However, a few studies have shown that LPP effects to negative stimuli are present but reduced in size in case of implicit emotional tasks (Fischer & Bradley, 2006). At any rate, no differences were observed across seasons or groups for LPP, unlike the P1 and EAP effects.
3.5 Conclusion

In conclusion, study 2 extended the finding of study 1 by showing an EAP to winter words in the s-SAD group in the winter, and no EAP to winter words in the summer. Our results offer evidence that the EAP may be a reflection of an early 'affective' stream, which directly activates the amygdala/rACC to rapidly process emotionally salient, threatening stimuli. This system bypasses the in-depth visual categorization of the stimulus (possibly reflected in the P1) to immediately initiate behavioral responses that have survival value. We propose that in people with subclinical affective disorders this affective "threat-detection system" may be activated by content-specific stimuli that may been given special meaning by being associated with the individual’s particular disorder, while being innocuous for people without those symptoms. For this reason s-SAD participants appear to process winter-related words in the same way as highly salient, negative stimuli, such as depression words.

The main limitation of this study is that because of its longitudinal nature the sample size was small. However, please note that we attained a study adherence of about 60%, which is remarkable given the population studied. Note also that we did not have explicit predictions about P1 effects; therefore they should be treated as exploratory. Futures studies are needed to replicate and characterize further these findings. Our claim that the EAP reflects implicit processing of emotion needs to be verified in futures studies contrasting implicit versus explicit emotion conditions (e.g., eStroops where subjects categorize the emotion while ignoring the colour). It would be interesting to see how this manipulation affects the P1 and LPP effects as well.
Future directions of this work could include using patients with clinical SAD, and using fMRI in the same populations to more precisely identify the brain regions activated in this task.

We ultimately hope that these findings will represent a step forward in understanding the dysfunctional pathways at play during relapse and remission in patients with various subtypes of clinical depression.
3.6 Figures

Figure 3.1  Study 2- Winter Stroop Stimuli
Figure 3.2 Study 2- Depression Stroop Stimuli
Figure 3.3  Study 2 Emotion by Season for the wStroop Task
Figure 3.4  Study 2- Emotion by Season for the dStroop Task

![Bar chart showing reaction times (ms) for depression and neutral words in the dStroop task, categorized by season (Winter and Summer).](image)
Figure 3.5  Study 2- wStroop in both groups during the winter

A. s-SAD group (n=15)

B. Comparison group (n=14)
Figure 3.6  Study 2 dStroop in Both Groups during the Winter
Figure 3.7  Study 2- EAP (200-300ms) for the wStroop Across Seasons in Both Groups
Figure 3.8 Study 2- P1 w/Stroop effects within the Winter Season

A. s SAD
P1 modulation
(100-150ms),
not significant

B. Comparison,
P1 modulation
(100-150ms),
highly significant
Figure 3.9  Study 2 P1 effects for the wStroop Across Seasons

A. s-SAD Group (n=9, P1 100-150 ms), winter-summer difference highly significant over the right hemisphere

B. Comparison Group (n=11, P1 100-150 ms), winter-summer difference not significant
Figure 3.10  Study2- EAP (200-300ms) dStroop in the Summer

s-SAD group (n=9)

A. EAP (200-300ms) not significant in s-SAD group

Comparison (n=11)

B. EAP (200-300 ms) highly significant in Comparison group
### 3.7 Tables

Table 3.1  Study 2- Demographics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Winter Participants</th>
<th>Summer Participants</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>High SPAQ (n = 15)</td>
<td>Low SPAQ (n = 14)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High SPAQ (n = 9)</td>
</tr>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Gender</td>
<td>5 33.3</td>
<td>6 42.9</td>
</tr>
<tr>
<td>Female</td>
<td>10 66.7</td>
<td>8 57.1</td>
</tr>
<tr>
<td>Handedness</td>
<td>(right)</td>
<td></td>
</tr>
<tr>
<td>(right)</td>
<td>13 86.7</td>
<td>14 100</td>
</tr>
<tr>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Age (years)</td>
<td>19.87 4.033</td>
<td>21.86 3.26</td>
</tr>
<tr>
<td>BDI</td>
<td>(8.56) (4.82)</td>
<td>(2.14) (1.73)</td>
</tr>
</tbody>
</table>

*Note. BDI scores in brackets are the winter scores for the group that returned in the summer.*
<table>
<thead>
<tr>
<th>Condition</th>
<th>Winter Participants*</th>
<th>Summer Participants†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High SPAQ</td>
<td>Low SPAQ</td>
</tr>
<tr>
<td>Previous Depression</td>
<td>3 20.0</td>
<td>1 7.1</td>
</tr>
<tr>
<td>Previous Anxiety</td>
<td>2 13.3</td>
<td>1 7.1</td>
</tr>
<tr>
<td>ADHD</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>Thought Disorder</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>Motor Problems</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>Loss of Consciousness</td>
<td>2 13.3</td>
<td>0 0</td>
</tr>
<tr>
<td>Concussion</td>
<td>4 26.7</td>
<td>2 14.3</td>
</tr>
<tr>
<td>Sleep Disorder</td>
<td>1 6.7</td>
<td>0 0</td>
</tr>
<tr>
<td>Migraines</td>
<td>0 0</td>
<td>1 7.1</td>
</tr>
<tr>
<td>Previous Scans</td>
<td>2 13.3</td>
<td>2 14.3</td>
</tr>
</tbody>
</table>
Table 3.3  Stimuli used in the Emotional Stroop tasks

<table>
<thead>
<tr>
<th>Winter eStroop Stimuli</th>
<th>Winter</th>
<th>Freq.</th>
<th>Neutral</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNOW</td>
<td>59</td>
<td>ROOF</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>RAIN</td>
<td>70</td>
<td>HILL</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>STORM</td>
<td>26</td>
<td>SHIRT</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>ICE</td>
<td>45</td>
<td>CUP</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>WINTER</td>
<td>83</td>
<td>SPREAD</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>DARK</td>
<td>185</td>
<td>VIEW</td>
<td>186</td>
<td></td>
</tr>
<tr>
<td>BLIZZARD</td>
<td>7</td>
<td>ELEPHANT</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>WET</td>
<td>53</td>
<td>HAT</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>FROST</td>
<td>6</td>
<td>NAPKIN</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depression eStroop Stimuli</th>
<th>Depression</th>
<th>Freq.</th>
<th>Neutral</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAD</td>
<td>34</td>
<td>BUS</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>LONELY</td>
<td>24</td>
<td>BARREL</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>MISERY</td>
<td>15</td>
<td>FABRIC</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>FAILURE</td>
<td>89</td>
<td>CLOTHES</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>HOPELESS</td>
<td>15</td>
<td>DRIVeway</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>SORROW</td>
<td>9</td>
<td>MANUAL</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>MISFORTUNE</td>
<td>15</td>
<td>TYPEWRITER</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>GRIEF</td>
<td>10</td>
<td>ELBOW</td>
<td>10</td>
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</tr>
<tr>
<td>DEFEAT</td>
<td>33</td>
<td>JACKET</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>
### Table 3.4   Errors for Depression and Neutral words across Groups and Seasons

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High SPAQ</td>
<td>Low SPAQ</td>
</tr>
<tr>
<td></td>
<td>P (error)</td>
<td>SD</td>
</tr>
<tr>
<td>Depression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>words</td>
<td>0.056</td>
<td>0.031</td>
</tr>
<tr>
<td>Neutral</td>
<td>0.042</td>
<td>0.035</td>
</tr>
</tbody>
</table>

*Note.* All values in table are calculated on the group that returned for the summer session.
3.8 Questionnaires

Questionnaire 3.1  Mass testing Demographics questionnaire

Please answer the demographic questions below:

1. Did you participate in mass testing last semester?
   Yes _____  No _____

2. Which Psychology classes are you taking this semester? ______

3. How old are you (in years)? ______

4. What is your gender? ______

5. How many semesters have you completed at SFU? ______

6. What is your major (if known)? ______

7. Were you born in Canada?
   Yes ______  No (please specify country) ______

8. Are you a foreign student?
   Yes ______  No ______

9. For how many years have you spoken English fluently? ______

10. Is English your first language?
    Yes ______  No ______

11. What is your racial/ethnic heritage?
    (We realize that selecting a broad racial category/ethnic category can be difficult for some people. Please choose the one or more than one categories that best identify how you would describe yourself.)
    Asian (Chinese, Japanese, Korean) ______
    Black ______
    First Nations ______
    Indo-Canadian ______
    Middle Eastern ______
    Hispanic (Middle or South America) ______
    White (Caucasian) ______
    Other (please specify) ______

12. The social/cultural groups that we relate and belong to, influence who we are as individuals. Which racial/ethnic group do you most closely identify with IN YOUR OWN WORDS? ______

   ______

   ______
This questionnaire is part of a larger study. Completing this questionnaire will add you to the pool of subjects who may be called back for the second part of the study. The second study involves cognitive tests and an ERP experiment, and is worth 4% towards your final mark.

Call-backs will be made through e-mail as soon as possible.

Date: ____________  Male _____  Female _____

The purpose of this questionnaire is to find out how your mood and behaviour change over time. Note: We are interested in your experience; not the experience of others you may have observed.

1. To what degree do the following change with the seasons?
(One square only for each question)

<table>
<thead>
<tr>
<th></th>
<th>0 No change</th>
<th>1 Slight Change</th>
<th>2 Moderate Change</th>
<th>3 Marked Change</th>
<th>4 Extremely Marked Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Sleep length</td>
<td></td>
<td></td>
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<td>B. Social Activity</td>
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<tr>
<td>C. Mood (feeling of well-being)</td>
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<tr>
<td>D. Weight</td>
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<td>E. Appetite</td>
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<td>F. Energy Level</td>
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</table>
2. At what time of year do you?
(Please put an X in the box for each month that applies. This may be a single month X, or a cluster of months XXX).

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<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
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<td>G.</td>
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<td>H.</td>
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<td>I.</td>
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<td>J.</td>
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<td>or no particular month(s) stand out as extreme on a regular basis.</td>
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</tr>
</tbody>
</table>

3. If you experience changes with the seasons, do you feel that these are a problem for you?

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
</table>

If yes, is the problem?

<table>
<thead>
<tr>
<th>Mild</th>
<th>Moderate</th>
<th>Marked</th>
<th>Severe</th>
<th>Disabling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>
4. By how much does your weight fluctuate during the course of the year? (Please tick only one box)

<table>
<thead>
<tr>
<th>Weight Range</th>
<th>0-3 lbs</th>
<th>4-7 lbs</th>
<th>8-11 lbs</th>
<th>12-15 lbs</th>
<th>16-20 lbs</th>
<th>over 20 lbs</th>
</tr>
</thead>
</table>

5. Approximately how many hours of each 24-hour day do you sleep during the season? (including naps) (Please circle one number for each row)

<table>
<thead>
<tr>
<th>Season</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Over 18 hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WINTER</td>
<td>(Dec 21-Mar 20)</td>
<td>(Mar 21-June 20)</td>
<td>(June 21-Sept 20)</td>
<td>(Sept 21-Dec 20)</td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18</td>
<td>0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18</td>
<td>0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18</td>
<td>0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18</td>
</tr>
</tbody>
</table>

6. Do you notice a change in food preference during the different seasons?  

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Please specify:</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. If you suffer from any other changes in your well-being across the seasons of the year, please describe in the space below.
3.9 Reference List


CHAPTER 4 GENERAL CONCLUSIONS

The goal of this work was to explore the temporal course and scalp distribution of the eStroop task, and evaluate the effect of depression or s-SAD status on the behavioural and electrophysiological correlates of disorder-congruent eStroop tasks. We found that emotional words elicited three effects, a P1 enhancement at occipital sites (100-150ms), an anterior frontal positivity effect (EAP, 200-400 ms), and a late posterior potential (LPP, 400-600 ms post stimulus onset). We suggest that these effects reflect the temporal course of cognitive biases, as they occur in healthy people with and without symptoms of depression or SAD.

The first study describes for the first time an early anterior potential (EAP, 200-300 ms) to depression words in participants with high and low depression symptoms. Using dipole source analysis we found that a source in rACC was the main contributor to this effect. In the second study we elicited the EAP again for winter words in participants with sub-syndromal SAD during the winter, which disappeared in the summer, along with symptom remission. In this study we also observed a P1 modulation over occipital scalp that appeared to occur only when the EAP was not present.

A possible interpretation of the EAP and P1 effects, particularly as a function of group and season in experiment 2, could be based on a dual pathway model for the processing of salience and threat (Phelps, 2002; Williams, in preparation). The EAP effects may index the affective stream in which information would travel from the thalamus directly to the amygdala and then to the rACC for evaluating and planning...
behavioural responses to emotionally salient, threatening stimuli. This system would be used to initiate immediate behavioural responses of survival value. In s-SAD the system appears to display a lower threshold to winter-related words during winter. In contrast, P1 modulations may index the ‘cognitive’ pathway, reaching the amygdala indirectly, after full perceptual analysis of the stimulus through the ventral visual stream. Feedback projections from the amygdala to secondary and primary visual cortex have been identified, allowing top-down control of incoming visual information, resulting in enhanced processing of salient stimuli through a sensory gain control mechanism (Phelps, 2002; Pourtois & Vuillermeier, 2006). In future work we hope continue to explore the effect of task-relevance on the processing of emotion and on the elicitation of P1 and EAP effects.