Toward a Model of Boredom: Investigating the Psychophysiological, Cognitive, and Neural Correlates of Boredom

by

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Author's Declaration

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

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Abstract

Boredom is a universal human experience that has the potential to impact a broad range of activities, especially when experienced at chronic and/or elevated levels. Despite this, research is only beginning to gain a better understanding of the construct itself. This thesis set out to examine three aspects of boredom. First, the psychophysiology of state boredom was explored to better understand whether it differs from that of sadness, a similarly valenced state (used as a proxy for depression) and to determine whether boredom is associated with increased or decreased physiological arousal. Next, state and trait boredom were examined with respect to different attentional tasks to determine whether boredom interacts with these types of attention in distinct ways. Finally, the neural underpinnings of state boredom were explored, using resting state fMRI and spatial independent components analyses. Broadly speaking, results of Experiment 1 suggested that the patterns psychophysiological responses associated with state boredom are distinguishable from sadness and that boredom is associated with increased arousal and decreased attention. In Experiment 2, trait boredom was associated with faster reaction times on a cued attention task and higher error rates on a sustained attention task, suggesting that highly boredom prone individuals may be better able to disengage their attention from transient stimuli but worse at self-sustaining attention over time. Finally, in Experiment 3, robust activation of the default network (DN) was seen during a classic resting state scan, as well as during two boring tasks (i.e., watching a boring video and completing a sustained attention task). In addition, activity in the insular cortex was anticorrelated with activity in the DN during the two boring tasks, suggesting that boredom may interfere with switching between the DN and task-positive networks when attention is required to be directed externally. Taken together, results of this thesis offer new insights into the physiological, behavioural, and neural processes that characterize the experience of boredom. Results are discussed in terms of current models of boredom.

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Chapter 1: Introduction.

Boredom represents a common phenomenon that impacts a broad and heterogeneous range of human activities. Despite the universal nature of the experience of boredom, very little research has been devoted to examining its psychological, behavioral, physiological, and neural characteristics. Most researchers agree that boredom is a subjectively unpleasant state that typically arises when a situation is construed as being monotonous or dull (Barmack, 1939; Geiwitz, 1966; Hill & Perkins, 1985; Martin, Sadlo, & Stew, 2006; Mikulas & Vodanovich, 1993); however, a range of differing theories have been proposed to explain the experience. For example, psychodynamic and existential theories focus on emptiness, inactivity, and a longing for meaningful pursuits while, at the same time, being unaware of or unable to engage in activity that would resolve these feelings (Fenichel, 1951; Frankl, 1984). Other theories focus on arousal and stimulation and hypothesize that boredom occurs when a particular environment cannot provide an optimal level of arousal (i.e., an activity or environment provides too much or too little stimulation for it to be a satisfying experience; Berlyne, 1960; Hebb, 1966; O'Hanlon, 1981). Cognitive and attentional theories posit that boredom results when individuals perceive their environment as dull or uninteresting, and that bored individuals have difficulties with concentration and sustaining attention (Carriere, Cheyne, & Smilek, 2007; Cheyne, Carriere, & Smilek, 2006; Eastwood, Frischen, Fenske, & Smilek, 2012; Fisher, 1998; Hamilton, 1981). Indeed, research has indicated that boredom is positively correlated with lapses in attention, an inability to sustain attention over time, and the subjective overestimation of the passage of time (Carriere et al., 2007; Cheyne et al., 2006; Damrad-Frye & Liard, 1989; Danckert & Allman, 2005). In addition, boredom has been investigated in relation to temperament and personality factors, addiction, as well as the function it plays in truancy, psychopathology, and other human factors (Blaszczynski, McConaghy, & Frankova, 1990; Culp, 2006; Farmer & Sundberg, 1986;

Leong & Schneller, 1993; Orcutt, 1984; Vodanovich, 2003; Vodanovich & Rupp, 1999; Watt, 1991). Despite the breadth of research related to boredom, surprisingly little research has been devoted to understanding the psychological, behavioural, physiological, and/or neural underpinnings of the construct itself. Without this understanding, it is difficult to establish criteria to identify and measure the experience.

A more comprehensive empirical understanding of the experience of boredom itself would potentially aid our understanding of certain difficult-to-treat clinical syndromes or disorders, in which self-reported boredom is a prominent symptom. For example, the subjective experience of boredom is associated with depression, and both boredom and depression often co-occur in the aftermath of traumatic brain injury (TBI; Binnema, 2004; Goldberg, Eastwood, La Guardia, & Danckert, 2011; Goldberg & Danckert, 2013; Hamilton, Haier, & Buchsbaum, 1984; Passik, Inman, Kirsh, Theobald, & Dickerson, 2003; Theobald, Kirsch, Holtsclaw, Donaghy, & Passik, 2003; Vodanovich, Verner, & Gillbride, 1991; Vodanovich, 2003). Indeed, up to two thirds of patients recovering from TBI report problems with boredom, which can be a serious impediment, hindering their engagement in rehabilitation and re-engagement in normal activities of daily life (Seel & Kreutzer, 2003). Although depressed patients may not commonly endorse experiencing boredom in a clinical setting, both boredom and depression have been highly correlated in a number of studies in the literature (e.g., $r = 0.72$ in Goldberg et al., 2011) and both are associated with related constructs including anhedonia and apathy (Goldberg et al., 2011). Thus, the experience of boredom, in and of itself, may represent a major impediment to rehabilitation or recovery (Farmer & Sundberg, 1986; O'Hanlon, 1981; Todman, 2003). Despite this, therapeutic attempts to alleviate patients' emotional distress often focus on and target symptoms of depression alone (Passik, 2003; Passik et al., 2003; Theobald et al., 2003), typically neglecting boredom altogether or conceptualizing it as an epiphenomenon of the targeted clinical symptoms. This approach may have detrimental clinical consequences. For example, in an 8-week-long open label trial of citalopram, patients who reported high levels of both boredom and depression showed early improvements in depression but no significant improvements in boredom until week six (Theobald et al., 2003). Thus, building a preliminary foundation of basic research geared toward improving our understanding of the nature of boredom and its unique features may ultimately have practical applications such as helping clinicians better recognize and address its expression.

The aim of this thesis was not to provide a complete definition or characterization of the experience of boredom; rather, the current research was designed to draw upon convergent psychophysiological, cognitive, and neuroimaging paradigms to comprehensively explore some of the processes underlying the phenomenon. This work represents some of the first steps towards building a more comprehensive understanding of boredom itself by examining its physiological, behavioural and neural substrates and endeavours to provide valuable basic information that may ultimately assist in developing treatment strategies for psychopathological and neurological disorders in which boredom is pervasive and interfering. Experiment 1 aimed to determine whether boredom has a psychophysiological profile that is distinct from the related state of sadness (here, operating as a proxy for depression). Specifically, mood induction and physiological monitoring was used to evaluate the psychophysiological correlates of boredom as contrasted with states of sadness and interest. Broadly speaking, the physiological results suggested that boredom represents a disengagement of attention associated with a negatively valenced affect. Experiment 2 built on this work by investigating the relationship between boredom (both trait and state) and measures of transient and sustained attention. The results of this experiment indicated that trait boredom had divergent effects on these distinct attentional processes. Finally, Experiment 3 used resting state functional magnetic resonance imaging (fMRI) to examine the relationship between boredom and activity in the Default Network (DN), a set of brain regions consistently linked with both mind wandering and inattention. Results from this experiment showed similar activity in the brain for both resting state scans and a boredom induction and suggest that the anterior insula, a region important for both attention and affect, plays a role in the experience of boredom. The final chapter summarizes and highlights key findings from this body of research.

Chapter 2: Exploring the physiological signature of boredom[1].

2.1. Introduction

Researchers agree that boredom is a subjectively unpleasant state arising in situations construed as monotonous (Martin et al., 2006; Mikulas & Vodanovich, 1993). However, it is not clear whether boredom is a distinct construct or an epiphenomenon of other syndromes such as ADHD or depression (Kreutzer, Seel, & Gourley, 2001). In addition, it is unclear whether boredom should be characterized as an agitated state associated with *increased* arousal (Berlyne, 1960; London, Schubert, & Washburn, 1972), or as a state of ennui associated with *decreased* arousal (Barmack, 1939; Geiwitz, 1966; Hebb, 1955; Mikulas & Vodanovich, 1993). Examining the physiological signature of boredom directly will address this distinction.

Unfortunately, the small body of research exploring the *physiological* characteristics of boredom has failed to yield consistent results perhaps because boredom has been examined indirectly. For example, previous studies have found that state boredom (i.e., situational or transient boredom as opposed to trait boredom, which reflects stable individual differences in affect) is associated with decreases in heart rate (HR) and/or skin conductance levels (SCL; Henning, Sauter, & Krieg, 1992; Mascord & Heath, 1992; Pattyn, Neyt, Henderickx, & Soetens, 2008), whereas others have reported positive associations between state boredom and physiological arousal (London et al., 1972; Lundberg, Melin, Gary, & Holmberg, 1993; Ohsuga, Shimono & Genno, 2001). This inconsistency may arise due to the fact that these studies have not focused on eliciting or examining boredom directly. Instead, they have explored boredom as a secondary consequence of tasks that were designed as control conditions for interest-eliciting

[1] This chapter has been published as Merrifield, C., & Danckert, J. (2014). Characterizing the psychophysiological signature of boredom. *Experimental Brain Research, 232,* 481-491. doi: 10.1007/s00221-013-3755-2

tasks (Henning et al., 1992; Mascord & Heath, 1992; Lundberg et al., 1993; Ohsuga et al., 2001; Pattyn et al., 2008). Studies that have explicitly contrasted state boredom and an induced state of interest did so using tasks that were non-equivalent on a range of different factors (London et al., 1972; Lundberg et al., 1993). For example, London and colleagues (1972) contrasted conditions in which participants monitored light flashes or wrote the same two letters over and over (i.e., the boring condition), with a condition in which participants wrote stories based on cards from the Thematic Apperception Test (TAT) or wrote stories based on emotionally-valenced photographs (i.e., the interesting condition). Clearly, these tasks differ on a vast array of factors. So, on one hand, research has described boredom as an apathetic state associated with low arousal; while, on the other hand, it has been described as a state of agitation, associated with increased arousal. Clearly, further research is required to disentangle these possibilities.

In addition, all previous studies that have examined the physiological signature of state boredom have contrasted boredom with distinct or even *opposite* emotional states (i.e., interest; London et al., 1972). While contrasting boredom and interest is important to our understanding of the experience of boredom, the fact that boredom also has also been consistently associated with syndromes such as depression suggests that another useful comparison would be to examine differences between boredom and sadness. Indeed, the experience of boredom has been repeatedly shown to be highly correlated with depression (Farmer & Sundberg, 1986; Goldberg et al., 2011; Passik, 2003; Passik et al., 2003; Theobald, et al., 2003; Vodanovich, 2003). This is not surprising, given that some of the symptoms that must be present for a diagnosis of Major Depressive Disorder include: 1) a sad, depressed mood; 2) a loss of interest and pleasure in usual activities; and 3) a shift in activity level, showing either psychomotoric agitation or retardation (APA, 2013). Despite the fact that previous research has demonstrated that boredom and depression are, in fact, distinct affective constructs (Goldberg et al., 2011), the two constructs remain highly correlated both at a behavioural level and at the level of symptomatology. Whereas depression is, of course, a complex and heterogeneous syndrome of symptoms and associated features that cannot be elicited in a laboratory setting, sadness represents a hallmark symptom of the syndrome that can be reliably elicited in the laboratory, where its psychophysiological characteristics can be measured and compared to that of other states (Gross & Levenson, 1995; Rottenberg, Ray, & Gross, 2007; Schaefer, Nils, Sanchez & Phillippot, 2010).

Thus, in the present study, healthy undergraduates viewed video clips previously validated to induce the subjective emotional states of boredom, and sadness, while heart rate (HR), skin conductance levels (SCL), and cortisol levels were measured at multiple epochs. A third video clip, intended to return participants' affective response to baseline between the boring and sad videos, was shown in pilot testing to induce a state of interest (Appendix C). As such, it offered the further opportunity to compare autonomic arousal during a state of interest with that of boredom and sadness. With respect to HR and SCL, peripheral autonomic nervous system (ANS) activity is considered to be a major component of the emotion response in many recent theories of emotion (Boucsein, 1992; Lang, 1995; Papillo & Shapiro, 1990; Stern, Ray, & Quigley, 2001; Winton, Putnam, & Krauss, 1984). The experience of several basic emotions has been consistently associated with changes in heart rate and/or skin conductance, indicating that these parameters represent a useful index of affect-driven psychophysiological reactivity (Cacioppo, Tassinary, & Berntson, 2000; Ekman, Levenson, & Friesen, 1983; Rainville, Bechara, Naqvi, & Damasio, 2006). Research has also demonstrated the role of the ANS in mediating the regulation of effort and attention, which make HR and SCL particularly useful measures for studying boredom given the experience has been frequently associated with deficient allocation of attention (Berntson & Cacioppo, 2000; Obrist, Webb, Sutterer, & Howard, 1970; Öhman, Hamm, & Hugdahl, 2000; Stemmler, 2004). With respect to cortisol, research has suggested that psychological stress is a potent trigger of the hypothalamic–pituitary–adrenal (HPA) axis. This system is activated simultaneously with the sympathetic nervous system (a branch of the ANS) in response to stressful conditions, including negative affective experiences, resulting in increased release of the hormone cortisol in the blood, which then diffuses to the saliva (i.e., salivary cortisol levels show a close linear relationship with plasma cortisol levels; Ansseau, 1984; Cook, et al., 1986; Greenwood & Shutt, 2004; Harris, Watkins, Cook, & Walker, 1990). Thus, in the current study, distressing affective arousal, as indexed by the activation of the HPA axis, was measured by salivary cortisol levels.

The purpose of this study was to determine whether state boredom demonstrated a psychophysiological signature that could be distinguished from the affective state of sadness. An ancillary purpose was to compare the psychophysiological response during a state of boredom to that of a state of interest. In addition, this study sought to further clarify whether the experience of boredom is associated with an increase or a decrease in physiological arousal. The final aim of this study was to examine the extent to which individual differences in trait boredom proneness are associated with the physiological measures employed. Given that boredom and depression have been shown to be distinct affective constructs (Goldberg et al., 2011), it was hypothesized that boredom would also be distinguishable from sadness in terms of both psychophysiology and self-reports of affect. As boredom and interest represent contrasting affective states, it was hypothesized that they too would be distinguishable at the level of both psychophysiology and self-reported affect. Although hypotheses regarding the direction or magnitude of differences between boredom and sadness, as well as boredom and interest, were necessarily speculative at this stage it was expected that increases in both HR and SCL would be observed if boredom is a state of high arousal whereas decreases in both measures would be expected if boredom is a state of low arousal.

2.2. Method

Participants

Participants were 68 undergraduate students (44 female), between the ages of 17 and 23 years, (*M*=18.93, *SD*=1.35) from the University of Waterloo who participated in exchange for course credit. All participants reported having normal or corrected to normal hearing and vision. None of the participants had a history of cardiac abnormalities, nor were any taking medications that altered their heart rate and/or rhythm. Participants' eligibility to participate in the current study was determined based on their scores on two measures: the Boredom Proneness Scale (BPS; Farmer & Sundberg, 1986; described below) and the Beck Depression Inventory II (BDI-II; Beck, Steer, & Brown, 1996; described below). As we were interested in how state boredom is manifested in healthy individuals, we used a selection procedure that ensured that any participants who had a high propensity to experience boredom or were experiencing significant symptoms of depression were not included in the study. Specifically, participants were eligible to participate if their total score on the BPS fell within one standard deviation of the mean of a larger pool of potential participants (*M*=99.18, *SD*=17.84, *n*=2,563) and their total score on the BDI-II was less than 19 (Beck et al., 1996). In the smaller experimental sample, the mean score on the BPS was 96.36 (*SD*=9.89) and the mean score on the BDI was 6.00 (*SD*=4.20). All procedures were reviewed by and received approval from the Office of Research Ethics at the University of Waterloo.

Self-Report Measures

Trait boredom. The BPS, developed by Farmer and Sundberg (1986), assesses an individual's general propensity to experience boredom. Participants rated their agreement with statements such as "I find it easy to entertain myself" on a seven-point Likert scale (Appendix A). Responses on each item were summed to obtain a total score ranging from 28-196, with higher scores reflecting greater boredom proneness (Sommers & Vodanovich, 2000; Vodanovich et al., 1991; Watt & Vodanovich, 1999). The original true/false version of the scale demonstrates adequate internal consistency (α=.79; Farmer & Sundberg, 1986). Cronbach's alpha for the current sample was .82.

Depressive Symptoms. The Beck Depression Inventory-II (Beck et al, 1996) assesses the presence and severity of depressive symptoms. In samples of individuals with a clinical diagnosis of depression, scores ranging from 0-13 reflect minimal levels of depression, 14-19 reflect mild levels, 20-28 reflect moderate levels, and 29-63 reflect severe levels (Beck et al. 1996). The 21-item inventory includes two subscales, measuring symptoms of depression across somatic-affective and cognitive domains. Cronbach's alpha for the current sample was .93.

State affect and mind wandering. The State Affect (SA) questionnaire, consisting of 24 emotion terms, was used to assess participants' general state affect (Appendix A)[2]. To assess emotion intensity, participants indicated the greatest amount of each emotion term they felt at the beginning of the study (baseline) and after watching each film (post-film) on a Likert scale ranging from 0 (*none/not at all*) to 8 (*a great deal/extremely*). To assess the valence of

[2] This scale was developed for this study based on similar procedures used by others (Ekman, Friesen, & Ancoli 1980; Gross & Levenson, 1995; Philippot, 1993). The emotion terms were derived from the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellengen, 1988), which itself was derived from a principal components analysis of Zevon and Tellegen's (1982) mood checklist. It was argued that this checklist broadly tapped the affective lexicon.

participants' state affect, individuals rated the pleasantness of their emotional state on a Likert scale ranging from 0 (*unpleasant*) to 8 (*pleasant*). In the post-film version, one item assessed whether participants engaged in mind wandering (Appendix A).

Apparatus

Mood induction videos. Three video clips were shown to each participant. Each video was selected from a set of videos that were validated in a pilot study (Appendix B). All videos were 233 seconds (s) in length and were presented on a standard color television with a 35-inch screen, while participants were seated in a comfortable chair approximately 2 meters from the television. The video used to induce boredom was created for this study and portrayed two men hanging laundry to dry, while occasionally asking each other for a clothes pin. Based on Gross and Levenson's (1995) work, to induce sadness, we used a clip from the movie *The Champ,* portraying a young boy grieving over the death of his father (Lovell & Zeffirelli, 1979). A third clip, initially intended to elicit a neutral emotional state, was included to return participants' affect to baseline levels between the emotionally-valenced video clips. This clip was an excerpt from the British Broadcasting Company's (BBC) documentary film, *Planet Earth* (Fothergill, Berlowitz, Malone, & Lemire, 2007) and depicted exotic animals, landscapes, and vegetation, with voice commentary and background music (Figure 2.1). In piloting this clip (Appendix B), we observed that this video tended to increase self-reported interest amongst participants rather than inducing a neutral affective state. Nevertheless, induced interest was included as it was hypothesised to be useful to examine alongside sadness and in contrast to induced boredom. As such, the 'neutral' epoch will henceforth be referred to as the 'interesting' epoch.

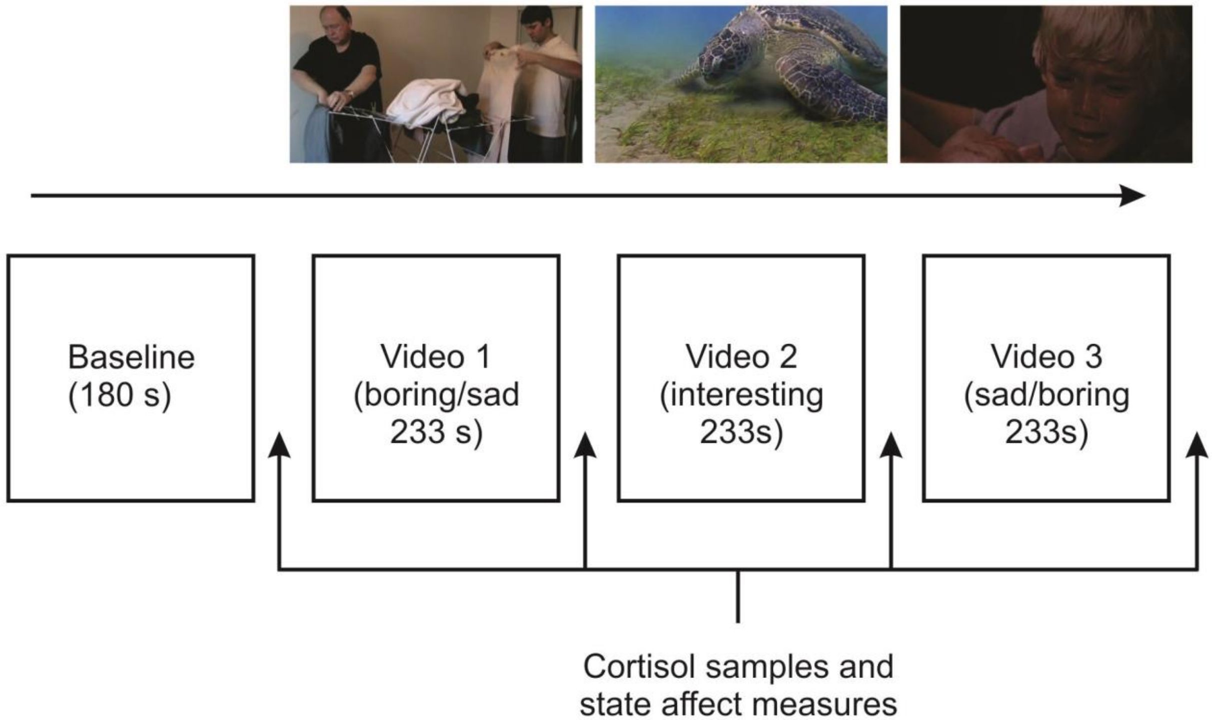

Figure 2.1 The laboratory protocol for Study 1.

Psychophysiological equipment. In the current study, monitoring of HR and SCL was carried out using equipment and software designed by the James Long Company (JLC; Caroga Lake, NY), and with the data-acquisition program Snap-Master™ for Windows.

Heart rate (HR). Heart rate (in beats per minute) was recorded via two resting, conductive adhesive electrodes (CDI UMP3-P). The two electrodes were placed, laterally, on participants' torso, one on the left side and one on the right side at approximately the same level as the fifth rib (active sites). A third reference electrode was placed on the midline of participants' torso at the mid-sternum level. Before the electrodes were attached, participants' skin in these areas were cleansed with alcohol wipes and allowed to dry. ECG signals were amplified using a JLC Bioamplifier Output Box and SA Instrumentation Bioamplifiers (James Long Company). Data were analyzed using a computer program (ECGRWAVE program by JLC) that utilized an algorithm to detect R-waves and artifacts. Artifacts (e.g., a body movement incorrectly coded as an R-wave) were corrected manually off line. R-waves that were missed by automated detection were also inserted manually by the experimenter, off line. HR values (number of R-waves per minute) were calculated on a second-by-second basis.

Skin conductance levels (SCL). Skin conductance levels were measured by two silver/silver chloride (Ag-AgCl) electrodes (UFI 1081FG), placed on the palmar side of the medial phalanges of the third and fourth fingers of individuals' non-dominant hand with Velcro strips. Each electrode was filled with electroconductive gel (Electro-Gel). SCLs were averaged over one second intervals and are reported in microsiemens (µS).

Electrocardiogram (HR) and SCLs were measured continuously throughout the experiment. Epochs of interest were defined using a manual event marker, which was engaged by the experimenter to mark the beginning and end of each epoch. These measures were digitized at 512 samples per second with a 31-channel A/D converter operating at a resolution of 12 bits, with an input range of -2.5 volts to +2.5 volts. Amplification rates, high-pass filter (HPF), and low-pass filter (LPF) settings were as follows: ECG (Gain=500 volts per µS, HPF=0.1 Hz, LPF=1000 Hz) and SCL (Gain=0.1 volts per µS, HPF=none/DC, LPF=10 Hz, 6 dB/octave, single pole RC).

Cortisol. Four saliva samples were collected from each participant throughout the laboratory session, as described below, using the 'Salivette' device (Sarstedt, Montreal, Canada), which consists of a cotton swab in a capped plastic tube. Participants were instructed to gently chew the cotton swab for approximately 1 minute before placing the saturated swab into the plastic tube. Tubes were stored at -20 °C. Once all data had been collected, the samples were sent to an off-site laboratory in Dresden, Germany, for biochemical analysis. After thawing, samples were centrifuged at 2700 rpm for 5 min. Free salivary cortisol levels were measured by a radioimmunoassay (RIA) with a scintillation proximity assay (SPA; Amersham Biosciences Europe, Freiburg, Germany). The lower detection limit of the assay is 150 pg/ml. Inter-assay and intra-assay coefficients of variance were 0.5. Test–retest reliability of the assay was assessed on 25 randomly selected saliva samples, using Pearson correlation coefficients (r=0.98, p<.001). Results are reported in nanomols per litre (nmol/L).

Procedure

Upon arrival at the laboratory participants were asked to wash their hands using water only and informed written consent was obtained. Next, the HR and SCL electrodes were attached to participants by the experimenter and they were asked to sit in a comfortable chair, with their eyes closed for a period of 3 minutes to become accustomed to the equipment and to establish their baseline physiological response. At the end of this baseline period, a cortisol sample was obtained, following which participants filled out the self-report state affect measure (SA). Next, participants watched either the boring video or sad video (video order was counterbalanced). Immediately after watching the first video, another cortisol sample was collected and participants completed the SA measure. Participants next watched the interesting video, which was always shown second. This was done as the primary purpose of the interest video was to return participants' affective response to a state that approximated their baseline after having viewed either the boring or sad mood inductions. Immediately after participants viewed this video, another cortisol sample was collected and the SA measure was repeated. Next, participants watched the third video (i.e., either the boring or sad video, counterbalanced). After the final video, a final cortisol sample was collected and participants filled out the SA measure one last time. Each participant watched three video clips (one boring, one interesting, one sad) during a single laboratory session lasting approximately 45 minutes (Figure 2.1).

Data Analysis

Mood induction.

A manipulation check was performed, as a first step, to ensure that each target emotion was elicited by the videos in the current sample and to determine which emotion(s) participants felt most strongly during the baseline period. The highest rated emotions during each epoch were submitted to a 4 (epoch) x 3 (emotion) repeated measures ANOVA, with multiple comparisons. Finally, to examine carry-over effects of the mood inductions, a 4 (epoch) x 2 (order) mixed factorial ANOVA was carried out separately for both the boredom and sadness ratings.

Psychophysiological measures. Overall epoch means were calculated based on the mean raw estimates for each participant during each epoch. Two separate repeated measures ANOVAs were conducted on mean HR and SCL separately, with epoch (baseline, boring, interesting, sad) as the within-subjects factor. A priori multiple comparisons, contrasting each epoch with all other epochs, were included in both analyses. To examine carry-over effects in the psychophysiological variables, 4 (epoch) x 2 (order) mixed factorial ANOVAs were carried out for both mean HR and mean SCL data. Next, mean HR (in bpm) and SCL were regressed on time (in 30 second bins) using time series linear regression analyses to examine the rates of change of HR and SCL over the course of each epoch.

Cortisol. Previous research has shown that salivary cortisol levels peak approximately between 5 to 20 minutes after the onset of a mildly stressful event (Bandelow et al., 2000; de

Weerth, Graat, Buitelaar, & Thijssen, 2003; Fibiger, Evans, & Singer, 1986; Hubert & de Jong-Meyer, 1989; Kirschbaum & Hellhammer, 1989). Thus, any changes in cortisol levels for the first boring or sad epoch would likely only be evident after the subsequent interesting video epoch, approximately 10 minutes after the onset of the first video (i.e., 4 minutes for each of the boring/sad and interesting videos, plus the time taken to complete questionnaires; Figure 2.1). Thus, changes in cortisol levels relative to state boredom were measured by analyzing mean cortisol values taken from the end of the interesting epoch which followed the boring video (i.e., approximately 10 minutes after commencing the boring video, given there was approximately three minutes between the end of one video and the start of the next). This was done only for conditions in which the boring video was shown first (i.e., boring + interesting; n=34). Similarly, changes in cortisol levels that occurred during the sad epoch were measured by analyzing the mean cortisol values from the end of the interesting epoch that followed the sad video, for participants who viewed the sad video first (i.e., sad + interesting; n = 34). Thus, three paired samples t-tests were used to examine differences in cortisol levels between 1) the baseline and boring epochs, 2) the baseline and sad epochs, and 3) the "boring + interesting" epoch and "sad + interesting" epoch.

2.3. Results

State Affect

No differences related to gender or culture were observed across reports of state affect. Results indicated that boredom was most strongly endorsed for the boring clip ($M_{boredom}$=5.54, SD=2.37; $F(3,224)$=79.73, p<.001) and sadness for the sad clip ($M_{sadness}$=5.10, SD=1.85; $F(3,224)$=177.58, p's<.001). Thus, each video reliably induced the target emotion.

Participants endorsed feelings of interest both at baseline (*M*=5.60, *SD*=1.65) and during the interesting video (*M*=5.93, *SD*=1.50), however, participants also reported feeling significantly more nervous at baseline than during other videos (*M*=2.09, *SD*=1.93, $F(3,224)=18.41$, $p<.001$; Figure 2.2; Appendix C). A greater number of participants endorsed mind-wandering during boring video (86%) than interesting (37%) or sad (26%) videos ($\chi 2(2) = 46.2$, $p < .001$).

No main effect of order emerged when comparing boredom ratings for participants who watched the boring video first verses those who watched the sad video first, $F(1,45)=.28$, $p<.60$. A significant interaction between epoch and order was observed wherein participants who watched the boring video first were slightly more bored while watching the interesting video, $F(3,135)=2.78$, $p=.04$. Given that 1) the interesting epoch was initially intended to be a secondary baseline and 2) boredom ratings during the interesting video were very low overall, carry over effects were deemed to be negligible for state boredom. For sadness ratings, no main effect of order, $F(1,45)=.14$, $p=.71$, or interaction between order and epoch, $F(3,135)=1.35$, $p=.26$, was observed indicating that no carry over effects were present for state sadness.

HR & SCL

Due to malfunctions of the psychophysiological monitoring equipment, HR and SCL data were not collected for 25 participants[3]. No differences related to gender or cultural backgrounds were observed across any of the psychophysiological data in the remaining sample. As such, all of the analyses that follow are based on the entire sample of 47 participants (21 male, 26 female) who completed the physiological monitoring.

[3] The power supply for the HR and SCL monitoring equipment failed and was sent off-site for repair during the time data was collected for this study. As such, HR and SCL data were not collected for 25 participants.

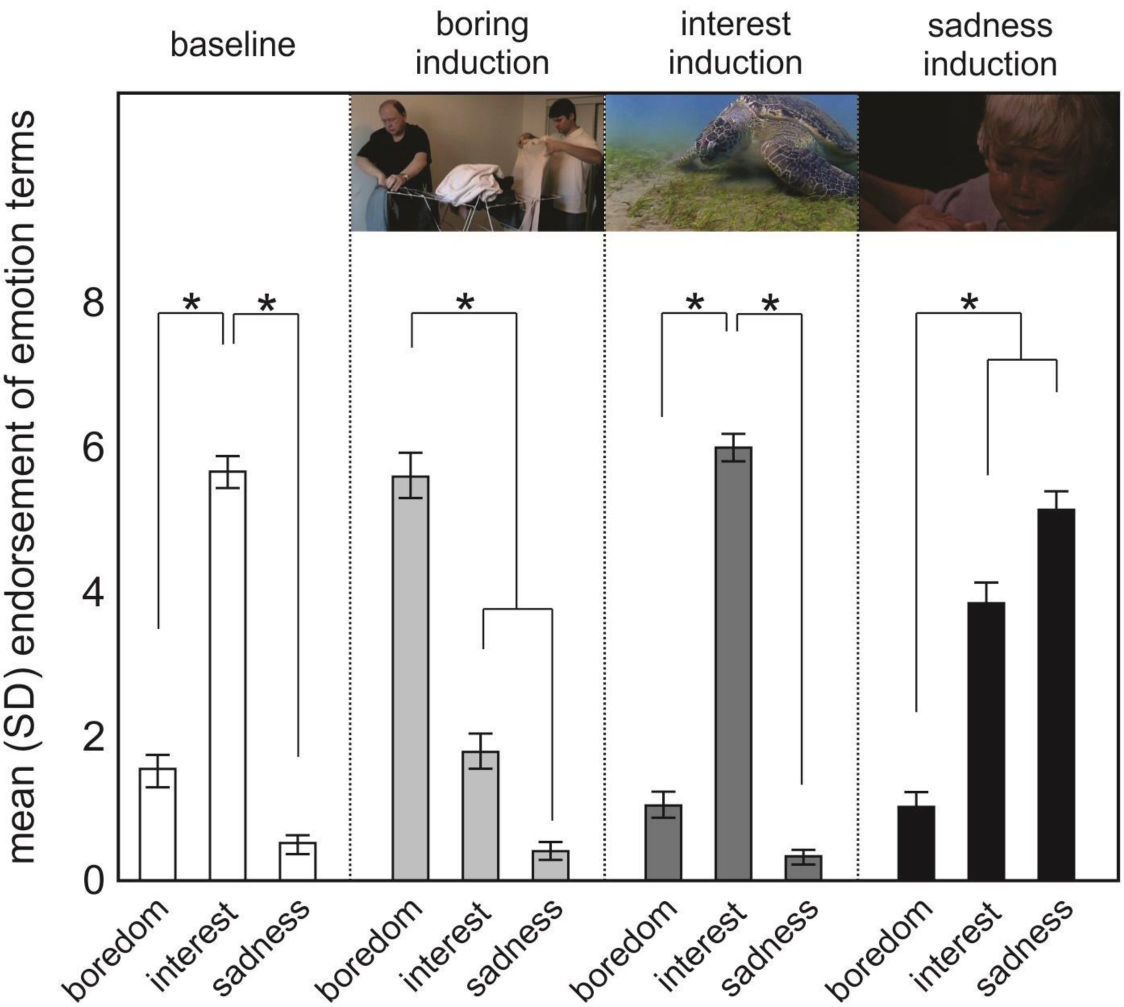

Figure 2.2 Means (SE) of self-reported emotions during each epoch.

Heart rate. A repeated-measures ANOVA with epoch as the within-subjects factor and mean HR as the dependent variable, indicated a main effect of epoch, $F(2.3,100.5)=17.53$, $p<.001$, $\eta^2=.29$, such that HR was highest during baseline relative to all other epochs ($M_{baseline}=75.20$, $SD_{baseline}=10.78$, all t's>2.84, all p's<.001). Mean HR during the boring epoch was numerically higher than during the interesting epoch, ($M_{boring}=72.73$, $SD_{boring}=9.82$, $M_{interesting}=71.74$, $SD_{interesting}=9.52$, $t(45)=1.53$, $p=.13$), and the sad epoch, ($M_{sad}=71.84$, $SD_{sad}=9.77$, $t(45)=1.50$, $p=.14$), although these differences did not reach statistical significance.

Mean HR during the sad and interesting epochs did not differ, $t(44)=.24$, $p=.81$ (Table 2.1; Figure 2.3).

No main effect of order, $F(3,135)=.30$, $p=.58$, or interaction between order and epoch, $F(1,45)=1.22$, $p=.23$, was observed when comparing HR for participants who watched the boring video first verses those who watched the sad video first. Thus, no carry over effects were present for HR.

Next, data from each epoch was divided into 30 s bins and compared across all four epochs using repeated-measures ANOVA. Main effects of epoch and interval were subsumed by a significant interaction, $F(8.5,349.6)=3.85$, $p<.001$, $\eta^2=.09$. Time-series linear regression analyses were conducted for each epoch with slope values being significant for the baseline and boring epochs only. That is, for both the baseline ($r^2=.31$, $F(1,177)=79.46$, $p<.001$; $\beta=.56$, $t=8.91$, $p<.001$), and boring epochs ($r^2=.05$, $F(1,231)=12.25$, $p<.001$; $\beta=.22$, $t=3.50$, $p<.01$), there was a significant *increase* in HR over time. Regression analyses for the sad and interesting epochs were not significant (Table 2.2).

Finally, using Pearson correlations, a significant positive association was found between BPS scores and mean HR during both baseline ($r=.31$, $p=.03$) and the boring epoch ($r=.33$, $p=.03$; Figure 2.4). This indicates that those reporting a higher level of trait boredom proneness were also likely to have higher HR when induced into a state of boredom. No other correlations between any of the self-report and physiological measures were significant.

To further explore the relationship between HR and boredom proneness, participants were divided into two groups, a higher boredom prone group ($n=23$) and a lower boredom prone group ($n=24$), using a median split of total BPS scores (*median*=95.0, *SD*=11.36). It is worth reiterating here that this sample was drawn from a larger group and have BPS scores that could

Table 2.1 Epoch means for HR, SCL, and cortisol.

	Epoch			
	Baseline	Boredom	Interest	Sadness
mean HR	75.20(10.87)[a]	72.73(9.82)[c]	71.74(9.52)[c]	71.84(9.77)[c]
mean SCL	6.30(2.75)[a]	8.57(3.45)[b]	9.21(8.32)[c]	9.66(4.44)[d]
mean cortisol	14.25(12.36)[a]	13.39(8.90)[a]	-	11.04(8.02)[b]

Note that across each row, differing superscripts indicate significant differences at p<.05 or less.

be considered ‘normal’. That is, the median split used here does not split this group into individuals with a high or low propensity for experiencing boredom, but merely separates those with higher and lower BPS scores *within this sample*. Even so, an independent samples t-test on mean HR during the boring epoch across the higher and lower BPS groups revealed a significant difference such that those with higher BPS scores had a higher HR when bored than those with lower BPS scores – a difference of around seven beats per minute ($M_{\text{Higher BPS scores}}$=76.14, $M_{\text{Lower BPS scores}}$=69.36, t=2.50, p=.02; Figure 2.4).

Skin conductance level. Repeated-measures ANOVA with epoch as the within-subjects factor and mean SCL during each epoch as the dependent variable revealed a significant main effect of epoch, $F(1.7,75.4)=64.64$, $p<.001$, $\eta^2=.59$. Multiple comparisons indicated that SCL during baseline was significantly lower than all other epochs (M_{baseline}=6.30, SD_{baseline}=2.75, all t’s>8.48, all p’s<.001). Mean SCL was significantly lower during the boring epoch relative to

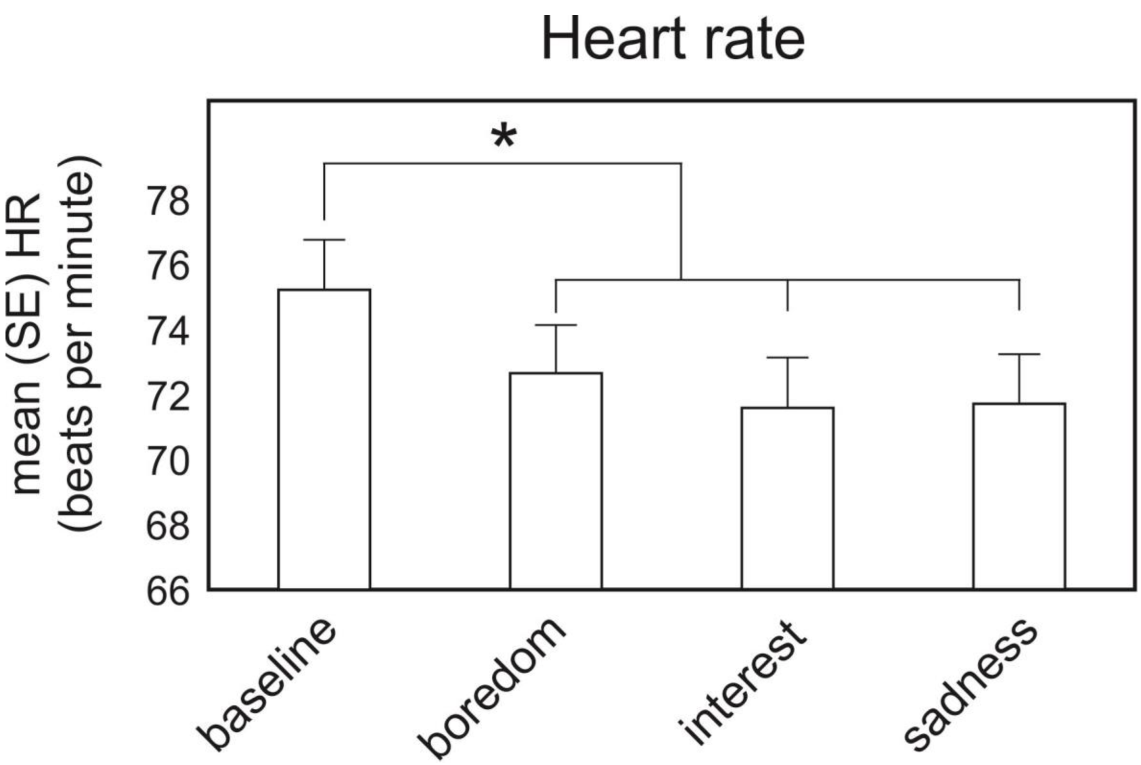

Figure 2.3 Mean heart rate (bpm) per epoch. Mean HR was significantly higher during baseline than any other epoch. Although heart rate was numerically higher during the boring epoch compared to the interesting (*p*=.13) and sad (*p*=.14) epochs, the difference did not reach significance. * denotes significant differences at *p*<.05 or less.

both the interesting (M_{boring}=8.57, SD_{boring}=3.45, $M_{interesting}$=9.21, $SD_{interesting}$=8.32, $t(46)=2.11$, $p=.04$) and sad epochs (M_{sad}=9.66, SD_{sad}=4.44, $t(45)=4.08$, $p<.001$). Finally, mean SCL during the sad epoch was significantly higher than during the interesting epoch, $t(45)=2.82$, $p=.01$ (Table 2.1; Figure 2.5).

No main effect of order, $F(3,135)=.01$, $p=.94$, or interaction between order and epoch, $F(1,45)=2.20$, $p=.12$, was observed when comparing SCLs for participants who watched the boring video first verses those who watched the sad video first. Thus, no carry over effects were present for SCLs.

Table 2.2 Regression coefficients for HR (in bpm) and SCL (in µS).

	Baseline		Boredom		Interest		Sadness	
	r^2	Slope	r^2	Slope	r^2	Slope	r^2	Slope
HR	.31*	.56*	.05*	.22*	.01	-.07	.01	.08
SCL	.70*	-.83*	.95*	-.98*	.97*	-.99*	.85*	-.92*

* $p<.05$

Next, means of 30s intervals were compared across all four epochs. Main effects of epoch and interval were subsumed by a significant interaction, $F(2.9,126.2)=15.97$, $p<.001$, $\eta^2=.27$, indicating that SCL during the interesting epoch decreased over time more so than for any other epoch. Time-series linear regressions were significant for each epoch such that SCL decreased systematically over time in each epoch (Table 2.2).

Cortisol. Repeated-measures ANOVA with epoch (baseline; boredom + interesting; sadness + interesting) as the between-subjects factor and mean cortisol level as the dependent variable, indicated a significant main effect of epoch, $F(1.7,55.8)=5.50$, $p=.01$, $\eta^2=.08$. Multiple comparisons revealed that cortisol levels during the boring induction and baseline periods were not significantly different, ($M_{baseline}=14.25$, $SD_{baseline}=12.36$, $M_{boring}=13.39$, $SD_{boring}=8.90$, $t(33)=.66$, $p=.51$). However, cortisol levels for the boring and baseline epochs were significantly higher than those observed after the sadness induction ($M_{sad}=11.04$, $SD_{sad}=8.02$, all t's>2.28, all p's<.03; Table 2.1; Figure 2.6).

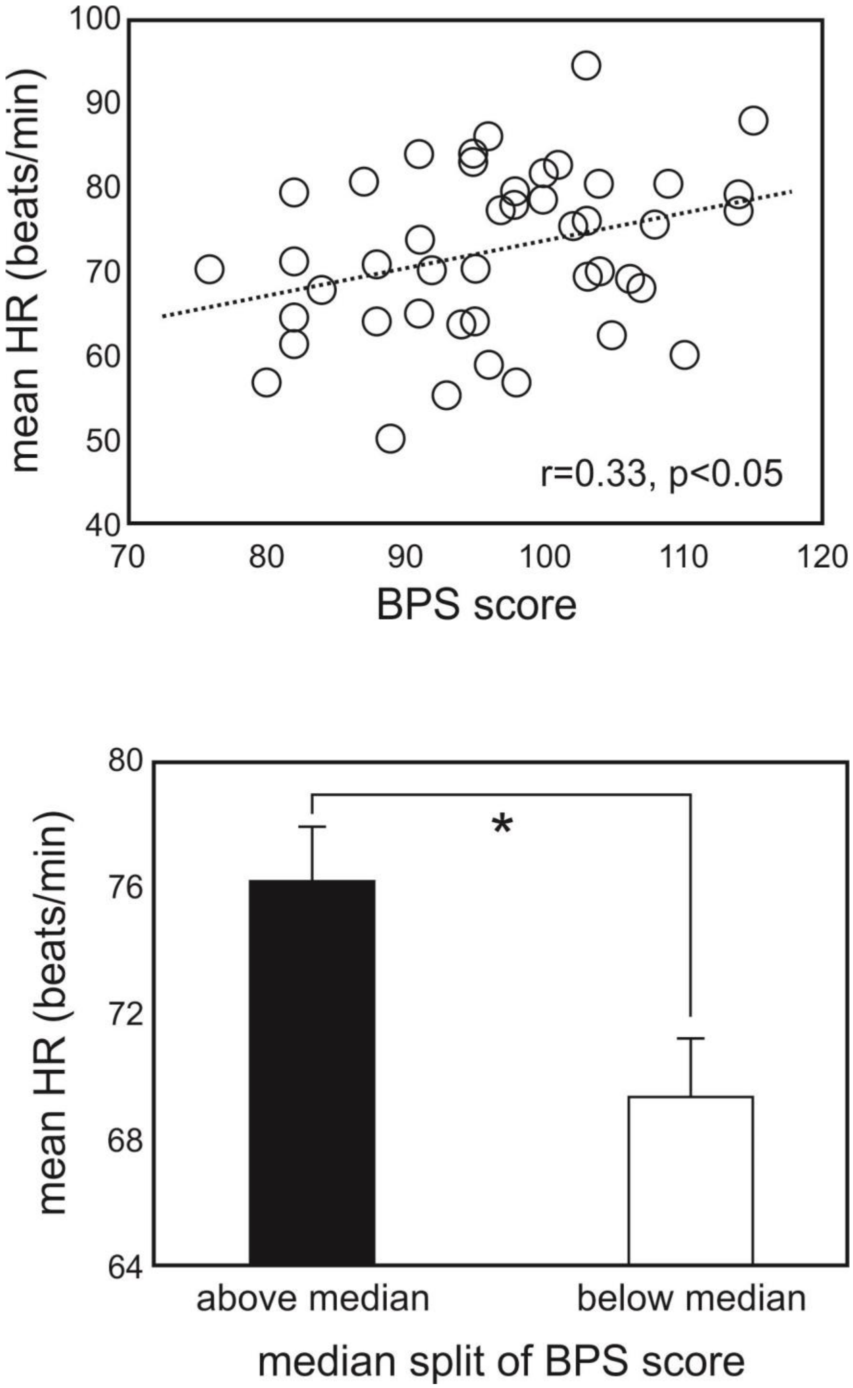

Figure 2.4 The relationship between HR and BPS score during the boring epoch (top panel). During the boring epoch, mean HR was significantly higher in HBP than LBP participants (bottom panel). * denotes significant difference at p=.02.

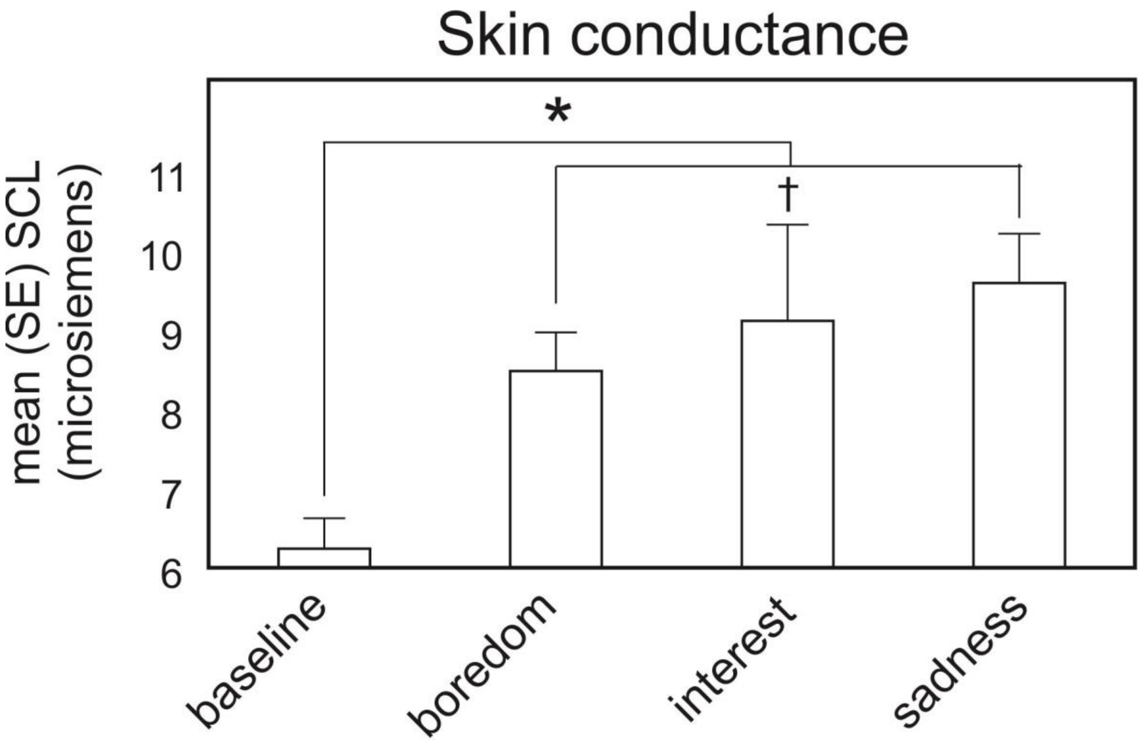

Figure 2.5 Mean SCL (μS) per epoch. Mean SCL was lowest at baseline and highest during the sad epoch. Mean SCL values were significantly different at every epoch. * and † denote significant differences at *p*<.05 or less.

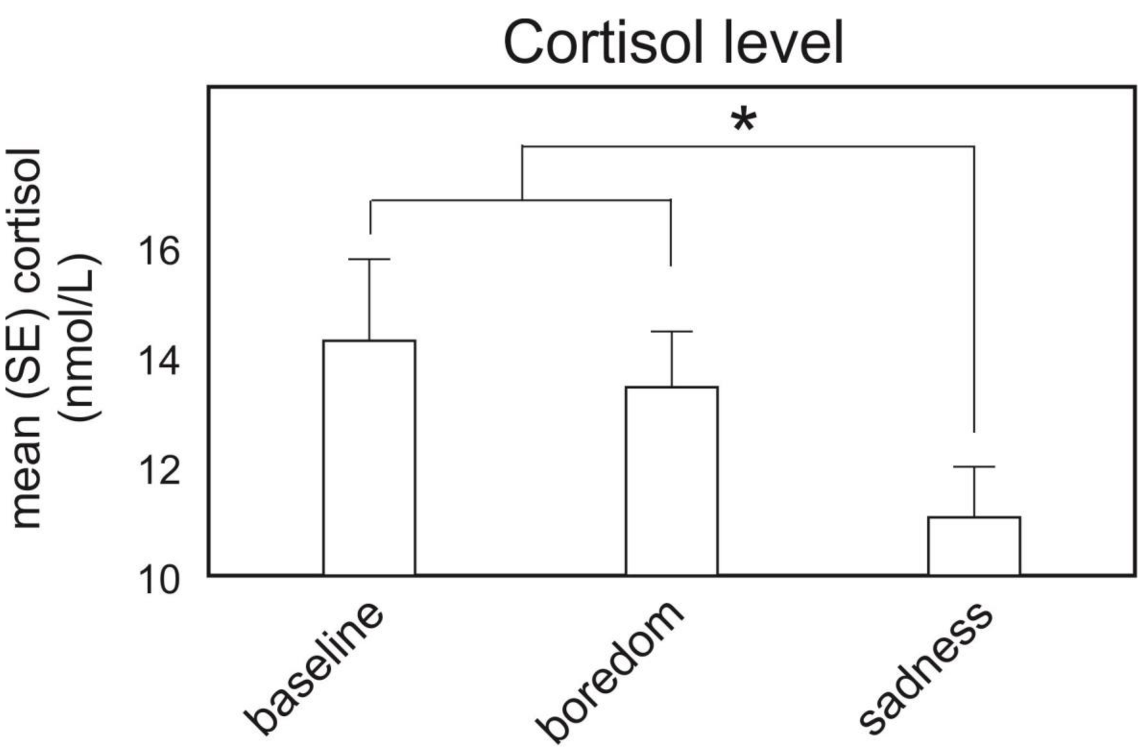

Figure 2.6 Mean cortisol decreased from baseline. Cortisol was significantly higher after the boring video than the sad video. * denotes significant differences at *p*<.05 or less.

2.4. Discussion

The current study examined the psychophysiological signature of boredom in order to distinguish it from the similarly valenced state of sadness – a hallmark symptom of depression and to determine whether boredom is best characterized as an agitated (i.e., increased arousal) or an apathetic state (i.e., decreased arousal). This study also presented the opportunity to compare boredom with the dissimilar state of interest, although this was not a primary aim of the research. This work also examined individual differences in trait boredom proneness with respect to physiological responding.

Results indicated that participants' physiological responses during the boring, sad, and interesting epochs were associated with lower mean HRs, and higher SCLs relative to baseline. Cortisol levels were numerically highest during the baseline period, although this difference was not significant between the baseline and boring epochs. The observed higher relative overall arousal levels during baseline may simply reflect participants' failure to habituate quickly to the laboratory environment, which may have been anxiety-provoking. Indeed, given that participants were in an unfamiliar environment, attached to equipment they were not acquainted with, and were asked to expose their chests in order to attach the HR electrodes, increased anxiety may not be unexpected. In fact, participants endorsed feeling significantly more "nervous" on the state affect questionnaire at baseline than during all other epochs.

With regard to the direct comparisons between boredom and sadness, which was the major aim of this study, mean HR during the boring epoch was slightly higher, although not significantly so, when compared with the sad epoch. In addition, boredom was associated with a linear *increase* in HR over time, whereas sadness showed no such increase. Both boredom and sadness were associated with significant linear decreases in SCLs over time. This pattern of results suggests that the peripheral ANS response associated with boredom, compared to sadness, is characterized by increasing HR and a decrease in SCL. The same pattern of results was observed when examining boredom with respect to interest.

Also found was a significant positive association between boredom proneness and HR such that higher levels of boredom proneness were associated with higher HR (Figure 2.3). When the sample was split into those with higher or lower BPS scores, a significant difference emerged in HR during the boring video induction, such that those with higher BPS scores had a significantly higher HR than those with lower BPS scores. No significant differences in HR were observed across these groups for the sad epoch. This result is particularly striking given the fact that our sample was selected from a larger pool of participants to have BPS scores within one standard deviation of the larger sample's mean, reflecting a normative sample. One might suspect that individuals prone to experiencing boredom in a more extreme sense would show an even greater increase in HR.

At first blush, the increasing HR and decrease in SCL seen during the boredom induction appears paradoxical. Indeed, it makes little sense that boredom would be associated with *both* an increase and decrease in arousal. This pattern of responding in which HR and SCL responses diverge has been observed previously and is known as *directional fractionation* (Lacey, 1959). In this context, our findings can be understood in relation to ANS-mediated regulation of effort and attention, as opposed to an emotional response per se (Obrist et al., 1970; Öhman et al., 2000). Research suggests that SCL reflects the general engagement of attention, with lower SCL related to decreased engagement of attention (Frith & Allen, 1983). O'Connell and colleagues (2008) recently reported increased skin conductance and improved accuracy on a sustained attention task only after attentional "training". In contrast, reductions in sustained attention over time were associated with reduced SCLs (O'Connell et al., 2008). Studies have also demonstrated a close relationship between attention and HR such that HR slows while attending (Coles, 1972; Lacey & Lacey, 1970; Papillo & Shapiro, 1990; Porges & Raskin, 1969; Ravaja, 2004; Turpin, 1986). Interestingly, directional fractionation has also been observed in individuals with Attention Deficit Hyperactivity Disorder (ADHD; Hermens, et al., 2004; Losoya, 1995; Snoek, Van Goozen, Matthys, Buitelaar, & Van Engeland, 2004), suggesting an important relation between boredom and attentional difficulties (Malkovsky, Merrifield, Goldberg, & Danckert, 2012).

With respect to the cortisol findings, the boredom induction resulted in significantly higher cortisol levels than did the sadness induction, supporting the notion that boredom is associated with *increased* physiological arousal relative to sadness. This finding is also consistent with other research indicating that activation of the HPA axis often co-occurs with sympathetic activation and that negative emotional states can activate both systems (LeDoux, 1996; Southwick et al., 1993).

Overall, these results suggest that boredom, relative to sadness, can be described as a negative affective state associated with increased arousal (i.e., increasing HR and cortisol levels) and decreased attentiveness. Not only does this explanation account for the pattern of directional fractionation in HR and SCL responses, it also fits with the divergent subjective descriptions of boredom, in which individuals report being agitated yet unable to engage in meaningful activities (Martin et al., 2006).

Although these preliminary, novel findings about the psychophysiology of boredom are intriguing, some limitations are worth noting. First, the baseline period of 180s may not have been long enough to allow for habituation to the laboratory environment. Increasing the length of that period to allow for participants' reactivity to decrease, or at least stabilize, may provide more detailed insights into the *magnitude* of physiological alterations one may expect to see associated with boredom. In addition, although the psychophysiological signature of boredom appears to be distinguishable from that of sadness (and interest), it is not yet clear what this might mean for the role of boredom in clinical syndromes such as depression and the relationship between these constructs. Indeed, although sadness is a prominent and important symptom of depression, sadness is a basic emotion, whereas depression represents a clinical disorder comprised of a number of cognitive, behavioral, and affective symptoms.

Additionally, although boredom seems to be associated with an overall increase in arousal compared to sadness and interest, it is worth noting that this response was small in comparison to other, more objectively arousing events. For example, research suggests that HR and SCLs associated with objectively arousing psychological and physical stressors, tend to be higher than the levels observed here (e.g., free living conditions, HR: 60-100 bpm, cortisol: 7.4-8.6 nmol/L; anticipating a speech, HR: 84-89 bpm, cortisol: 9-16 nmol/L; military stress, HR: 235-255bpm, cortisol: 19-21.3 nmol/L; e.g., de Rooij, Schene, Phillips, & Roseboom, 2010; Hofmann, Moscovitch, & Kim, 2005; Lackschewitz, Huther, Kroner-Herwig, 2008; Strahler, Mueller, Rosenloecher, Kirschbaum, & Rohleder, 2010). Thus, boredom may be less stressful or anxiety provoking than these other types of activities.

Finally, the results here suggest that an important avenue of future inquiry would be to further examine the links between boredom and attention. Results of this study converge with other research suggesting that boredom may be associated with inattention (Carriere et al., 2007; Cheyne et al., 2006; Ohsuga et al., 2001; Pattyn et al., 2008). Other work has suggested that the relationship between boredom and attention may not be a unitary one. Indeed, Malkovsky and colleagues (2012) recently demonstrated that among highly boredom prone participants, the tendency to experience boredom as an apathetic state was associated with lapses in attention; whereas, those who were prone to experiencing boredom as an agitated state demonstrated a decreased sensitivity to errors in sustained attention. Participants prone to experiencing agitated boredom also reported a greater frequency of symptoms of ADHD compared to those prone to apathetic boredom (Malkovsky et al., 2012). The next chapter examines boredom with respect to both transient and sustained measures of attention in an attempt to shed further light on the nature of the relationship between boredom and attention.

Chapter 3: Effects of Boredom on Transient and Sustained Attention.

3.1. Introduction

Results of Experiment 1 suggest that boredom has a physiological signature characterised by an increase in HR and a concomitant decrease in SCL levels. In addition, cortisol levels were higher for the boredom induction indicating the experience was related to elevated stress levels. Perhaps the most intriguing finding comes from the directional fractionation of HR and SCL, which is thought to be a marker decreased attention (Hermens et al., 2004; Losoya, 1995; Snoek et al., 2004). In support of this hypothesis, participants also reported a greater frequency of mind wandering while watching the boring video, suggesting that failures of attention represent an important component of the experience of boredom (Carriere et al., 2007; Cheyne et al., 2006; Malkovsky et al., 2012; Ohsuga et al., 2001; Pattyn et al., 2008).

The notion that attention and boredom are related is not a novel one. Indeed, cognitive theories of boredom posit that it is associated with a fundamental inability to engage and sustain attention, although the nature of the relationship between boredom and inattention is poorly understood (Berlyne, 1960; Damrad-Frye & Laird, 1989; Eastwood, et al., 2012; Hebb, 1955). Research has suggested that boredom proneness is related to decreased attention and poorer performance at work, school, and on various tasks requiring attentional resources (Kass, Vodanovich, Stanny, & Taylor, 2001; O'Hanlon, 1981; Pekrun, Daniels, Goetz, Stupinski, & Perry, 2010). Boredom proneness has also been associated with self-reports of everyday lapses of attention (e.g., pouring orange juice on your cereal; Carriere et al., 2008; Cheyne et al., 2006) and adults who report higher levels of boredom proneness also report higher levels of ADHD symptomatology when compared with low boredom prone individuals. This is true for both the hyperactive and inattentive subtypes of adult ADHD (Malkovsky et al., 2012).

Studies demonstrating a relationship between trait boredom proneness and various failures of attention support the notion that the ability to attend to the environment represents a key component of boredom (Eastwood et al., 2012); however, the majority of research examining the relationship between boredom and attention has focused on sustained attention only. Indeed, across a variety of sustained attention tasks, individuals who report higher levels of boredom also demonstrate decrements in performance (e.g., increases in errors, decreases in accuracy, decreased work output) compared to those who report low or no levels of boredom (Barmack, 1939; Scerbo, 1998; Thackray, Bailey, & Touchstone, 1977). More recent research has shown high boredom prone individuals to be insensitive to errors of sustained attention (Malkovsky et al., 2012). That is, on the Sustained Attention to Response Task (SART) participants are required to respond to single digits presented centrally while withholding responses to a particular pre-specified target (i.e., number 3; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Typically, reaction times (RTs) slow down following an error (i.e., responding to a 3) indicating an awareness of having made the error. High boredom prone individuals demonstrated no such slowing of RTs following an error (Malkovsky, et al., 2012), much like patients with frontal lobe damage (Kreutzer et al., 2001; O'Keeffe, Dockree, Moloney, Carton, & Robertson, 2007; Robertson et al., 1997) and individuals with ADHD (Bellgrove, Hawi, Kirley, Gill, & Robertson, 2005; Johnson et al., 2007; Johnson et al., 2007; Manly et al., 2001).

While such studies provide good evidence that boredom and attention are related, they do not provide a complete picture of the precise nature of this relationship. Furthermore, other research has reported contradictory findings with respect to boredom and attention. For example, distraction from tasks requiring attention has been shown to result in reports of both increased

(Damrad-Frye & Laird, 1989) and decreased (Fisher, 1998) boredom. In addition, one study examining sustained attention observed declines in performance over time in only one of two conditions, despite both conditions being rated as equally boring by participants (Hitchcock, Dember, Warm, Moroney, & See, 1999). In this study, a sustained attention vigilance task (a long, monotonous task that required sustained monitoring of a display for infrequent, difficult to detect stimuli) was employed under two conditions. In one condition, appearances of targets were preceded by a cue while in the other condition targets were uncued. Performance decrements on the task were observed in the uncued condition only (Hitchcock et al., 1999).

One potential reason for the inconsistencies reported in the literature with respect to the relationship between boredom and attention could be that different types of attention are being engaged by the tasks employed in the various studies. On one hand many of the tasks employed evoke sustained attention which can be characterised as a top-down, controlled process of directing and maintaining one's attentional focus. In contrast, attention has been examined via tasks that evoke rapid, transient shifts of attention towards salient external stimuli on a moment-to-moment basis. Given this distinction (what will be referred to throughout as sustained and transient attention respectively), it seems likely that, in the study by Hitchcock and colleagues (1999), described above, the uncued condition engaged sustained attention while the cued condition recruited transient attention. Indeed, perhaps boredom interacts in distinct ways with different types of attention. The current study examined this possibility by contrasting performance on tasks of transient and sustained attention after experimentally inducing boredom. In the literature to date, no studies have attempted to study these relationships by manipulating boredom itself. In the current study it is hypothesised that high state boredom levels will be associated with attention decrements in sustained but not transient attention. In terms of trait boredom, it was hypothesized that high boredom prone individuals may actually *outperform* their low boredom prone counterparts on transient measures of attention. This latter hypothesis is derived from the notion that the experience of boredom would prompt an individual to seek out stimulation and thus make them more likely to engage in rapid shifts of attention – a strategy that would be advantageous in a task measuring transient attention.

3.2. Pilot Study

Initially, a study was designed to examine the influence of boredom on transient and sustained attention in which boredom was elicited, using the same boring video used in Experiment 1. Performance on tasks measuring both types of attention was examined before and after the mood induction in separate experimental sessions. As in Study 1, participants completed the BPS to assess trait boredom proneness. Self-reports of state affect were taken both before and after the mood induction and at six time intervals (approximately once every three minutes) during the experimental tasks.

The Covert Orienting of Visual Attention Task (COVAT) was used to assess transient attention. The COVAT requires participants to fixate centrally while responding to peripheral targets that can appear at a cued (i.e., valid trials) or uncued (i.e., invalid trials) location (Figure 3.1; Posner, Walker, Friedrich, & Rafal, 1984). Typically, there is a reaction time (RT) advantage for valid over invalid trials, the magnitude of which can be represented as a cue effect size (i.e., CES; invalid RT – valid RT; Posner et al., 1984). Sustained attention was measured using the Starry Night task (Rizzo & Robin, 1990). Participants were required to detect sudden onsets and offsets of “stars” in a cluttered visual array (Figure 3.1). These events occur infrequently and are difficult to detect, thus requiring sustained attention. This task was chosen

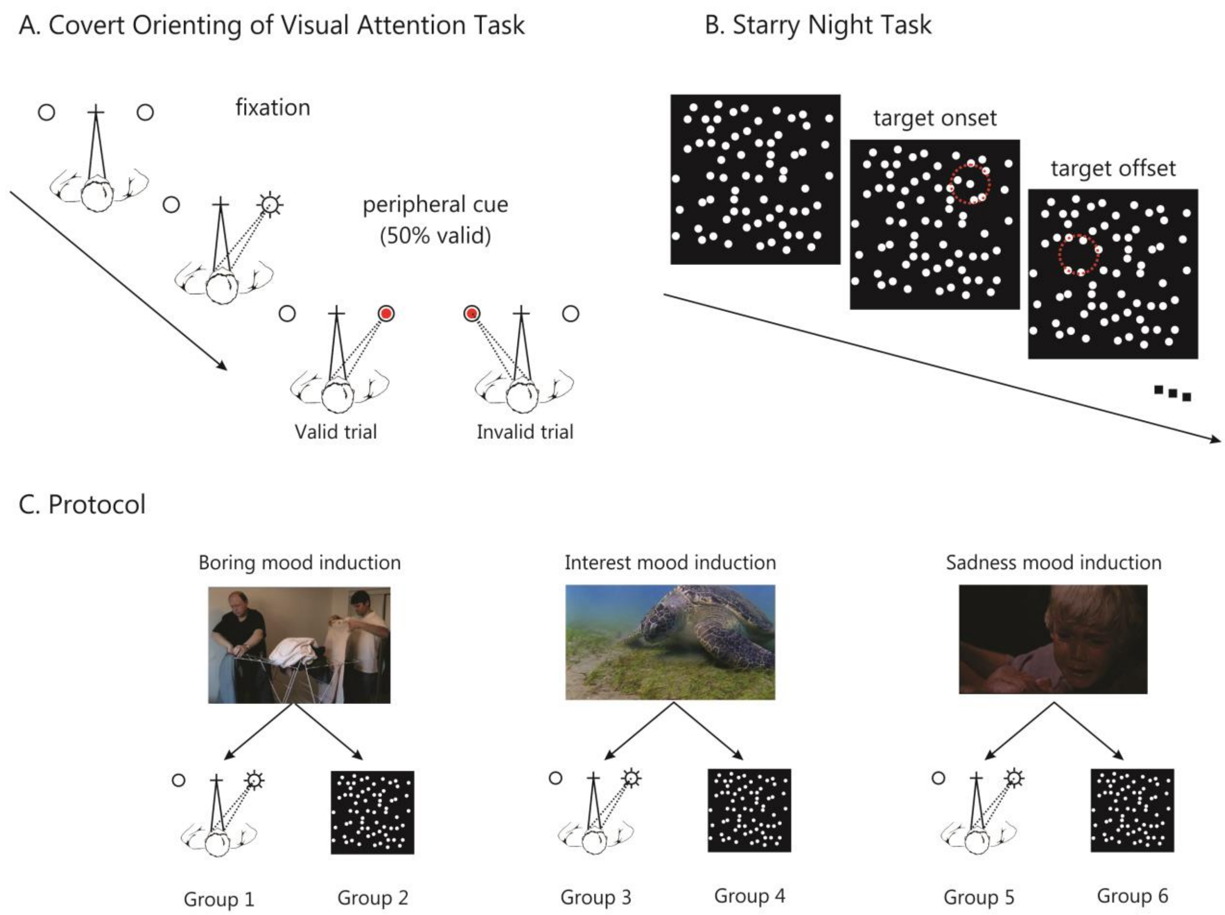

Figure 3.1 The experimental tasks and protocol for Experiment 2

as it may be more sensitive to performance differences due to boredom than was the SART in part because it involves a longer performance window (~20 minutes), more infrequent stimulus changes, and has no requirement to inhibit a specific response. While both tasks involve shifts of spatial attention, the COVAT employs sudden onset, visually salient, and rapidly presented peripheral stimuli that engage transient attention, whereas the Starry Night involves a lower event rate and stimuli that are not easily seen, thus requiring endogenously derived sustained attention to the task. Unfortunately, too few participants completed the post-induction tasks to conduct meaningful pre/post analyses[4]. Nonetheless, a set of initial analyses were carried out, and yielded some tentative findings, upon which Experiment 2 was based. First, self-reported boredom rose rapidly during the pre-induction phase and, based on the limited number of participants who completed both tasks; this rise in boredom was clearly steeper than in the post induction phase. This indicated that the tasks employed were inducing boredom, probably at ceiling levels *prior to* watching the boredom induction video. Furthermore, for those participants with a full data set, results indicated that boredom ratings were in fact lower *after* watching the boring video than after completing the pre-induction Starry Night task. Thus, the tasks themselves induced boredom, with the Starry Night task being more boring than both the COVAT and the boring video, which was itself intended to induce boredom. Second, for the COVAT, standard covert orienting effects were observed (i.e., faster RTs at later SOAs, RT advantage for validly versus invalidly cued targets, and a left side RT advantage) and cue effect sizes (CESs) were as expected. The HBP group had nominally faster RTs than the LBP group, although this effect did not reach significance. Finally, both boredom and the number of missed targets increased (i.e., accuracy decreased) across the pre-induction Starry Night task.

Thus, Experiment 2 was re-designed in order to explore whether the differences hinted at in the initial study were robust. Given the fact that the tasks themselves acted as boredom inductions, the current experiment employed a between subjects approach to examine the influence of boredom on attention. Having participants complete only one of the attention tasks on one occasion ensured that participants did not become so bored that they discontinued their participation. Indeed, all participants completed the full experimental protocol. The present study also made use of several distinct mood inductions, which provided the opportunity to contrast the

[4] Of the 34 individuals who participated, only 29 (85%) completed the post-induction transient attention task and 5 (15%) completed the post-induction measure of sustained attention. Participants reported that they found the task too boring to complete a second time.

effects of a boring mood induction with a dissimilar mood state (interest) and a similarly valenced state (sadness). In the initial attempt to explore the effects of boredom on attention just described, the sample tested consisted of largely ‘normal’ boredom prone individuals (i.e., BPS: M=91.06, SD=20.21). For the current experiment, groups of participants who scored high and low on the BPS were specifically recruited.

3.3. Method

Participants

Participants were 120 undergraduate students (86 female) between the ages of 17 and 43 (M=20.0, SD=3.22) who participated in exchange for course credit or cash remuneration. Participants were eligible to participate if their scores on the BPS fell one standard deviation or more above or below the mean derived from a larger sample (M=96.42, SD=17.23, n=2873) to create high (HBP) and low (LBP) boredom prone groups. Individuals who participated in Experiment 1 or the pilot study for Experiment 2 were not eligible to participate in this study. All participants reported having normal or corrected to normal hearing and vision.

Self-Report Measures

Trait boredom. As in Experiment 1, the Boredom Proneness Scale (BPS; Farmer & Sundberg, 1986) was used to assess trait boredom. In the current sample, Cronbach’s alpha was .92.

State affect. The State Affect (SA) questionnaire was used to assess participants’ state affect. State boredom was measured on-screen immediately prior to the first trial and after every 80 trials (approximately every three minutes) throughout each attention task. Participants were asked to rate on a Likert scale ranging from 0 (*not at all*) to 8 (*extremely*), "How bored are you right now?" and responded by entering a digit via a keyboard.

Mood Induction Videos

The same 233s-long videos utilized in Experiment 1 were used in the current study to induce boredom, interest, and sadness (Fothergill et al, 2007; Lovell & Zeffirelli, 1979).

Attention Tasks

Covert Orienting of Visual Attention (COVAT; Posner, 1984). While seated in front of a 19-inch computer monitor with a refresh rate of 85Hz, participants were presented with non-informative (i.e., 50% valid) abrupt-onset peripheral cues at target locations 12° to the left and right of a central fixation cross (Figure 3.1). Target locations were demarcated by green circles subtending 2° of visual angle. Cues consisted of a brightening of one of the target locations and targets consisted of a red circle presented within the cue (Figure 3.1). Participants were instructed to respond, by pressing a single centrally located button, as quickly and accurately as possible to the appearance of a target while maintaining central fixation (eye gaze was monitored, visually, by the experimenter). Each trial began with fixation for a variable period, followed by a cue. Targets then appeared either 50, 150, or 300ms after the onset of the cue (i.e., stimulus onset asynchrony; SOA) at either the cued (valid) or uncued (invalid) location with equal probability. Both the cue and target remained visible until the participant responded or 3000ms elapsed. Participants' RT was recorded for each trial. Each participant completed 60 trials per cue x target side x SOA combination for a total of 360 cued trials. Forty (20 left, 20 right) uncued trials were included in order to gauge simple RT; thus, participants completed a total of 400 trials in a single block. The entire task took approximately 15 minutes to complete.

Starry Night (Rizzo & Robin, 1990). While seated in front of the same monitor, participants were presented with a visual display consisting of a black background with approximately 250 white target dots (approximately 0.5° of visual angle, maximal contrast) randomly located across the screen to resemble a starry nighttime sky (Figure 3.1). Events occurred at random temporal intervals and consisted of one star appearing or disappearing at a random location on the screen. Participants were instructed to respond, via button press, as quickly and accurately as possible, to the appearance of a "star" while maintaining their gaze at fixation (Figure 3.1). Parameters for each event were as follows: if the number of stars on-screen was between 248 and 252, a random event occurred (i.e., appearance or disappearance); if the number of stars on the screen was 247, an appearance event occurred; and if the number of stars on-screen was 253, a disappearance event occurred. These rules ensured that the number of stars on the screen at any one time ranged between 247 and 253 (i.e., 250 +/-3). Appearance and disappearance events were equally likely and occurred randomly in any region of the screen with a minimum of 2000ms between events. Participants were presented with 400 events (200 appearance and 200 disappearance events) over a span of approximately 20 minutes[5].

Procedure

Participants were seated in front of the computer monitor. After obtaining informed consent, participants completed the BPS and, to establish their emotional baseline, the SA questionnaire. Participants were then randomly assigned to watch either the boring, interesting,

[5] Results of the pilot study indicated that participants were largely unable to detect offset events (on average, participants were able to detect only 4.2% of disappearance events). Thus, although 400 events were presented (200 appearance and 200 disappearance), participants were asked to respond to appearance events only (200 trails).

or sad video. Immediately after watching the video, participants were randomly assigned to complete either the COVAT or the Starry Night task (i.e., each participant watched one video – boring, interesting, or sad, and then completed one task – either the COVAT or the Starry Night). The session lasted approximately 45 minutes (Figure 3.1).

3.4. Results

COVAT

Trait boredom. To demonstrate that our selected groups did, in fact, differ on BPS scores, an independent samples *t*-test indicated that participants in the HBP group (n=30; M=113.02, SD=7.50) scored significantly higher on the BPS than participants in the LBP group (n=30; M=75.27, SD=16.37; $t(58)$=10.43, p<.001, d=2.96). Within the HBP participants, mean BPS scores were not significantly different across video conditions ($F(2,27)$=.70, p=.51). Likewise, for the LBP participants, mean BPS scores were not significantly different across video conditions ($F(2,27)$=.21, p=.81).

Mood manipulation. Means (SD) for each video are listed in Table 3.1. The top rated emotion term endorsed after watching each video (boredom, interest, and sadness) was entered into a 3 (emotion) x 3 (video) mixed factorial ANOVA. Results revealed a significant effect of emotion ($F(2,114)$=21.27, p<.001, η_p^2=.39), a significant main effect of video ($F(1,57)$=9.75, p<.001, η_p^2=.37), and a significant interaction between emotion and video ($F(4,114)$=5.56, p<.001, η_p^2=.25). Multiple comparisons indicated that boredom was the most strongly reported emotion after watching the boring video, interest was the most strongly reported emotion after watching the interesting video. With respect to the sad mood induction, however, there were no differences between participants' reports of boredom, interest, or sadness (Table 3.1). As a

Table 3.1. Means (SD) of post video emotion ratings from COVAT

		Pre-video	Post-video
Boring video	Boredom	3.71 (1.76)	**5.13 (2.40)[a]**
	Interest	4.46 (2.06)	3.63 (2.64)[c]
	Sadness	1.21 (2.09)	.71 (1.30)[d]
Interesting video	Boredom	3.19 (1.86)	2.23 (1.82)[b]
	Interest	4.35 (2.31)	**5.04 (2.22)[a]**
	Sadness	.92 (1.65)	.19 (.57)[d]
Sad video	Boredom	3.36 (1.44)	3.60 (1.66)[c]
	Interest	4.76 (2.24)	**4.16 (2.34)[c]**
	Sadness	.48 (1.05)	3.80 (2.69)[c]

Note that the highest rated emotions after watching each video are indicated in bold. Ratings with identical superscripts are not significantly different from each other (p>.05).

second manipulation check, mood ratings prior to watching each video were contrasted with ratings made immediately after watching the video via a 2 (order: pre, post) x 3 (emotion: boredom, interest, sadness) x 3 (video: boring, interesting, sad) x 2 (group: HBP, LBP) mixed factorial ANOVA. Results indicated significant main effects of order ($F(1,54)=4.28$, $p=.04$, $\eta_p^2=.06$), emotion ($F(2,108)=64.42$, $p<.001$, $\eta_p^2=.48$), and video ($F(1,54)=5.94$, $p<.01$, $\eta_p^2=.15$). No main effect of group emerged. Importantly, the 3-way interaction between order, emotion, and video was significant ($F(4,108)=13.00$, $p<.001$, $\eta_p^2=.27$). Multiple comparisons indicated that, for the boring video, boredom ratings increased significantly at the post-video stage, while interest and sadness did not change. For the interesting video, interest rose significantly post

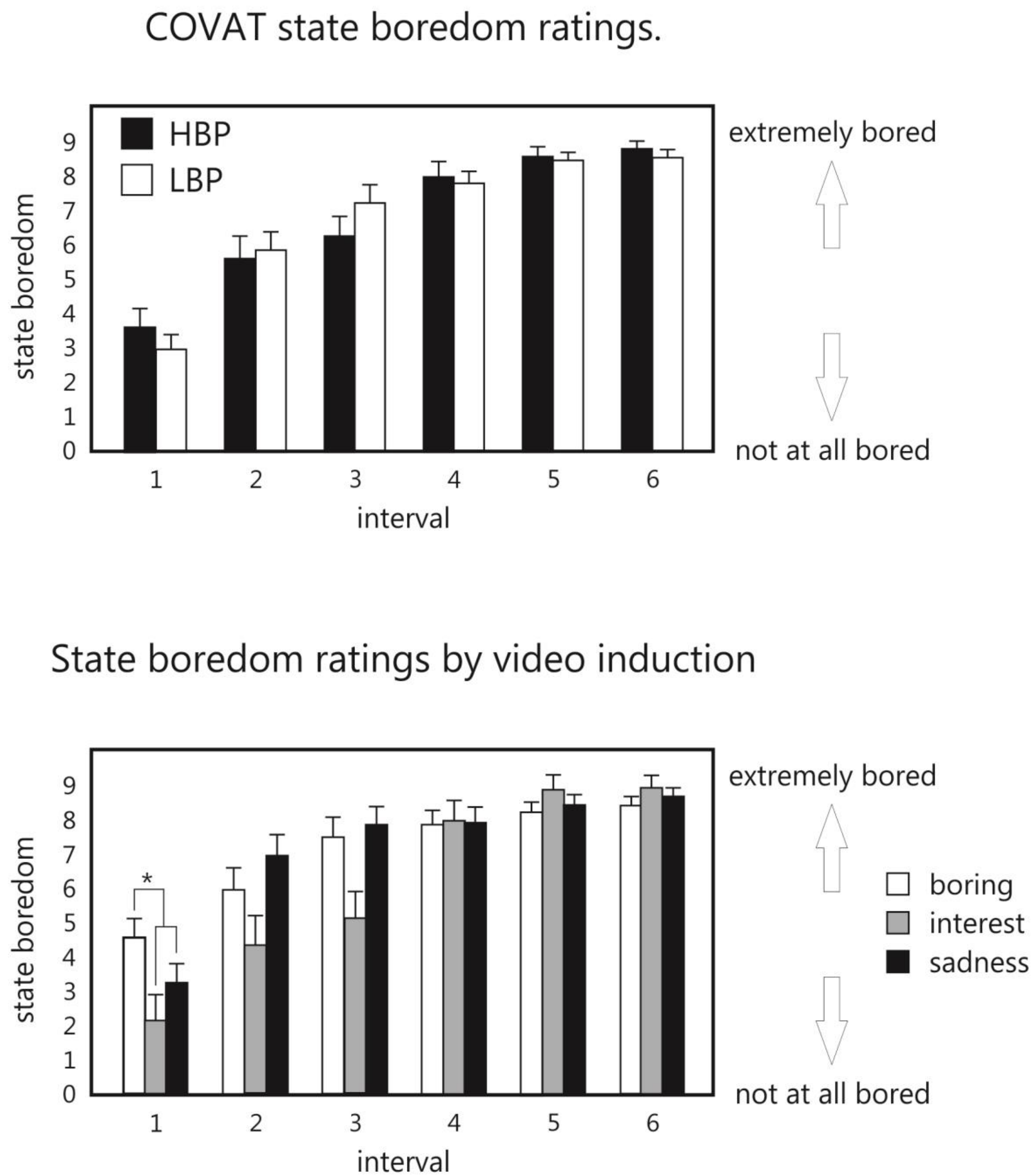

Figure 3.2 Mean (SE) of state boredom ratings at each interval during the COVAT. Note that boredom ratings are collapsed across video induction in the top panel and boredom proneness group in the bottom panel. * indicates significant differences at $p<.05$ or less.

video, while boredom and sadness did not change. Finally, for the sad video, sadness increased significantly from pre- to post-video, while boredom and interest did not change (Table 3.1). Taken together, results indicate that each video effectively induced its target emotion, although for the sad mood induction, the emotional experience reported seemed to reflect a mix of feelings.

State boredom. A mixed factorial ANOVA with interval (the 6 measurement intervals throughout the COVAT) as the within-subjects factor and video (boring, interesting, or sad) and BPS group (HBP vs. LBP) as between-subjects factors, revealed a main effect of interval, such that boredom increased significantly at each interval throughout the task ($F(5,270)=77.95$, $p<.001$, $\eta_p^2=.73$). The main effect of video was not significant ($F(2,54)=1.42$, $p=.26$, $\eta_p^2=.09$), nor was the main effect of BPS group ($F(1,54)=.01$, $p=.92$, $\eta_p^2<.01$). The interaction between interval and BPS group was not significant ($F(5,270)=1.55$, $p=.18$, $\eta_p^2=.05$; Figure 3.2); however, a significant interaction between interval and video was observed ($F(10,270)=4.37$, $p<.001$, $\eta_p^2=.23$). Multiple comparisons indicated that participants who watched the boring video were more bored at interval one than participants who watched either the interesting or sad videos (Figure 3.2). At intervals two and three, boredom ratings of participants who watched the boring video and sad video were not significantly different while participants who watched the interesting video were significantly less bored. Finally, at intervals four through six, boredom ratings were not significantly different between the video groups (Figure 3.2). In other words, the boredom induction worked in that initial ratings of boredom were highest after watching that video relative to the sadness and interest videos. However, the task proved to be a powerful boredom induction itself (as was the case for both tasks), with subjective reports of boredom rapidly reaching the same levels in all groups.

Reaction time. First, a four-way mixed factorial ANOVA with cue (valid, invalid) and SOA (50, 150, 300) as within subjects factors (with RTs collapsed across side) and video (boring, interesting, sad) and group (HBP vs. LBP) as between subjects factors revealed significant main effects of SOA, such that RTs significantly decreased with increasing SOA (50ms SOA, *M*=445.29, *SD*=134.03; 150ms, *M*=418.96, *SD*=120.89; 300ms SOAs, *M*=411.64, *SD*=108.73; $F(2,108)=15.53$, $p<.001$, $\eta_p^2=.35$). Although participants were faster to detect validly cued targets (*M*=421.77, *SD*=118.60) than invalidly cued targets (*M*=428.83, *SD*=123.84), the effect did not reach significance ($F(1,54)=1.75$, $p=.20$, $d=.06$). The main effect of group approached significance and indicated that overall, participants in the HBP group responded around 74 ms faster to targets than did participants in the LBP group ($M_{HBP}=388.30$, $SD_{HBP}=100.99$; $M_{LBP}=462.30$, $SD_{LBP}=131.49$; $F(1,54)=2.81$, $p=.06$, $d=.63$; Figure 3.3); however, the main effect of video was not significant ($F(2,54)=.63$, $p=.54$, $\eta_p^2=.04$). Importantly, the two-way interactions between BPS group and cue, and between video and cue were not significant, indicating that CESs (the difference between valid and invalid RTs, collapsed across side and SOA) did not differ between HBP and LBP participants, nor did CES differ depending on which video was watched (both *F*'s<1.66, both *p*'s>.21; Figure 3.3).

When comparing uncued targets, an ANOVA with video (boring, interesting, sad) and group (HBP, LBP) as the between-subjects factors found a significant main effect of group, such that participants in the HBP group were faster to respond to uncued targets than participants in the LBP group ($M_{HBP}=427.32$, $SD_{HBP}=92.27$; $M_{LBP}=491.00$, $SD_{LBP}=121.74$; $F(1,54)=2.60$, $p=.05$, $d=.58$). No main effect of video emerged, nor did the interaction between video and group reach significance, indicating that the video participants watched prior to completing the COVAT had no effect on their simple RT for detecting targets. To examine how RTs changed over time

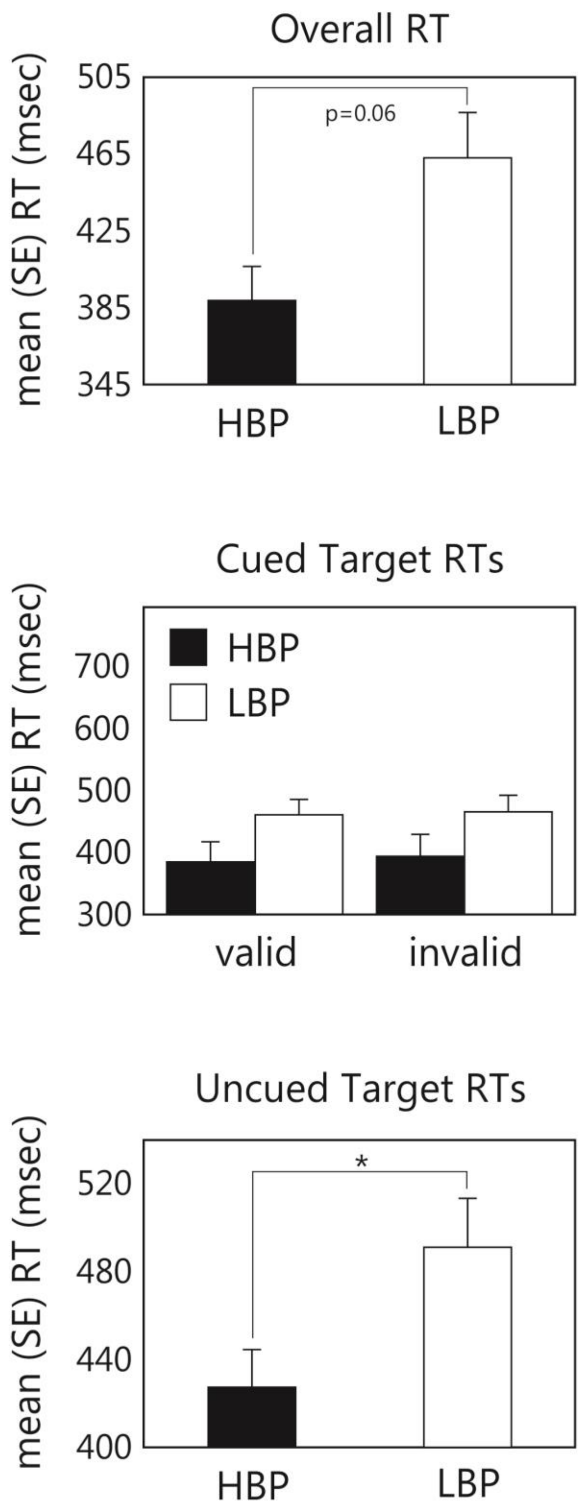

Figure 3.3 Reaction times for the COVAT collapsed across video condition. * indicates a significant difference at *p*=.05.

Table 3.2. Regression coefficients for RTs during the COVAT

	R^2	*slope*	*t*	*p*
HBP	.93	.048	7.37	<.01
LBP	.80	.049	3.95	.02
boring video	.86	.046	4.87	<.01
interesting video	.71	.034	3.12	.04
sad video	.62	.051	2.53	.07

Note that RTs are collapsed across cue, side, and SOA.

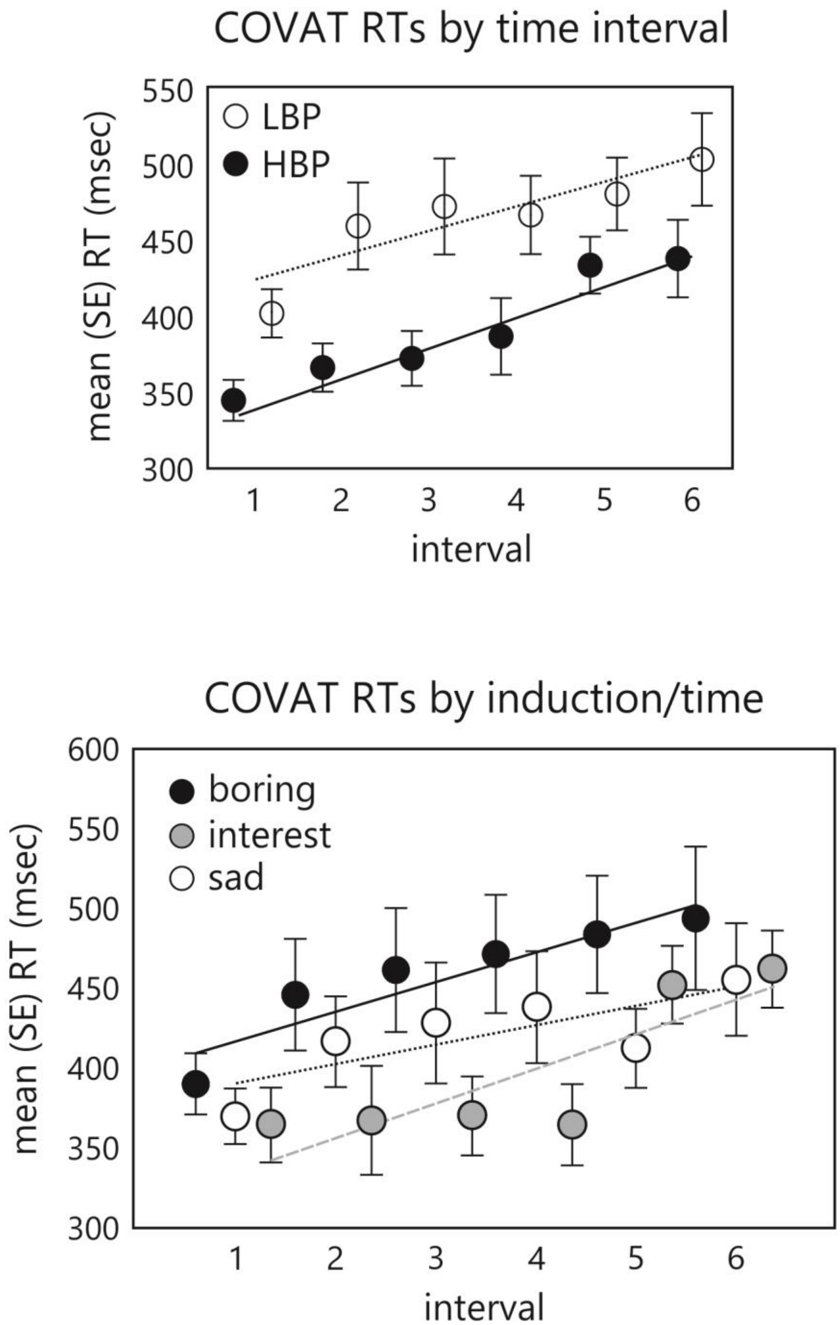

Figure 3.4 Time series linear regressions for the COVAT. Reaction times are collapsed across cue, side and SOA in both panels. In the top panel, RTs are also collapsed across video condition.

throughout the study, a time series linear regression was conducted, collapsed across cue, side, SOA, and video, with measurement interval as the independent variable and RT as the dependent variable. Results of this analysis indicated that RTs increased linearly across the six measurement intervals in both the HBP and the LBP groups as well as in each of the video groups (Table 3.2). Direct comparisons between the HBP and LBP groups indicated that slopes were not significantly different (t(58)=.21, p=.84), however R^2 was significantly larger in the HPB than the LBP group (z=1.93, p=.054; DeCoster, 2005; Table 3.2, Figure 3.4).

Starry Night.

Trait boredom. Again, to demonstrate that our selected groups did, in fact, differ on BPS scores, an independent samples *t*-test indicated that participants in the HBP group (n=30; M=117.12, SD=10.01) scored significantly higher on the BPS than participants in the LBP group (n=30; M=81.75, SD=17.26; t(58)=10.43, p<.001, d=2.51). Within the HBP participants, mean BPS scores were not significantly different across video conditions (F(2,27)=1.14, p=.35). Likewise, for the LBP participants, mean BPS scores were not significant across video conditions (F(2,27)=.76, p=.48).

Mood manipulation. Means (SD) for each video are listed in Table 3.3. The top rated emotion term endorsed after watching each video (boredom, interest, and sadness) were entered into a 3 (emotion) x 3 (video) mixed factorial ANOVA. Results revealed a significant effect of emotion (F(2,114)=11.53, p<.001, η_p^2=.24), a significant main effect of video (F(1,57)=3.99, p=.03, η_p^2=.18), and a significant interaction between emotion and video (F(4,114)=7.62, p<.001, η_p^2=.30). As with the COVAT, multiple comparisons indicated that boredom was the most strongly reported emotion after watching the boring video and interest was the most

Table 3.3. Means (SD) of post video emotion ratings from Starry Night task

		Pre-video	Post-video
Boring video	Boredom	3.69 (2.18)	**5.23 (2.83)**[a]
	Interest	4.23 (2.46)	3.69 (2.72)[c]
	Sadness	1.69 (2.63)	.62 (1.45)[d]
Interesting video	Boredom	3.23 (1.30)	2.15 (2.11)[b]
	Interest	4.85 (1.95)	**4.92 (2.22)**[c]
	Sadness	1.15 (2.00)	.31 (.75)[d]
Sad video	Boredom	3.69 (1.37)	3.23 (1.69)[b]
	Interest	4.23 (2.49)	3.85 (2.73)[c]
	Sadness	.15 (.38)	**4.23 (2.71)**[c]

Note that the highest rated emotions after watching each video are indicated in bold. Ratings with identical superscripts are not significantly different from each other (p>.05).

strongly reported emotion after watching the interesting video. Again, with respect to the sad mood induction, there were no differences between participants' reports of boredom, interest, or sadness (Table 3.3). Once again, a second manipulation check was performed contrasting mood ratings prior to watching each video against ratings made immediately after watching the video via a 2 (order: pre, post) x 3 (emotion: boredom, interest, sadness) x 3 (video: boring, interesting, sad) x 2 (group: HBP, LBP) mixed factorial ANOVA. Results indicated a significant main effect of emotion ($F(2,108)=25.52$, $p<.001$, $\eta_p^2=.44$), and video ($F(1,54)=2.61$, $p<.05$, $\eta_p^2=.09$). As with the COVAT, no main effect of group emerged. Importantly, the order x emotion x video 3-way interaction was significant ($F(4,108)=8.76$, $p<.001$, $\eta_p^2=.35$). Multiple comparisons

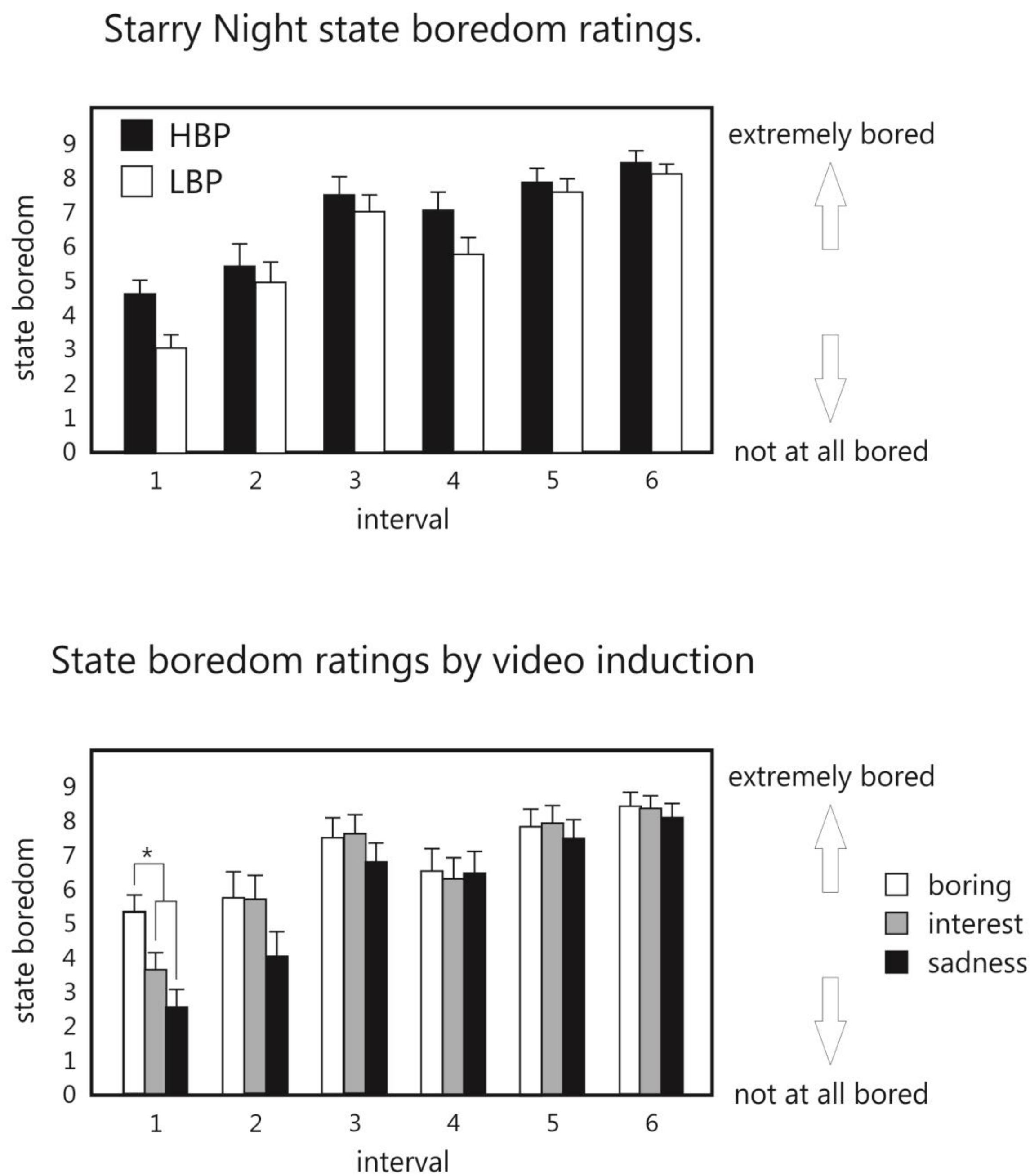

Figure 3.5 Mean (SE) of state boredom ratings at each interval during the Starry Night task. Note that boredom ratings are collapsed across video induction in the top panel and boredom proneness group in the bottom panel. * indicates significant differences at $p<.05$ or less.

indicated that, for the boring video, boredom increased significantly from pre- to post-video while interest and sadness did not change significantly. For the interesting video, interest rose post video while boredom decreased significantly in the post video phase. Sadness did not change while watching the interesting video. Finally, for the sad video, sadness increased significantly from pre- to post-video, while boredom and interest did not change (Table 3.3). Taken together, these results indicate that each video effectively induced its target emotion, although again, the sad mood induction seemed to result in a mixed emotional experience for participants.

State boredom. A mixed factorial ANOVA with interval (the 6 measurement intervals) as the within-subjects factor and video (boring, interesting, or sad) and BPS group (HBP vs. LBP) as the between-subjects factors, revealed a main effect of interval, such that boredom tended to increase throughout the task ($F(5,270)=45.57$, $p<.001$, $\eta_p^2=.57$). The main effect of BPS group was also significant, such that participants in the HBP group, on average, were more bored than participants in the LBP group ($M_{HBP}=6.82$, $SD_{HBP}=2.01$, $M_{LBP}=6.09$, $SD_{LBP}=1.92$; $F(1,54)=2.62$, $p=.05$, $d=.37$). The main effect of video was not significant, nor was the interaction between interval and BPS group. The interaction between interval and video approached significance ($F(1,54)=1.69$, $p=.09$, $\eta_p^2=.09$). Closer examination of boredom ratings early in the task (i.e., at the first interval) indicated that boredom was significantly higher for participants who watched the boring video than for participants who watched either the interesting or sad videos (Figure 3.5).

Accuracy. An ANOVA with video (boring, interesting, sad) and BPS group (HBP, LBP) indicated that participants in the HBP group missed more targets than participants in the LBP group ($M_{HBP}=12.84$, $SD_{HBP}=4.34$, $M_{LBP}=10.10$, $SD_{LBP}=5.08$; $F(1,54)=3.47$, $p=.05$, $d=.58$; Figure

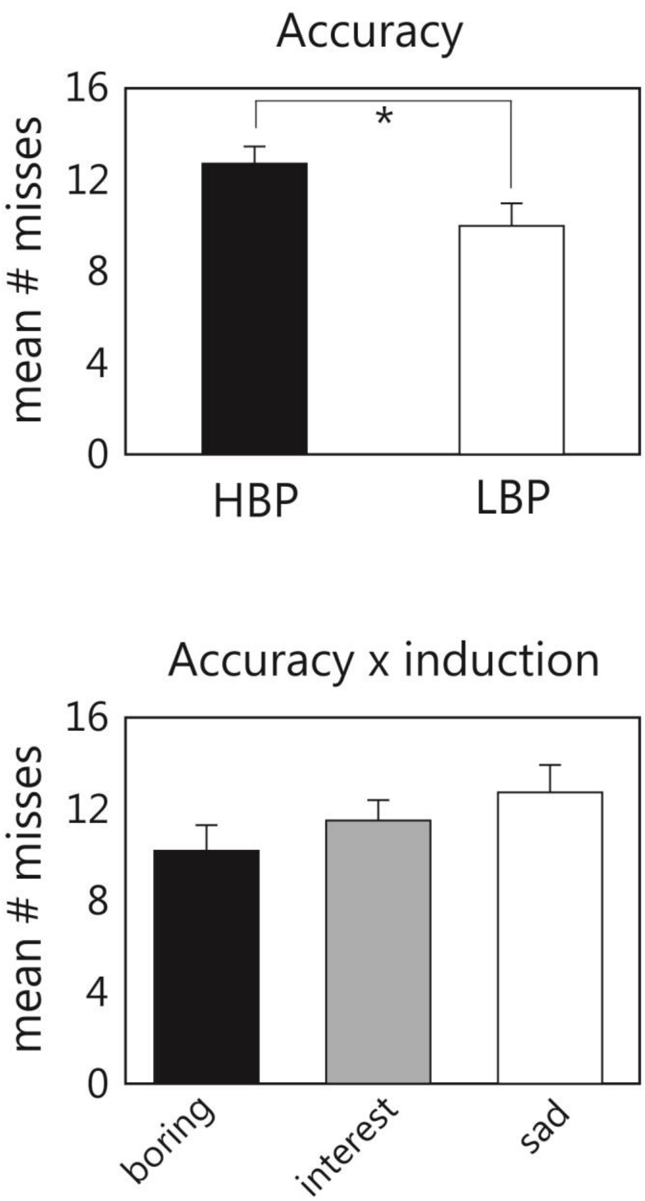

Figure 3.6 Average number of missed targets during the Starry Night task. Note that accuracy is collapsed across video induction group in the top panel and boredom proneness group in the bottom panel. * indicates a significant difference at *p*=.05.

3.6). The main effect of video was not significant, nor was the interaction between video and BPS group, although the latter approached significance ($F(2,54)=2.41$, $p=.11$, $\eta_p^2=.12$). A time series linear regression with the six rating intervals as the independent variable and number of

Table 3.4. Regression Coefficients for Accuracy (number of missed targets) during the Starry Night task

	R^2	*slope*	*t*	*p*
HBP	.87	.63	5.58	.04
LBP	.84	.92	4.56	.01
boring video	.51	.77	2.03	.11
interesting video	.87	.58	5.28	<.01
sad video	.81	.58	4.11	.02

Note that each row represents a separate regression analysis with a single predictor.

misses as the dependent variable indicated that, in both the HBP and LBP groups, the number of missed targets increased (i.e., accuracy decreased) linearly over the course of the Starry Night task. In addition, regression analyses were significant for the interesting and sad video conditions (R^2's>.81, *slopes*>.58, *t*'s>4.11, *p*'s<.02) and approached significance for the boring video condition (R^2=.51, *slope*=.77, *t*=2.03, *p*=.11; Table 3.4; Figure 3.7). An ANOVA with video (boring, interesting, sad) and BPS group (HBP, LBP) as between-subjects factors indicated that the slopes of the regression lines were not different between any of the groups (all *F*'s<1.92, all *p*'s>.18, all η_p^2's<.15). The difference between R^2 values were not significantly different between the HBP and LBP groups (*z*=.20, *p*=.84; DeCoster, 2005).

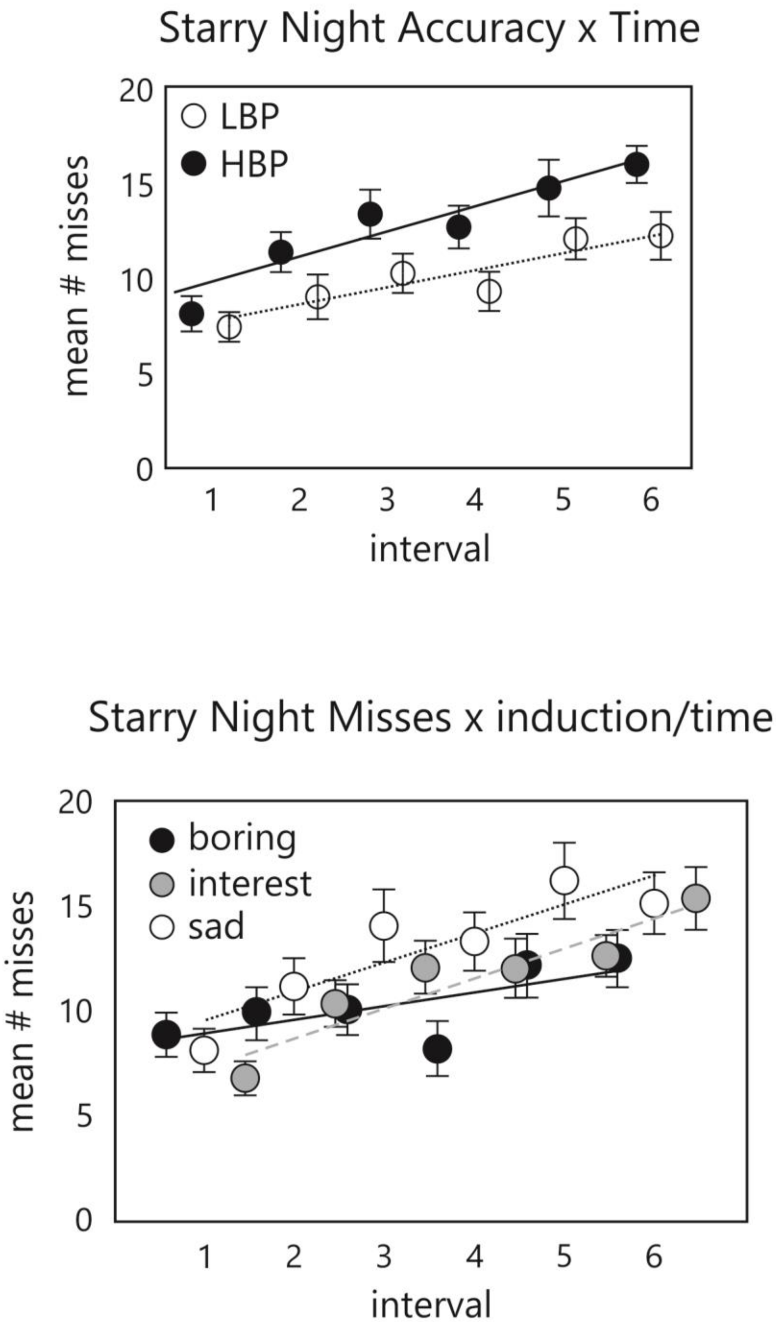

Figure 3.7 Time series linear regressions for the Starry Night task. In the top panel, accuracy is collapsed across video induction. In the bottom panel accuracy is collapsed across boredom proneness group.

3.5. Discussion

Experiment 2 examined performance on transient and sustained measures of attention as a function of boredom (both state and trait measures) to explore whether boredom interacts in distinct ways with these different types of attention. Results indicated that high boredom prone participants were faster to respond to targets during a transient attention task and were less accurate when performing a sustained attention task. With respect to the state affect inductions, while each video did elicit its intended target emotion, the inductions had little to no effect on the measures of attention. This may be due to the fact that the tasks themselves operated as superb boredom inducers. While state boredom ratings were initially higher in those who had watched the boring video, ratings rapidly rose for the other mood inductions to match that of the boring group. Another possibility is that the small number of participants in each condition (i.e., n=10 in each of the 12 video x boredom proneness groups) did not allow for sufficient power to detect these effects.

Interestingly, participants in the HBP group reported being more bored overall than participants in the LBP group, only during the sustained attention task, suggesting that HBP participants found the sustained attention task to be more boring than the transient measure. The notion that HBP individuals may be more prone to experiencing boredom in sustained attention settings is also supported by research demonstrating a robust relationship between the tendency to experience lapses in attention and boredom proneness (Carriere et al., 2007; Cheyne et al. 2006). Although both attention tasks were monotonous and subjectively boring, perhaps the fact that the COVAT task has more events per trial (fixation, cue, target in less than 1000 ms) compared to the Starry Night (one event – appearance or disappearance of a “star” - per trial over 2000 ms), made it slightly less boring. That is, although both task were monotonous, the higher event rate during the COVAT gave participants something more to do, which, compared to the Starry Night's lower event rate, was perceived to be less boring for HBP participants, who may have a tendency to seek out stimulation (Malkovsky et al., 2012). In fact, during the COVAT, HBP participants trended toward being faster overall to detect targets (p=.06), significantly so for uncued targets. This supports the notion that HBP individuals re-orient attention toward transient stimuli more rapidly than LBP individuals, and may suggest that they actively search their environment for stimulation.

During the Starry Night task, all participants became more bored and less accurate (missed more targets) over time; however, the HBP participants were even less accurate when compared to LBP participants. This result strengthens work that has found significant relationships between boredom proneness and sustained attention as measured by self-report questionnaires (Carriere et al., 2007; Cheyne et al. 2006) by providing behavioural evidence for the relationship.

Thus, results suggest that *trait* boredom may interact in distinct ways with different types of attention. That is, in tentative support of the proposed hypotheses, higher trait boredom was associated with faster RT's to uncued targets on the transient attention task and a higher number of missed targets on the sustained attention task. Arguably, this could be taken to reflect *better* performance on the transient attention measure (faster RTs) and *worse* performance (more misses) on the measure of sustained attention in individuals with higher trait boredom. The former result also provides evidence for the notion that the experience of boredom may prompt an individual to seek out stimulation and thus make them more likely to engage in rapid shifts of attention. Thus, trait boredom exerted distinct influences on performance on measures of transient and sustained attention, suggesting a fundamental difference in the way individuals who are high versus low in boredom proneness process their environment and that this difference is not influenced by transitory state affect.

Although results of the current study offer some interesting contributions to our understanding of the nature of the relationship between boredom and different types of attention, a number of limitations are worth noting. First, as mentioned, because the tasks themselves were so boring, state boredom quickly rose to levels that "washed out" any effects of the mood inductions. Future research examining the relationship between boredom and other state emotions should take precautions to guard against such rapid rises in task-induced boredom. For example, perhaps shorter or more interesting tasks could be employed. In terms of the COVAT, the fact that no cueing effect was observed (i.e., there was no difference in reaction times between validly and invalidly cued targets) might suggest that the task did not function as expected. One possible explanation for the lack of cueing effect could be that participants did not maintain a centrally fixated gaze throughout the task. Although eye gaze was monitored visually by the experimenter, a better approach would have been to employ more formal eye tracking protocol such as an electronic eye tracker. Despite this, the component of the task being emphasised here involves the high event rate (i.e., fixation, cue, target all presented within less than a second, then repeated many times over) in contrast to the low event-rate of the sustained attention task (for onset detection 1 event every 6 seconds). Such a high event rate evokes the rapid deployment of attention with temporary or transient focus on short-lived events. Thus, despite the absence of a cuing effect, participants still appeared to be faster at directing attention within a rapidly changing environment. Finally, it is important to note the inherent limitations associated with small sample sizes, including low power to detect effects. Furthermore, statistics from larger samples more reliably reflect population statistics; thus, an important next step would be to replicate the current findings in a larger sample.

It may be the case that the relationship between boredom and attention, in addition to the type of attention being considered, is modulated by the *type* of boredom proneness (as opposed to the *level* of boredom proneness as was examined here). While Cheyne and colleagues (Carriere et al., 2007; Cheyne et al. 2006) found that lapses in everyday attention – a kind of failure of sustained attention – lead to the experience of boredom generally, further work has revealed that only those boredom prone individuals who demonstrate a high need for *internal* stimulation show such lapses in everyday attention (Malkovsky et al., 2012). In contrast, boredom prone individuals reporting a high need for *external* stimulation show little evidence of such lapses in attention, but fail to adapt their behaviour to errors of sustained attention on a laboratory task (Malkovsky et al., 2012). With the small sample sizes tested in the current experiment it was not feasible to explore the potential differences in the need for internal or external stimulation here. One might imagine that individuals who have a high need for external stimulation may demonstrate a strong propensity to rapidly search their environment for interesting stimuli, making them faster at disengaging and re-orienting attention to transient events as was observed in the current study for those more generally high on trait boredom proneness. At the same time, these externally attuned individuals may be less sensitive to errors and lapses in sustained attention. Individuals who have a high need for internal stimulation, however, might be better characterized as apathetic, and thus may perform more poorly (i.e., slower RTs, increased errors) on both types of tasks. Further research examining the nature of boredom proneness as predominantly focusing on either internal or external stimulation (i.e., boredom proneness *type*) with respect to both transient and sustained attention may further explain the relationship between boredom and attention.

What is clear from the current experiment is that HBP individuals are impaired on measures of sustained attention. In the previous chapter, it was also observed that HBP participants reported a higher frequency of mind wandering. Both boredom and sustained attention have been consistently linked with mind wandering (Carriere et al., 2008; Cheyne et al., 2006; Manly, Robertson, Galloway, & Hawkins, 1999; Robertson et al., 1997). Furthermore, recent research has demonstrated correlations between mind wandering and activation of the so-called "default network", making this network a compelling contender for the neural underpinnings of the experience of boredom (Christoff, 2011; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al. 2007). Thus, the next chapter used fMRI to examine the relationship between boredom and the default network.

Chapter 4: Exploring the Neural Correlates of Boredom

4.1. Introduction

In Experiment 1, boredom was characterized by a physiological signature that is indicative of attentional disengagement (i.e., directional fractionation) and was positively associated with self-reports of mind wandering. Further examining the relationship between boredom and behavioural measures of attention in Experiment 2 revealed that individuals who were higher in trait boredom proneness performed worse (i.e., detected fewer targets) on a sustained attention task than those lower in boredom proneness. Thus, what the results of the first two chapters of this thesis suggest is that the relationship between boredom and attention reflects a disengagement from the environment or task at hand.

As outlined in Chapter 3, other research has also highlighted the relationship between boredom and both lapses in attention (Bamack, 1939; Damrad-Frye & Liard, 1989; Malkovsky et al., 2013; Pattyn et al., 2008; Scerbo, 1998; Thackray et al., 1977) and mind wandering (Carriere et al., 2008; Cheyne et al., 2006) using a range of self-report and behavioural measures, which further supports the notion that boredom is associated with a disengagement of attention. With respect to mind wandering in particular, research suggests that it is not a unitary construct. Indeed, recent research has indicated that it is spontaneous as opposed to deliberate mind wandering that is associated with boredom (Christoff, 2012, Christoff et al., 2009)[6]. Other work has distinguished between task-related and task-unrelated mind wandering, and has found mind wandering that is unrelated to, and prevents attentional engagement with, the task at hand to be associated with negative affect (Killingsworth & Gilbert, 2010; Smallwood, O'Connor, Sudbery, & Obonsawin, 2007). When considering the neural underpinnings of these constructs, both

[6] Recent work in our lab has found boredom proneness is more strongly correlated with spontaneous mind wandering (r=.43) than with deliberate mind wandering (r=.19; z=10.95, p<.001).

spontaneous, task-unrelated mind wandering and lapses in attention on behavioural tasks have been shown to be related to activity in a set of interconnected brain regions known as the default network (DN; Binder et al. 1999, 2012; Bonnelle et al., 2011; Buckner et al., 2008; Christoff , 2011; Christoff et al., 2009; Gusnard & Raichle 2001; Mason et al., 2007; Weissman, Roberts, Visscher, & Walforff, 2006). Thus, if boredom can be characterised by disengaged attention, then it might be expected that many of the same areas that have been reported to be active when mind wandering or experiencing a lapse in attention (i.e., areas that make up the DN) will also be associated with boredom.

The default network (DN) refers to a set of brain regions that support internally-focused thought (e.g., thinking to oneself, imagining the past, envisioning the future, elaborating, considering the perspective of others, etc.) and becomes active when individuals are not engaged in an externally-focused activity (Andrews-Hanna, 2012; Buckner et al., 2008; Gusnard et al., 2001; Mason et al., 2007; Raichle et al. 2001). In addition, activity in the DN has been shown to decrease when one is actively engaged in a task and attention is directed externally (Minoshima et al., 1997; Gusnard & Raichle 2001). Indeed, when a participant is actively engaged in a demanding task, activity in the executive control network typically increases while activity in the DN decreases (Greicius, Krasnow, Reiss, & Menon, 2003; Mason et al., 2007; Weissman, et al., 2006). Structurally, research has converged to suggest that the main components of the DN include the posterior cingulate cortex (PCC)/precuneus and ventromedial prefrontal cortex (vmPFC) and that these two main "hubs" are highly interconnected with lateral parts of the cortex including the lateral temporal cortex (LTC), inferior parietal lobule (IPL), and temporoparietal junction (TPJ; see Buckner, 2008 for review).

Given the results of Experiments 1 and 2, as well as the demonstrated link between boredom and mind wandering, it seems reasonable to hypothesize that both boredom and mind wandering may share common neural underpinnings. Research has consistently shown mind wandering to be associated with DN activation (Christoff et al., 2009; Gusnard, Akbudak, Shulman, & Raichle, 2001; Mason et al., 2007; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011). Indeed, in a pioneering study, Mason and colleagues (2007) investigated the relationship between DN activity and mind wandering using fMRI and self-reports of participants' experience. When queried immediately after completing the tasks, participants reported having experienced a greater frequency of mind wandering during a practiced working memory task than during a novel one. When blood oxygen level dependent (BOLD) activity was examined as a function of task type (i.e., practiced versus novel), DN activity was greater during the practiced task, when participants' reported increased frequency of mind wandering. Christoff and colleagues (2009) extended this work using experience sampling to measure reports of mind wandering online, as participants completed a sustained attention task while in the scanner. Analysis of the BOLD signals corresponding to periods of self-reported mind wandering revealed robust activation of the DN. In addition, activation of the DN was associated with errors on the sustained attention task (Christoff et al., 2009). While this work did not examine associations between mind wandering and boredom per se, it does highlight the link between disengagement of attention, mind wandering, and activation of the DN, and hints at possible neural substrates of the experience of boredom.

Other research has suggested that activity in the DN is associated with lapses or deficits in sustained attention, which, in turn, has been consistently associated with mind wandering and boredom, both in the current research and elsewhere (Bonnelle et al., 2011; Weissman et al., 2006). In one study, Weissman and colleagues (2006) found that longer reaction times on a behavioural task measuring attention were positively associated with DN activity. In another study, both individuals who had sustained a traumatic brain injury (TBI) and healthy controls demonstrated increased activity in the DN associated with poorer performance (i.e., longer reaction times and reduced accuracy) on a sustained attention task. In the TBI group, who had also been assessed as having deficits in sustained attention, the association between poorer performance on the attention task and increased activation of the DN became stronger over time across the duration of the study (Bonnelle et al., 2011). Other research has found that task-induced deactivations of the DN are attenuated in individuals with ADHD (Fassbender et al., 2009; Liddle et al., 2011; Peterson et al., 2009). Again, while this work did not examine boredom per se, research associating activity in the DN with both mind wandering and reduced sustained attention provides indirect evidence that the experience of boredom itself may evoke activation of the DN.

Indeed, recent research has suggested a direct link between the experience of boredom per se and activation of the DN. In one study, investigators examined neural activity associated with boredom while participants played a first-person shooter video game in the scanner (Mathiak, Klasen, Zvyagintsev, Weber, & Mathiak, 2013). Periods of time during play wherein participants displayed an absence of goal-directed game play for longer than 10 seconds that were associated with lowered affect on the Positive and Negative Affect Scale (PANAS) were characterized as ‘boring’ by researchers. Using this experimenter-imposed definition, periods of so-called ‘boredom’ were associated with increased activation, bilaterally, in the vmPFC and insular cortex. Reductions in activation during boredom were noted in the precuneus and hippocampus (Mathiak et al., 2013). While this study provides some clues as to the neural underpinnings of a passive behavioural state associated with negative affect (the PANAS measures general positive and negative affect, not any one specific emotion), it cannot be concluded that this experience corresponded to one of boredom per se. A better approach would have been to query participants' subjective experience of boredom directly. Indeed, more convincing evidence of the role of the DN in the experience of boredom comes from a study in which researchers examining the neural substrates of the experience of "flow" (i.e., a mental state wherein an individual is completely focused, immersed, and in a state of enjoyment while performing an activity) used boredom as a control condition and had participants rate their subjective experience of each state (Ulrich, Keller, Hoenig, Waller, & Grön, 2014). In this study, participants completed mental arithmetic in boring (low task demand – summing only two digits), flow (task demands automatically and continuously adjusted to participants' skill level) and overload (high task demand – high level of task difficulty) conditions while undergoing perfusion MRI. After completing each condition, participants' subjective experience of boredom was measured by self-report. Results revealed that boredom was associated with an increase in neural activity (as indexed by mean regional cerebral blood flow, rCBF) in the medial PFC (a main hub of the DN) and in a cluster including the left amygdala, hippocampus and parahippocampal gyrus (areas of the temporal lobe memory system that are highly interconnected with the main hubs of the DN; Ulrich et al. 2014). While this study suggests that at least one component of the DN is active when individuals are bored (i.e., the medial PFC), the type of task employed may have actually led to reduced DN activity. That is, reduced activity or deactivation of the DN is commonly observed when individuals engage in an experimental task (so-called "task-induced deactivations;" Gusnard & Raichle, 2001; Minoshima et al., 1997). Having participants engage in mental arithmetic may have led to attenuated activity in other DN structures, which may explain why activity was not observed in other, more prototypical DN components (e.g., the PCC and precuneus).

Despite the fact that previous research has implicated the DN in mental processes associated with boredom and disengaged attention (i.e., mind wandering and lapses in attention), these studies have not examined neural activity directly associated with the experience of boredom. In order to better understand whether activity in the DN is associated with the experience of boredom, the current experiment explicitly induced participants into a state of boredom in the scanner by having them watch an 8 minute version of the boring video clip used in Chapters 2 and 3. This ‘boredom’ scan was contrasted to activity in a classic resting-state scan (i.e., participants simply rested quietly with their eyes open) intended to elicit activation of the DN. Finally, participants completed an 8 minute version of a sustained attention task (the Starry Night task from Chapter 3). In this way, spontaneous brain activity under resting conditions (i.e., DN activity) could be contrasted to brain activity when bored and when engaged in a sustained attention task. Self-reports of participants’ experience of boredom and frequency of mind wandering were also collected. Blood oxygenation level dependent (BOLD) signals from each condition were analysed using independent components analysis to examine network connectivity. Independent components analysis (ICA) allows for the identification of sets of voxels with similar spatial patterns in different participants, even if the voxels are distributed in different parts of the brain, are influenced by different sources of noise, and have different time courses in different participants. In this way, temporal and spatial properties can be used to identify task-unrelated noise and components that reflect functional networks in the brain (Beckmann, DeLuca, Devlin, & Smith 2005). In addition, ICA identifies distinct functional networks without relying on a priori hypotheses regarding network anatomy. Although this work is exploratory in nature, some tentative hypotheses may be proposed. Indeed, given the links between mind wandering and sustained attention with both boredom and activation of the default network, it seems reasonable to suggest that the experience of boredom will be associated with activation of the default network. No specific hypotheses regarding differences in default network activation between the boredom induction, the sustained attention task, and the resting state scan were made.

4.2. Method

Participants

Participants were 14 healthy adults (3 female, 11 right-handed) from the University of Waterloo between the ages of 21 and 38 (*M* =25.6, *SD*=4.4) who participated in exchange for cash remuneration. Participants were recruited from a pool of undergraduate and graduate students who had expressed interest in participating in fMRI research, Individuals who participated in any of the previous experiments were not eligible to participate in this study. All participants reported having normal or corrected to normal hearing and vision and had no history of neurological difficulties or head trauma. All procedures were approved by the Office of Research Ethics at the University of Waterloo and the Tri-Hospital Research Ethics Board of Waterloo, Ontario, Canada.

Data from four participants were not included in the fMRI analyses for the following reasons. Data from one participant was removed after motion artefacts were detected during preprocessing. One participant fell asleep during scanning and another reported having sustained a previous head injury (with loss of consciousness for longer than five minutes) subsequent to participating. Data for both of these participants were also removed from analyses. Functional data from a fourth participant was not collected due to technician error at the time of collection. Thus, the results that follow are based on the remaining sample of 10 participants (2 female, M_{age}=26.0, SD_{age}=4.8, 8 right-handed).

Self-Report Measures

Boredom Proneness. As in Experiments 1 and 2, the Boredom Proneness Scale (BPS; Farmer & Sundberg, 1986) was used to assess trait boredom. In the current sample, Cronbach's alpha was .87. Participants completed the questionnaire after exiting the MRI scanner.

State Boredom. The same Likert scale used in Experiment 2, ranging from 0 (*not at all*) to 8 (*extremely*) asking "How bored are you right now?" was presented visually via a pair of LCD goggles. At the end of each run, the scale was displayed and the experimenter asked, via a microphone system, "How bored are you right now?" Participants responded verbally and their responses were recorded by the experimenter.

Mind wandering. On a scale ranging from 0 (*not at all*) to 8 (*extremely*), participants were asked "While [watching the video/resting with your eyes open/completing the Starry Night task], how much did you mind wander?" Participants completed the item three times (one for each of the three scanning conditions) after exiting the MRI scanner.

Boredom Induction Video

The same boring video described in Experiments 1 and 2 was used in the current study to induce boredom (Fothergill et al, 2007; Lovell & Zeffirelli, 1979). The version used here was eight minutes long.

Starry Night (Rizzo & Robin, 1990).

The Starry Night task was the same as described in Experiment two. Participants were presented with approximately 160 trails (80 appearance, 80 disappearance) over the span of eight minutes. Actual performance on this task was not assessed in the current investigation; rather, the task was used as a means of examining and describing activity in large-scale brain networks while completing a task requiring an external focus of attention[7].

Apparatus

All stimuli (boring video, fixation screen for the resting state scan, Starry Night task, and boredom rating scale) were presented on an Avotec Silent VisionTM (Model SV-7021) fibre-optic visual presentation system with binocular projection glasses controlled by a computer-running E-Prime software (version 1.1, Psychology Software Tools, Pittsburgh, PA) synchronized to trigger-pulses from the magnet.

Procedure

After obtaining informed consent, each participant underwent a brief screening to confirm 1) their physical/medical suitability for entering the MRI scanner and 2) that no incidental metal items were present on their person. Following this, participants were positioned in the scanner and underwent an anatomical scan prior to the three functional runs consisting of 1) a boredom run, 2) a resting state run, and 3) a Starry Night run. The three functional runs occurred in random order and each participant underwent all three conditions. During the

[7] The same program that was used to present the Starry Night task in Experiment 2 was used in the present experiment. The program was terminated manually after 8 minutes (normal running time≈20 minutes). Unfortunately, this meant that behavioural data was not successfully recorded. Participants were not aware that behavioural data was not collected.

boredom scan, participants watched the eight minute boring video after being instructed to simply watch the video while trying to remain still. During the resting state scan, participants were instructed to keep their eyes open, relax, and remain still, following which they were presented with a fixation cross on a blank screen for eight minutes. During the Starry Night scan, participants were instructed to respond, via button press, as quickly and accurately as possible, to the appearance of a "star" while maintaining their gaze at fixation. The task lasted for eight minutes. Participants rated their current level of boredom prior to the first functional run, to obtain a measurement of baseline state boredom, and after each of the boredom, resting state, and Starry Night scans. After exiting the MRI scanner, participants completed the BPS and mind wandering questions. The entire experimental session lasted approximately 55 minutes.

fMRI Data Acquisition

Functional data were collected using gradient echo-planar T2*-weighted images acquired on a Philips 1.5 Tesla machine (TR = 2000 ms; TE = 40 ms; slice thickness = 5 mm with no gap, 26 slices; FOV = 220 x 220 mm^2; voxel size = 2.75 x 2.75 x 5 mm^3; flip angle = 90°). An experimental run consisted of 26 slices/volume and 240 volumes (eight minutes). At the beginning of the session, a whole-brain T1-weighted anatomical image was collected for each participant (TR = 7.5 ms; TE = 3.4 ms; voxel size, 1 x 1 x 1 mm^3; FOV, 240 x 240 mm^2; 150 slices; no gap; flip angle, 8°).

Preprocessing and Statistical Analyses

Data were pre-processed and analysed using Brain Voyager QX (version 2.1, Brain Innovation B.V., Maastricht, the Netherlands). Prior to statistical analyses, each participant's functional data was aligned to their own 3-D anatomical images and transformed into standard stereotaxic space (Talairach and Tournoux 1988). All functional data were pre-processed, which included slice-time correction, linear trend removal, and three cycles of temporal high pass filtering. Each functional run was visually inspected for motion artefacts by playing a virtual movie of each volume in sequence (Culham et al. 2003). For all 10 participants, trilinear/sinc interpolation was used to correct for motion artefacts in functional runs. Spatial smoothing using a Gaussian kernel (4 mm Full Width Half Maximum) was applied (Mason et al., 2007). Segmentation of the cortical sheet was carried out and cortex-based volume time course (VTC) masks were created for each participant prior to carrying out the ICA analyses.

First, single-subject ICAs were carried out for each participant using the fastICA algorithm (Hyvarienen, Hoyer, & Inki, 2001). For each participant, 30 independent components (IC) were extracted and the IC ‘fingerprint’ for each component was inspected in order to determine which components were related to blood oxygen level dependent (BOLD) responses. A so-called fingerprint characterizes each independent component along several temporal and spatial features, making it possible to classify components as related to BOLD responses, motion artefacts, vasculature, etc. via visual inspection of the fingerprint (De Martino et al., 2007; Figure 4.1). Next, group-level ICAs were carried out, separately, for the DN, boredom, and Starry Night scans using the self-organising group ICA (sogICA) algorithm (Esposito et al., 2005). For each sogICA, all single-subject component maps from a functional run were “clustered” at the group level (e.g., for the boredom sogICA, the 30 components extracted for each participant from the boredom functional run were clustered) matching the most similar spatial patterns across subjects. From this, 30 group-averaged clusters were extracted and an average spatial map was computed and assumed to be representative for the cluster. The consistency of the clusters was

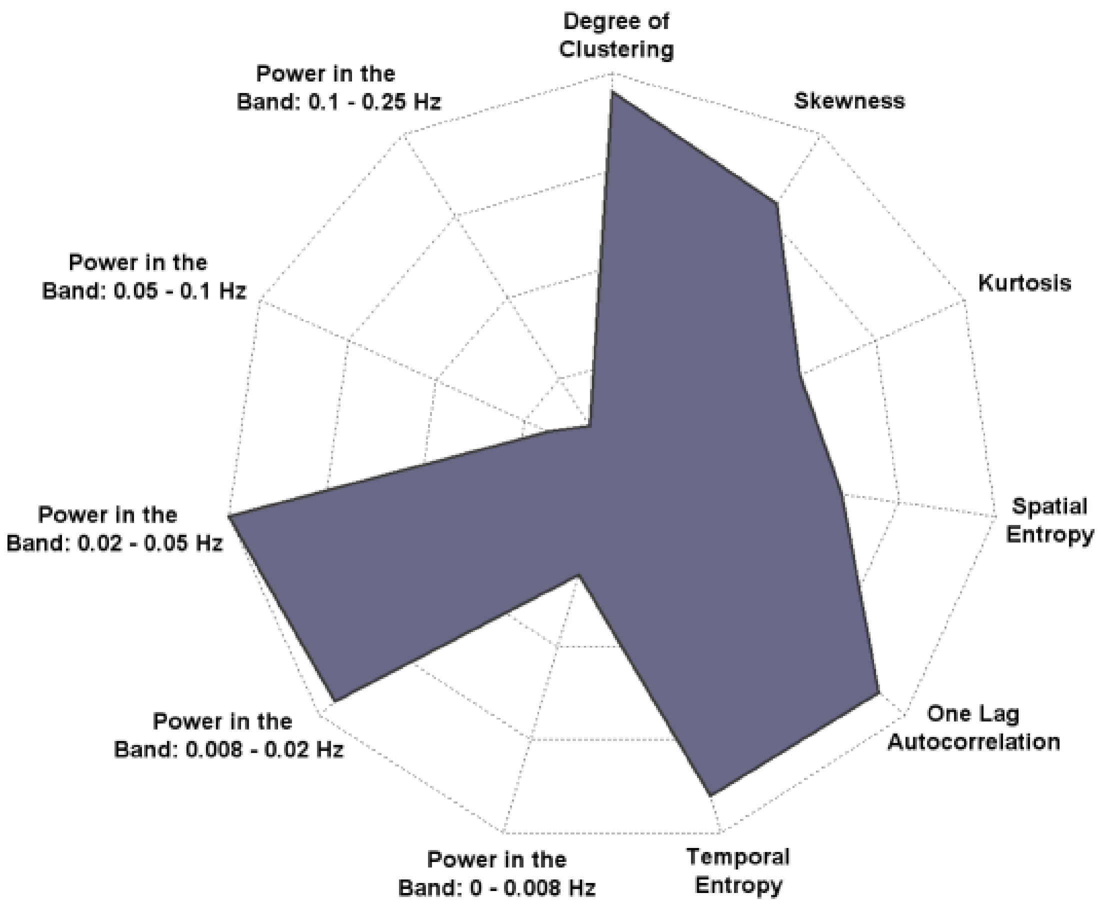

Figure 4.1 Plot representing a typical BOLD fingerprint and the 11 features used to characterize independent components (Brain Innovation BV, The Netherlands).

expressed in terms of a similarity mean (*s*), which is defined as the average of the pair-wise spatial correlations between the constituting single-subject IC maps and is based on a hierarchical clustering procedure. That is, the sogICA algorithm converted similarity measures to Euclidean distances and these were used to fill a matrix of "distances". Based on this distance matrix, a supervised hierarchical clustering procedure was run, with the supervising constraint consisting of accepting only one component per participant in each cluster formed by the hierarchical procedure. Each of the spatial maps was then visually inspected to identify any major network components. Potential networks and network components were then examined to determine whether they corresponded to BOLD responses, by examining their single-subjects maps and fingerprints. Clusters that were identified as artifacts through this procedure were eliminated from further exploration.

4.3. Results

Self-reports

Boredom. Participants' mean score on the BPS was 79.5 (*SD*=18.56, range=51-106). Of note, the BPS score observed here is lower than that typically observed in an unselected sample. For example, mean BPS scores in the large pool of participants described in Chapters 2 and 3 were significantly higher than in the current sample (Chapter 2: *M*=99.18, *SD*=17.84, *n*=2563; Chapter 3: *M*=96.42, *SD*=17.23, *n*=2873). Indeed, BPS scores in the current experiment were similar to those observed in the low boredom prone (LBP) participant groups in Chapter 3 (*M*=75.27, *SD*=16.37). Mean state boredom ratings at baseline and following each of the functional scans were entered into a repeated measures ANOVA with results revealing a significant main effect ($F(3,27)=6.69$, $p=.002$, $\eta^2=.43$, observed power=.95). Multiple comparisons indicated that participants endorsed feeling significantly more bored during each of the functional scans than at baseline ($M_{baseline}=2.40$, $SD_{baseline}=1.72$; $M_{Boredom}=4.80$, $SD_{Boredom}=2.00$; $M_{RestingState}=5.30$, $SD_{RestingState}=2.20$; $M_{StarryNight}=4.50$, $SD_{StarryNight}=1.58$; all *t*'s>2.54, all *p*'s<.03); however, no differences were observed in boredom ratings across the three functional scans (all

t's>1.58, all p's>.22)[8]. A similar pattern was observed when boredom ratings were examined over time (instead of as a function of scanning condition). That is, mean state boredom ratings at baseline (time 0, M=2.40, SD=1.72) and at each of the subsequent rating intervals (time 1, M=3.50, SD=1.35; time 2, M=4.40, SD=1.96; and time 3, M=5.40, SD=2.07) were also entered into a repeated measures ANOVA with results revealing a significant main effect (F(3,27)=5.54, p=.004, η^2=.38, observed power=.90). Multiple comparisons indicated that participants endorsed feeling significantly more bored at times 1-3 than at baseline (all t's>2.45, all p's<.04); however, no differences were observed between boredom ratings at times 1-3 (all t's<1.77, all p's>.11). Finally, when directly compared using paired-samples t-tests, no differences were found between boredom at any of times 1-3 and any of the functional scans (all t's<1.48, all p's>.17).

Mind wandering. Although participants reported engaging in mind wandering during each of the functional scans (M_{Boredom}=5.20, SD_{Boredom}=1.55; $M_{\text{RestingState}}$=5.90, $SD_{\text{RestingState}}$=2.33; $M_{\text{StarryNight}}$=4.70, $SD_{\text{StarryNight}}$=1.70), a one-way repeated measures ANOVA indicated that there were no significant differences in self-reports of mind wandering corresponding to each of the functional scans (F(2,18)=.93, p=.41, η_p^2=.09).

fMRI

Three independent component (IC) clusters corresponding to BOLD signals were identified for each of the boredom, resting state, and Starry Night functional scans. Spatial patterns for these clusters were consistent across the majority of participants (Figure 4.2).
An IC cluster consisting of common DN structures was identified in each of the boredom, resting state, and Starry Night conditions. Each of these clusters was comprised of three main regions of

[8] Ratings of boredom during the resting state scan were numerically higher than during both the boring scan (t(13)=1.73, p=.31) and the Starry Night scan (t(13)=1.77, p=.22), however, the ratings were not statistically different.

activation, which were highly consistent across all three conditions. These included a large area of activation, bilaterally, in the posterior cingulate cortex and precuneus and smaller, albeit consistent, activation, bilaterally, in the lateral temporal cortex and medial prefrontal cortex (Tables 4.1-4.3, Figure 4.2). Also observed in this “default network” IC cluster for each functional scan were consistent anticorrelated regions that are typically associated with the executive control network including dorsal parts of the parietal and frontal cortices (Figure 4.2). In addition, anticorrelated regions were observed bilaterally in the insular cortex for the IC clusters corresponding to the boredom and Starry Night conditions (Tables 4.1-4.3, Figure 4.3). An IC cluster consisting of common visual network structures was also observed for each of the boredom, resting state, and Starry Night conditions and was also highly consistent across conditions. Each of these clusters consisted of a large bilateral region of the occipital cortex, generally including both the cuneus and lingual gyri (Tables 4.1-4.3; Figure 4.2). A third IC cluster was observed for each of the functional scans, although these clusters were not consistent across scans (e.g., the clusters involved occipital and anterior cingulate cortex in the boredom scan, regions of the central executive network structures in the resting state scan, and anticorrelated regions of the central executive network structures in the Starry Night scan). Details for each of these clusters, including anatomical structures involved, coordinates of the centroids, cluster size, and similarity means are listed in Tables 4.1, 4.2, and 4.3 for the boredom, resting state, and Starry Night scans, respectively.

Table 4.1. Independent component (IC) clusters corresponding to the boredom scan.

IC Cluster	Network	Polarity	Anatomical Region	Brodmann Area	Centroid			Size (voxels)	Similarity Mean
					x	y	z		
Cluster 3	Visual		Cuneus, Lingual gyrus	17, 18	4	-76	5	21534	.27
Cluster 6	Default	Correlated	Posterior cingulate, Precuneus	23, 7	-1	-53	21	13444	.26
		Correlated	Middle temporal gyrus, Superior temporal gyrus	39	46	-66	24	2381	
		Correlated	Medial prefrontal cortex	10	-1	56	-3	1298	
		Anticorrelated	Inferior parietal lobule	40	49	-42	7	7263	
		Anticorrelated	Insula	13	-35	15	8	2058	
Cluster 8		Correlated	Lingual gyrus, Lateral occipital gyrus	18	-32	-83	-4	5543	.22
		Anticorrelated	Anterior cingulate	32	7	46	2	2105	

Note. For clusters containing more than one area of activity, polarity of each area is indicated. Activity occurred bilaterally unless otherwise noted. Similarity means express the consistency of the clusters in terms of the average of the pair-wise spatial correlations between the constituting single-subject IC maps.

Table 4.2. Independent component (IC) clusters corresponding to the resting state scan.

IC Cluster	Network	Polarity	Anatomical Region	Brodmann Area	Centroid x	y	z	Size (voxels)	Similarity Mean
Cluster 4	Default	Correlated	Posterior cingulate/precuneus,	31, 30	-1	-55	22	21173	.27
		Correlated	Superior temporal gyrus	39	48	-60	21	3336	
		Correlated	Medial prefrontal cortex	10	3	55	4	2034	
		Anticorrelated	Lateral inferior frontal gyrus, Lateral precentral gyrus	44, 4	-47	6	20	3441	
		Anticorrelated	Inferior parietal lobule (supramarginal gyrus)	40	-52	-37	36	2790	
Cluster 6	Visual		Cuneus, Lingual gyrus	18, 17	4	-74	4	27970	.26
Cluster 7	Executive Control	Correlated	Right Inferior parietal lobule	40	42	-54	39	9007	.20
		Correlated	Right dorsolateral middle frontal gyrus, Right dorsolateral superior frontal gyrus	6, 9				5709	

Note. For clusters containing more than one area of activity, polarity of each area is indicated. Activity occurred bilaterally unless otherwise noted. Similarity means express the consistency of the clusters in terms of the average of the pair-wise spatial correlations between the constituting single-subject IC maps.

Table 4.3. Independent component (IC) clusters corresponding to the Starry Night scan.

IC Cluster	Network	Polarity	Anatomical Region	Brodmann Area	Centroid x	y	z	Size (voxels)	Similarity Mean
Cluster 3	Default	Correlated	Posterior cingulate, Precuneus	23, 31, 7	-1	-54	25	13278	.24
		Correlated	Superior, Middle temporal gyrus	39	48	-62	23	3229	
		Correlated	Medial prefrontal cortex, Anterior cingulate	10	1	55	1	3258	
		Correlated	Middle frontal gyrus	8	-24	22	47	3210	
		Anticorrelated	Insula	13	34	14	8	1638	
		Anticorrelated	Left precentral gyrus, Left postcentral gyrus, Left inferior parietal lobule	44, 4, 40	-41	7	7	528	
Cluster 5	Visual		Cuneus, Lingual gyrus	18, 17	0	74	0	23840	.26
Cluster 6	Executive Control	Correlated	Superior temporal gyrus, Precentral gyrus, Insula	22, 44, 13	52	-4	5	2690	.22
		Anticorrelated	Right dorsolateral middle frontal gyrus, Right dorsolateral superior frontal gyrus	44	51	-13	32	2644	

Note. For clusters containing more than one area of activity, polarity of each area is indicated. Activity occurred bilaterally unless otherwise noted. Similarity means express the consistency of the clusters in terms of the average of the pair-wise spatial correlations between the constituting single-subject IC maps.

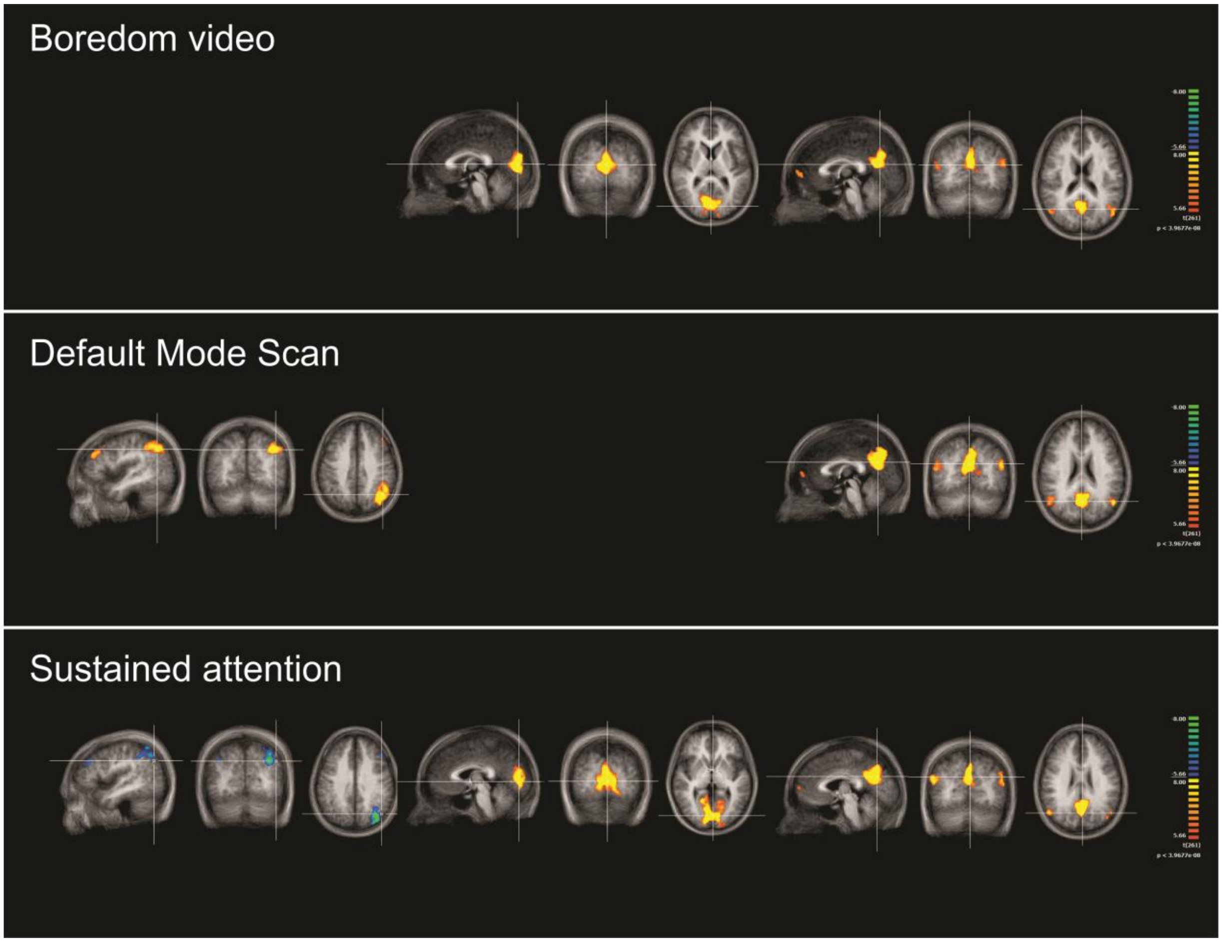

Figure 4.2 Network activity observed during each scanning condition.

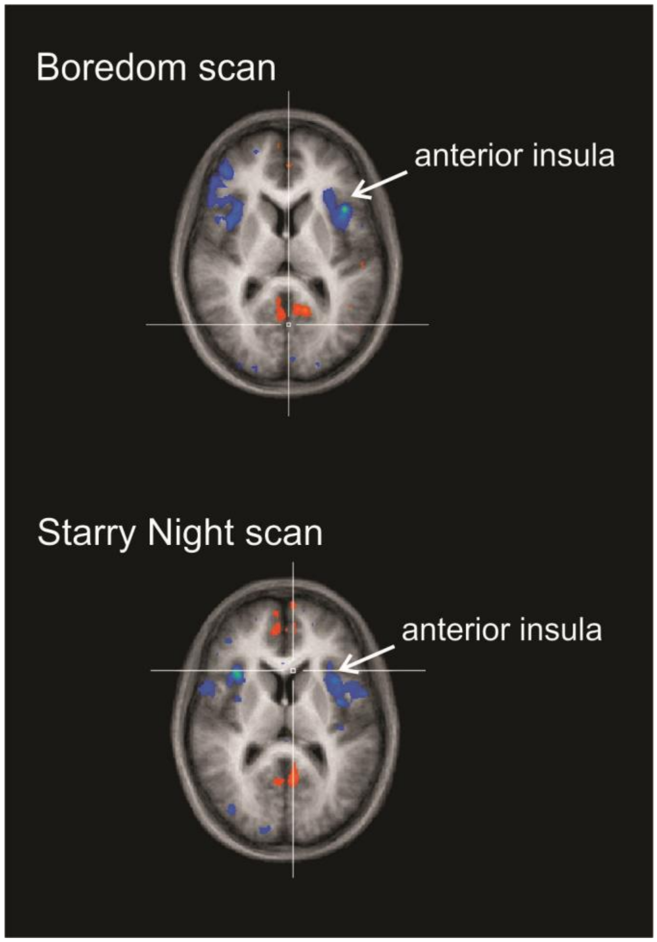

Figure 4.3 Insula activity observed during the boredom and Starry Night scans. This activity was anticorrelated with activity in DN structures.

4.4. Discussion

Data from the current Experiment examined activity in large-scale brain networks during a resting state scan, while passively viewing a boring video, and while engaging in a sustained attention task in order to better understand the neural underpinnings of the experience of boredom. A group-level spatial independent components analysis revealed three clusters corresponding to BOLD signals. In one cluster, observed in each of the boredom, resting state, and Starry Night scans, robust activity was observed in regions commonly associated with the DN and concurrent anticorrelated activation of regions associated with the executive control network and the insular cortex. A second cluster consisting of activation in areas associated with visual processing was also observed in all three conditions. A third cluster involved activation of occipital and anterior cingulate cortex in the boredom scan, regions of the central executive network structures in the resting state scan, and anticorrelated regions of the central executive network structures in the Starry Night scan. Participants reported being significantly more bored during each of the scanning runs than at baseline, but were equally bored during the functional scans. No differences in reports of mind wandering were observed across the boredom, resting state, and Starry Night scans.

The observation of DN activity with concomitant anticorrelated activation of executive control network structures during the resting state scanning condition in the current experiment is not surprising given the vast number of studies that have demonstrated this phenomenon to date (Greicius et al., 2003; Mason et al., 2007). Previous research has also demonstrated that, although they are distinct, there is some overlap between regions of the DN and the executive control network, which includes the dorsolateral prefrontal cortex (dlPFC), posterior parietal cortex (PPC), dorsal anterior cingulate cortex (ACC), and orbitofrontal cortex (OFC), and areas that comprise a visual network (Allman, Hakeem, Erwin, Nimchinsky, & Hof, 2001; Alvarez, & Emory, 2006; Christoff, 2012; Christoff, Ream, & Gabrieli, 2004; Rolls, & Grabenhorst, 2008). Given this, our finding of robust activity in areas associated with visual processing in all three scans is also not unexpected. More interesting, however, was that this same pattern (i.e., DN activity with anticorrelated activation of the executive control network) was observed for both the boredom and Starry Night conditions, both of which involved a greater level of externally-oriented attention than the resting state scan. That is, although task demands varied across scanning conditions, boredom, sustained attention and resting state scans all led to robust activation of parts of the DN. Given that activity in the DN has generally been shown to coincide with internally-focused thinking or being off-task, activation of the DN during both the boring video and the Starry Night task would suggest that participants' attention was not directed in a sustained way toward these tasks. Indeed, DN activity during these conditions was similar to that observed during the resting state scan in which there was nothing external to focus attention on. This finding also links with the results of Experiments 1 and 2, which demonstrated that the experience of boredom was associated with difficulty sustaining attention. Given that DN activity has most typically been associated with internally-focused thought, further research, perhaps using experience sampling, would be useful to determine whether, broadly speaking, participants' thoughts are directed internally or externally at moments when the DN is active during scans that involve a task.

Of note, deactivation of the insular cortex with concurrent activation of the DN was observed during the boredom and Starry Night conditions only. No activation (or deactivation) of the insula was noted for the resting state scan. Interestingly, it has been proposed, recently, that the insula plays an integral role in switching between brain networks involved in externally oriented attention and internally oriented or self-related cognition (i.e., switching between central-executive and default-mode networks; Gao & Lin, 2012; Menon & Uddin, 2010; Seeley, et al., 2007; Spreng, Sepulcre, Turner, Stevens, & Schacter, 2013; Sridharan, Levitin, & Menon, 2008). Indeed, Menon and Uddin (2010) propose that the insula is the hub of a "salience network," which functions to detect novel and/or salient stimuli across multiple modalities and increases activity in brain networks involved in attention and cognition in order to facilitate access to attention and working memory when an important event occurs (Menon & Uddin, 2010). Specifically, across varying stimulus modalities, the insula has been shown to play a causal role in activating the executive control network and deactivating the DN (Sridharan et al., 2008). With respect to the current findings, perhaps it is the case that boredom is associated with difficulty "switching off" the DN in order to direct attention externally. While participants reported feeling equally bored during the resting state scan as they did during the boredom and Starry Night scans, no insula activity was observed during the resting state scan. This may not be surprising given that no external task was present; thus, there was no need to switch from an internal to an external (or task-related) focus of attention. In other words, there was no need to deactivate the DN and activate a task-positive/executive control network, thus the insula or salience network was not recruited. During the boredom and Starry Night conditions, however, when demands for attention to be focused externally were somewhat greater, deactivation of the salience network hub (i.e., the insula) was observed. It may be that insula activity is required to deactivate the DN as the first stage in recruiting and activating the executive control network. Both the boredom and SN scans required an external focus of attention (to watch the video and detect target onsets) that would normally activate regions of the executive control network. Deactivation of the insula in the boredom and SN scans suggests that the events in these scans were not salient enough to maintain executive control network activity. A failure to engage this network would mean the DN was not deactivated. This offers a possible neural mechanism for the sustained attention difficulties observed when individuals are bored or perhaps a neural explanation for boredom itself.

While the results of the current experiment provide interesting clues about the neural underpinnings of the experience of boredom and associated attention-related difficulties, further research is clearly required to better characterise the neural bases of boredom. It will be important to first gain a better understanding of the relationship between boredom and mind wandering and how each is related to the DN. As already mentioned, recent results indicated that boredom was most strongly correlated with spontaneous and not deliberate mind wandering. This warrants closer examination. Indeed, one could imagine that deliberate mind wandering may represent a strategy to reduce or prevent boredom; thus, perhaps its neural underpinnings do not resemble those found here. Examining large-scale brain network activity as a function of trait boredom proneness will also clarify relationships between these constructs. With the relatively small sample tested here, and the fact that the average BPS score was in the low range, this was not possible in the current experiment; however, perhaps it is the case that individuals who are higher in trait boredom proneness demonstrate more broadly evident deactivation of the central executive network. Another possibility is that activation of the DN in higher boredom prone individuals occurs more quickly in time or activates more strongly compared to those who are lower in boredom proneness. Further research would be needed to better understand these relationships. In addition, a better understanding of how boredom might be associated with the ability to switch between default and executive or task-positive networks is needed. Results of the current experiment suggest that boredom may influence activity in the salience network, which is responsible for detecting important information and adjusting access to brain areas required to respond to this information (i.e., deactivating the DN and activating an executive or task-positive network). Given this, it will be important to understand which components of the salience network are most affected by boredom. For example, perhaps boredom is differentially associated with the different functions of the salience network. That is, maybe it is the case that bored individuals are able to search for and identify salient information, but are unable to switch off the DN when needed. On the other hand, perhaps individuals who are bored fail to identify and mark cues as salient altogether (i.e., they search for novel or salient information, but continually fail to correctly identify it) and thus chronically fail to disengage the DN. Indeed, recent work demonstrating that individuals who were characterized as agitated boredom prone were worse at discriminating between similar and dissimilar stimuli than those who were not prone to agitated boredom, lends support to this notion (Goldberg, 2012). Alternatively, it may be the case that boredom affects both functions. Results of Experiment 2, where it was found that individuals who were high in trait boredom proneness were somewhat better at a transient attention task (i.e., faster RT's) and worse at a sustained attention task (i.e., detected fewer targets), might suggest that the former hypothesis is more likely. It would be worthwhile to investigate whether the ability to switch between default and task-positive networks is associated with the type (as opposed to the level) of boredom proneness one experiences. As described in the previous chapter, research has suggested that boredom prone individuals with a high need for internal stimulation report more lapses of attention, while boredom prone individuals with a high need for external stimulation report fewer lapses in attention, but fail to adapt their behaviour when they make sustained attention errors on a laboratory task (Malkovsky et al., 2012). These distinct types of boredom proneness may evoke distinct activation (and deactivation) in both the

DN and executive control networks. Finally, given that the anterior insula is also thought to play an important role in affective experiences, it may be important to consider results of the current experiment from an emotional, as opposed to a strictly attentional, perspective. Insular activity is consistently associated with the experience of pain and a range of other negatively valenced emotions (see Craig, 2009 for review). It is possible then that emotions associated with being bored – for example, frustration, agitation – during the boring and Starry Night scans were what drove the insula activity observed here. Further research would be necessary to disentangle this possibility.

While results of the current study are intriguing, a number of limitations are important to note. First, while sufficient for an initial exploration of large-scale network activity, the small number of participants presented some challenges. For example, it was not possible to explore order effects with respect to the mood inductions given our sample size. In future research, it would be important to understand whether boredom ratings across scanning conditions reflect true differences (or equivalencies) in boredom or whether carry-over effects exist in relation to a particularly boring condition. It was also not possible in the current study to examine the relationship between self-reports (i.e., of mind wandering or trait boredom proneness) and BOLD activity given the relatively small sample size. Particularly important in this regard would be to better understand the role of mind wandering with respect to boredom and default network activity. A second, related, limitation was that mind wandering was not thoroughly assessed in the current study. Participants rated their frequency of mind wandering after exiting the scanner at the end of the experimental session. In order to better understand the role of mind wandering with respect to the current findings, a more comprehensive assessment of participants' mind wandering would be needed. In addition, it might be prudent in future research to assess mind wandering at the same time boredom ratings are obtained (i.e., immediately after each scanning condition) or during scanning via experience sampling methods.

In summary, what is clear from this experiment is that robust DN activity occurred during two boring tasks (one involving passive movie watching, the other a task of sustained attention) and this activation was broadly similar to that observed during a classic resting-state period. Thus, it would appear as though the experience of boredom is indeed associated with DN activity. Furthermore, boredom seems to interfere with deactivation of the DN (or activation of a task-positive/ central executive network) when a more externally-focused locus of attention is required, as it was associated with deactivation of the insular cortex, the hub of the so called "salience network," which is integral in switching between the default and executive networks.

Chapter 5: General Discussion.

Boredom is a universal human experience that has been broadly researched in a variety of fields. Within the field of psychology alone, a number of different theories have sought to explain the phenomenon and its relationship with numerous other constructs. Despite this, very little research has been devoted to gaining a better understanding of the construct itself. Thus, this thesis aimed to employ convergent psychophysiological, cognitive, and neuroimaging paradigms in order to carry out a systematic investigation of the processes that underlie the experience of boredom.

Experiment 1 explored whether boredom could be distinguished from the related state of sadness in terms of its psychophysiology. Specifically, mood induction and physiological monitoring was used to evaluate the physiological correlates of boredom and sadness. Results indicated that boredom may have a physiological signature that is distinguishable from sadness (i.e., increasing HR, higher cortisol levels, and lower skin conductance levels). In addition, a positive correlation was found between boredom proneness and HR and when the sample was split into groups of higher and lower boredom prone individuals, those who were higher in boredom proneness were found to have significantly faster HR than those lower in boredom proneness. This difference was observed during the boring epoch, but not the sad or interesting epochs, suggesting that more highly boredom prone individuals may experience boredom as more arousing than those who are lower in boredom proneness. Interestingly, it was recently reported that the cumulative effects of boredom may be associated with cardiovascular disease and early death (Britton & Shipley, 2010). Given the well-established links between stress, cortisol, and cardiovascular disease, it will be worthwhile for future research to further explore potential long-term health consequences of chronic boredom in those who are prone to experiencing it (Hiromichi, 2010; Looser et al., 2010). Interestingly, the psychophysiological signature of boredom observed in Experiment 1 (i.e., directional fractionation – increasing HR with a concomitant decrease in SCL) has also been associated with decreased attention and attention deficits (Coles, 1972; Frith & Allen, 1983; Hermens et al., 2004; O'Connell et al., 2008). Experiment 1 also revealed that boredom was associated with a higher frequency of mind wandering. Both of these findings converge with other research suggesting that boredom is associated with inattention (Carriere et al., 2007; Cheyne et al., 2006; Malkovsky et al., 2012; Ohsuga et al., 2001; Pattyn et al., 2008). In summary, the results of Experiment 1 suggest that boredom is an experience that is distinct from the closely related state of sadness and is associated with increased arousal and decreased attention.

Experiment 2 built on this work by investigating the relationship between boredom (both trait and state) and measures of transient and sustained attention. Results revealed that individuals who are high in trait boredom proneness were faster at detecting transient stimuli (significantly so for uncued transient stimuli) and less accurate (i.e., missed more targets) on the measure of sustained attention, suggesting that *trait* boredom may interact in distinct ways with different types of attention. These findings converge with recent work demonstrating that individuals who are high in boredom proneness tend to seek out stimulation and have a weaker preference for familiarity than individuals who are low in boredom proneness (Malkovsky et al., 2012). Indeed, perhaps it is the case that the ability to more quickly disengage and reorient attention is part of a more general tendency in highly boredom prone individuals to engage in rapid shifts of attention in order scan their environment for novel or interesting stimuli to combat feelings of boredom. This notion warrants further investigation. In addition, further research is needed to examine the relationships between attention and *type* of boredom proneness. That is, while the current research examined relationships between boredom and attention as a function of the *level* of boredom proneness (i.e., high or low), other work has identified differing types of boredom proneness (i.e., agitated or apathetic) that may be important to consider (Goldberg, 2012; Malkovsky, 2012; Mercer-Lynn, Flora, Fahlman, & Eastwood, 2013). State boredom had no effect on performance during the attention tasks in Experiment 2. Although it could be the case that state boredom levels do not impact attention significantly, this could not be concluded due to limitations in the study design. That is, as the number of participants per condition was small and because the tasks themselves increased boredom considerably across all conditions (which made comparisons between them with respect to state boredom impossible) effects of state boredom may not have emerged. As such, further investigation of the relationship between attention and state boredom is warranted. Indeed, one could imagine that state and trait boredom interact in a more complex manner than was observed here. For example, it may be the case that higher boredom prone individuals only demonstrate the attention effects observed in Experiment 2 when bored. When they are not bored, perhaps higher boredom prone individuals' attentional performance resembles that of lower boredom prone individuals. In order to ascertain this, future research would have to carefully consider the properties of the tasks employed to ensure that the tasks themselves do not function as boredom inductions. Perhaps tasks that are shorter in duration or are somewhat more engaging to perform would circumvent this problem (although researchers would also have to beware of using tasks that are overly interesting and/or engaging, as this would counteract the effect of the boring mood induction). Whatever the case, a better understanding of the role of state boredom on attentional functioning is a worthwhile avenue for future inquiry.

Finally, Experiment 3 examined the relationship between boredom and activity in the Default Network (DN), a set of brain regions consistently linked with both mind wandering and inattention, using resting state fMRI. Results revealed robust activation of DN during the resting state scan, as well as during two boring tasks (i.e., watching a boring video and completing the Starry Night task). Given the purported functions of the DN, this result converges with those of Experiments 1 and 2, suggesting that individuals tend to engage in more mind wandering and have difficulty sustaining their attention when bored. In addition, activity in the insular cortex was observed to be anticorrelated with DN activity during the boredom and Starry Night scans. This finding may suggest that boredom interferes with switching between the DN and task-positive networks when attention is required to be directed externally by deactivating the insular cortex, which has recently been implicated as playing a key role in switching between the DN and executive control networks (i.e., it forms the hub of a "salience network"; Gao & Lin, 2012; Menon & Uddin, 2010; Seeley et al., 2007; Spreng et al., 2012; Sridharan et al., 2008). Due to the small sample size and low mean BPS scores in Experiment 3, it was not possible to examine neural activity with respect to trait boredom proneness; nonetheless, this represents an important avenue for future research. In Experiment 2, more highly boredom prone participants were faster at detecting transient stimuli. This result converges with recent research suggesting that individuals more highly prone to agitated boredom fail to adapt their behaviour after making errors of sustained attention (Malkovsky et al., 2012) and are worse at distinguishing between similar and dissimilar stimuli (Goldberg, 2012). A useful next step would be to better unify these findings. For example, it may be the case that individuals who are more highly prone to boredom (or to agitated boredom) are faster at detecting transient stimuli, fail to adapt their behaviour after an error, and have difficulty distinguishing between similar and dissimilar stimuli because they are unable to activate a salience network when bored. That is, perhaps activation of the default network when bored interferes with activation of the salience network; which, in turn could prevent individuals from marking important stimuli as salient. Such a failure to mark stimuli as salient could explain the faster disengagement from transient stimuli, inability to adapt to errors, and difficulty distinguishing between similar and dissimilar. Indeed, a better understanding of how these types of trait boredom proneness are related to activity in (or switching between) the default, executive control, and salience networks represents an essential next step in this line of research. Given the role of the anterior insula in emotional processing, it will be important, also, for future research to consider findings from both an attentional and an affective perspective.

In summary, data presented in this thesis suggest that boredom, at the state level, is a distinct construct with a psychophysiological signature that can be distinguished from related states and is associated with mind wandering, and activation of the default network, a set of brain regions associated with a decrease in externally-focused attention. At the trait level, the present research suggests that individuals who are higher in boredom proneness become more physiologically aroused (i.e., higher HR) when bored, are better able to engage in rapid shifts in attention (i.e., faster RTs on a transient attention measure), and are worse at sustaining attention (i.e., more missed targets on a sustained attention measure) compared to those who are low in boredom proneness. This work represents some of the first steps toward characterizing the experience of boredom in terms of its physiological, behavioural, and neural correlates and suggests that, in general, boredom is associated with increased arousal and difficulties with attention.

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Appendix A

Questionnaires

State Affect Questionnaire [post film version]

The following questions refer to how you feel *right now* [felt *while watching the previous film*].

0	1	2	3	4	5	6	7	8
not at all/ none				somewhat/ some				extremely/ a great deal

Using the scale above, please indicate the greatest amount of each emotion you feel [experienced while watching the previous film]

___ amusement	___ embarrassment	___ neutral
___ anger	___ fear	___ pride
___ nervous	___ guilt	___ sadness
___ confusion	___ happiness	___ shame
___ contempt	___ interest	___ surprise
___ disgust	___ joy	___ distress
___ boredom	___ alert	___ upset
___ excitement	___ hostility	___ love

Do you feel any other emotion [Did you feel any other emotion during the film]? ___ yes ___ no

If so, what is [was] the emotion? ________________________________

How much of this emotion do [did] you feel (using the above scale)? ___

Please use the following pleasantness scale to rate the feelings you have [had during the film]. Circle your answer:

0	1	2	3	4	5	6	7	8
unpleasant								pleasant

[Had you seen this film before? ___ yes ___ no]

[Did you close your eyes or look away during any scenes? ___yes ___ no]

[Did your mind wander or did you think about things other than the film while watching it? __ yes __ no]

Boredom Proneness Scale

1	2	3	4	5	6	7
strongly disagree	somewhat disagree	disagree	neutral	agree	somewhat agree	strongly agree

The following are some statements that may or may not describe you, in general, on a typical day. Please rate each statement using the 7-point scale above by circling the number that corresponds to how much you do or do not feel like the sentence describes you. Remember to rate each statement based on how much it describes you *in general*.

1. It is easy for me to concentrate on my activities.	1	2	3	4	5	6	7
2. Frequently when I am working I find myself worrying about other things.	1	2	3	4	5	6	7
3. Time always seems to be passing slowly.	1	2	3	4	5	6	7
4. I often find myself at "loose ends," not knowing what to do.	1	2	3	4	5	6	7
5. I am often trapped in situations where I have to do meaningless things.	1	2	3	4	5	6	7
6. Having to look at someone's home movies or travel slides bores me tremendously.	1	2	3	4	5	6	7
7. I have projects in mind all the time, things to do.	1	2	3	4	5	6	7
8. I find it easy to entertain myself.	1	2	3	4	5	6	7
9. Many things I have to do are repetitive and monotonous.	1	2	3	4	5	6	7
10. It takes more stimulation to get me going than most people.	1	2	3	4	5	6	7
11. I get a kick out of most things I do.	1	2	3	4	5	6	7
12. I am seldom excited about my work.	1	2	3	4	5	6	7
13. In any situation I can usually find something to do or see to keep me interested.	1	2	3	4	5	6	7
14. Much of the time I just sit around doing	1	2	3	4	5	6	7

nothing.

15. I am good at waiting patiently.	1	2	3	4	5	6	7
16. I often find myself with nothing to do - time on my hands.	1	2	3	4	5	6	7
17. In situations where I have to wait, such as a line or queue, I get very restless.	1	2	3	4	5	6	7
18. I often wake up with a new idea.	1	2	3	4	5	6	7
19. It would be very hard for me to find a job that is exciting enough.	1	2	3	4	5	6	7
20. I would like more challenging things to do in life.	1	2	3	4	5	6	7
21. I feel that I am working below my abilities most of the time.	1	2	3	4	5	6	7
22. Many people would say that I am a creative or imaginative person.	1	2	3	4	5	6	7
23. I have so many interests I don't have time to do everything.	1	2	3	4	5	6	7
24. Among my friends, I am the one who keeps doing something the longest.	1	2	3	4	5	6	7
25. Unless I am doing something exciting, even dangerous, I feel half-dead and dull.	1	2	3	4	5	6	7
26. It takes a lot of change and variety to keep me really happy.	1	2	3	4	5	6	7
27. It seems that the same things are on television or the movies all the time; it's getting old.	1	2	3	4	5	6	7
28. When I was young, I was often in monotonous and tiresome situations.	1	2	3	4	5	6	7

Beck Depression Inventory – II

This questionnaire consists of 21 groups of statements. Please read each group of statements carefully, and then pick out the **one statement** in each group that best describes the way you have been feeling during the **past two weeks, including today.** Circle the number beside the statement you have picked. If several statements in the group seem to apply equally well, circle the highest number for that group. Be sure that you do not choose more than one statement for any group, including item 16 (Changes in Sleeping Pattern) or item 18 (Changes in Appetite).

1. Sadness
0 I do not feel sad.
1 I feel sad much of the time.
2 I am sad all the time.
3 I am so sad or unhappy that I can't stand it.

2. Pessimism
0 I am not discouraged about my future.
1 I feel more discouraged about my future than I used to be.
2 I do not expect things to work out for me.
3 I feel my future is hopeless and will only get worse.

3. Past Failure
0 I do not feel like a failure.
1 I have failed more than I should have.
2 As I look back, I see a lot of failures.
3 I feel I am a total failure as a person.

4. Loss of Pleasure
0 I get as much pleasure as I ever did from the things I enjoy.
1 I don't enjoy things as much as I used to.
2 I get very little pleasure from the things I used to enjoy.
3 I can't get any pleasure from the things I used to enjoy.

5. Guilty Feelings
0 I don't feel particularly guilty.
1 I feel guilty over many things I have done or should have done.
2 I feel quite guilty most of the time.
3 I feel guilty all of the time.

6. Punishment feelings
0 I don't feel I am being punished.
1 I feel I may be punished.
2 I expect to be punished.
3 I feel I am being punished.

7. Self-Dislike

0 I feel the same about myself as ever.
1 I have lost confidence in myself.
2 I am disappointed in myself.
3 I dislike myself.

8. Self-Criticalness
0 I don't criticize or blame myself more than usual.
1 I am more critical of myself than I used to be.
2 I criticize myself for all of my faults.
3 I blame myself for everything bad that happens.

9. Suicidal Thoughts or Wishes
0 I don't have any thoughts of killing myself.
1 I have thoughts of killing myself, but I would not carry them out.
2 I would like to kill myself.
3 I would kill myself if I had the chance.

10. Crying
0 I don't cry anymore than I used to.
1 I cry more than I used to.
2 I cry over every little thing.
3 I feel like crying, but I can't.

11. Agitation
0 I am no more restless or wound up than usual.
1 I feel more restless or wound up than usual.
2 I am so restless or agitated that it's hard to stay still.
3 I am so restless or agitated that I have to keep moving or doing something.

12. Loss of Interest
0 I have not lost interest in other people or activities.
1 I am less interested in other people or things than before.
2 I have lost most of my interest in other people or things.
3 It's hard to get interested in anything.

13. Indecisiveness
0 I make decisions about as well as ever.
1 I find it more difficult to make decisions than usual.
2 I have much greater difficulty in making decisions than I used to.
3 I have trouble making any decisions.

14. Worthlessness
0 I do not feel I am worthless.
1 I don't consider myself as worthwhile and useful as I used to.
2 I feel more worthless as compared to other people.
3 I feel utterly worthless.

15. Loss of Energy
0 I have as much energy as ever.
1 I have less energy than I used to have.
2 I don't have enough energy to do very much.
3 I don't have enough energy to do anything.

16. Changes in Sleeping Pattern
0 I have not experienced any change in my sleeping pattern.
1a I sleep somewhat more than usual.
1b I sleep somewhat less than usual.
2a I sleep a lot more than usual.
2b I sleep a lot less than usual.
3a I sleep most of the day.
3b I wake up 1-2 hours early and can't get back to sleep.

17. Irritability
0 I am no more irritable than usual.
1 I am more irritable than usual.
2 I am much more irritable than usual.
3 I am irritable all the time.

18. Changes in Appetite
0 I have not experienced any change in my appetite.
1a My appetite is somewhat less than usual.
1b My appetite is somewhat greater than usual.
2a My appetite is much less than before.
2b My appetite is much greater than usual.
3a I have no appetite at all.
3b I crave food all the time.

19. Concentration Difficulty
0 I can concentrate as well as ever.
1 I can't concentrate as well as usual.
2 It's hard to keep my mind on anything for very long.
3 I find I can't concentrate on anything.

20. Tiredness or Fatigue
0 I am no more tired or fatigued than usual.
1 I get more tired or fatigued more easily than usual.
2 I am too tired or fatigued to do a lot of things I used to do.
3 I am too tired or fatigued to do most of the things I used to do.

21. Loss of Interest in Sex
0 I have not noticed any recent change in my interest in sex.

1 I am less interested in sex than I used to be.
2 I am much less interested in sex now.
3 I have lost interest in sex completely

Appendix B

Forty eight individuals (none of whom overlapped with the present study sample) participated in a study whose purpose was to assemble a set of three video clips that would elicit the states of 1) boredom, 2) sadness, and 3) a neutral state similar to participants' baseline that would serve as mood induction stimuli for the current study.

Table 1. Pilot Study – Means (SD) of Video Ratings on State Affect Questionnaire

Epoch							
Baseline	Boring Videos			Neutral Video	Sad Videos		
180 s	171s	233s	341s	233 s	171s	233s	341s
Interest[a]	Boredom[a]	Boredom[a]	Boredom[a]	Interest[a]	Sadness[a]	Sadness[a]	Sadness[a]
4.57 (1.57)	5.40 (2.61)	6.81 (2.11)	6.27 (2.52)	5.17 (2.17)	4.25 (2.54)	5.34 (2.34)	5.63 (2.60)
Happiness[a]	Confusion[b]	Confusion[b]	Confusion[b]	Amusement[a]	Alertness[b]	Upset[b]	Upset[b]
4.11 (2.26)	3.00 (2.75)	1.88 (2.13)	2.07 (2.19)	4.81 (2.13)	2.88 (2.45)	3.79 (3.17)	3.94 (2.67)
Alertness[a]	Alertness[b]	Anger[b]	Happiness[b]	Happiness[a]	Upset[b]	Interest[b]	Interest[b]
3.79 (2.26)	2.20 (2.01)	1.31 (2.55)	1.27 (1.98)	4.17 (2.51)	2.69 (2.39)	2.64 (2.62)	3.69 (2.60)
Pleasantness[i]	Pleasantness[ii]	Pleasantness[ii]	Pleasantness[ii]	Pleasantness[i]	Pleasantness[ii]	Pleasantness[ii]	Pleasantness[ii]
5.22 (1.57)	4.33 (2.13)	2.69 (.95)	3.43 (1.99)	5.52 (1.74)	2.73 (1.83)	2.62 (.96)	2.33 (1.61)

Note. In the upper section of the table, [a] is significantly different from [b] in each *column*. In the lower section of the table (i.e., for the pleasantness ratings), [i] is significantly different from [ii] across the *row*.

Epoch							
Baseline	Boring Videos			Neutral Video	Sad Videos		
180 s	171s	233s	341s	233 s	171s	233s	341s
Boredom[a]	Boredom[a]	Boredom[a]	Boredom[a]	Boredom[a]	Boredom[a]	Boredom[a]	Boredom[a]
1.98 (2.41)	5.40 (2.61)	6.81 (2.11)	6.27 (2.52)	1.30 (1.76)	1.44 (2.10)	2.00 (2.51)	1.00 (1.93)
Sadness[b]	Sadness[b]	Sadness[b]	Sadness[b]	Sadness[a]	Sadness[b]	Sadness[b]	Sadness[b]
.81 (1.86)	0	1.19 (2.26)	.56 (1.50)	.36 (1.24)	4.25 (2.54)	5.34 (2.34)	5.63 (2.39)
Interest[c]	Interest[c]	Interest[c]	Interest[b]	Interest[b]	Interest[c]	Interest[a]	Interest[c]
4.57 (1.89)	2.20 (2.01)	.69 (1.66)	.31 (.70)	5.17 (2.17)	2.56 (2.34)	2.64 (2.62)	3.69 (2.60)
Pleasantness[i]	Pleasantness[ii]	Pleasantness[ii]	Pleasantness[ii]	Pleasantness[i]	Pleasantness[ii]	Pleasantness[ii]	Pleasantness[ii]
5.22 (1.57)	4.33 (2.13)	2.69 (.95)	3.43 (1.99)	5.52 (1.74)	2.73 (1.83)	2.62 (.96)	2.33 (1.61)

Note. In the upper section of the table, [a, b,] & [c] are significantly different from each other within each *column*. In the lower section of the table (i.e., for the pleasantness ratings), [i] is significantly different from [ii] across the *row*.

Appendix C

Mood Induction Analyses

Differences within each epoch.

A manipulation check was performed, as a first step, to ensure that each target emotion was elicited by the videos and to determine which emotion(s) participants felt most strongly during the baseline period. For each epoch separately (i.e., baseline, boredom, interest, sadness), a repeated measures ANOVA was conducted to compare the top three emotion terms endorsed by participants during each epoch on the State Affect (SA) questionnaire.

Baseline. On the SA questionnaire during the baseline epoch, participants endorsed having felt interested (M=5.60, SD=1.65), happy (M=4.53, SD=2.09), and excited (M=3.75, SD=2.20) most strongly (Table 2.1). A repeated measures ANOVA, with a Greenhouse-Geisser adjustment for lack of sphericity, indicated that there were differences in the intensity with which participants endorsed feeling these states [$F(1.6, 105.4)=13.23$, $p<.001$, $\eta^2=.17$]. Multiple comparisons revealed that participants felt more interested than either happy (*mean difference*=1.07, $p<.001$) or excited (*mean difference*=1.85, $p<.001$). Participants also felt more happy than excited (*mean difference*=.78, $p<.01$).

Boredom. The highest rated emotion terms on the SA questionnaire during the boring video were boredom (M=5.54, SD=2.37), confusion (M=2.68, SD=2.48) and amusement (M=2.53, SD=2.56; Table 2). A repeated measures ANOVA, with a Greenhouse-Geisser adjustment for lack of sphericity, indicated that there were differences in how strongly participants felt each of these emotions [$F(1.7,111.8)=28.89$, $p<.001$, $\eta^2=.30$]. Multiple comparisons revealed that participants felt boredom more strongly than either confusion (*mean difference*=2.87, $p<.001$) or amusement (*mean difference*=3.02, $p<.001$). There was no difference between the intensity of participants confusion or amusement ratings (*mean difference*=.15, *p*>.99; Table 3).

Interesting. During the interesting video, on the SA questionnaire, participants endorsed having felt interest (*M*=5.93, *SD*=1.50), amusement (*M*=5.44, *SD*=1.85), and happiness (*M*=4.72, *SD*=2.03) most strongly (Table 2.1). A repeated measures ANOVA, with a Greenhouse-Geisser adjustment for lack of sphericity, indicated that there were differences in the intensity with which participants felt these emotions during the interesting epoch [$F(1.7,113.7)=21.06$, $p<.001$, $\eta^2=.24$]. Multiple comparisons revealed that participants felt more interest than either amusement (*mean difference*=1.21, *p*<.001) or happiness (*mean difference*=.49, *p*=.01). Participants rated their experience of amusement as more intense than their experience of happiness (*mean difference*=.72, *p*<.01).

Sadness. The highest rated emotion terms on the SA questionnaire during sad video were sadness (*M*=5.10, *SD*=1.85), upset (*M*=4.12, *SD*=2.19) and interest (*M*=3.84, *SD*=1.98; Table 2). A repeated measures ANOVA indicated that there were differences in how strongly participants felt each of these states [$F(2,134)=9.92$, $p<.001$, $\eta^2=.13$]. Multiple comparisons revealed that participants felt more sadness than both upset (*mean difference*=.99, *p*<.01) and interest (*mean difference*=1.27, *p*=.001). There was no difference in the intensity with which participants felt either upset or interest (*mean difference*=.28, *p*>.80).

Differences between epochs.

One-way repeated measures ANOVAs, with epoch (i.e. baseline, boredom, interest, sadness) as the within subjects factor, were conducted to determine whether the target emotions differed in intensity and valence across each of the four epochs.

Intesity.

Interest. There were significant differences in intensity of the SA questionnaire interest ratings across epochs [$F(3,201)=104.05$, $p<.001$, $\eta^2=.80$]. Multiple comparisons, revealed that interest ratings during the baseline epoch (*M*=5.60, *SD*=1.65) did not differ in intensity from interest ratings during the interesting epoch (*M*=5.93, *SD*=1.50; *mean difference*=.32, *p*>.90). Interest ratings during the sad epoch (*M*=3.84, *SD*=1.98) were less than during the baseline (*mean difference*=1.77, *p*<.001) and interesting (*mean difference*=2.09, *p*<.001) epochs and were greater than during boring epoch (*M*=1.76, *SD*=1.99; *mean difference*=2.07, *p*<.001). The intensity of participants' interest ratings during the boring epoch was significantly less than all other epochs (all *mean differences*>2.07, all *p*'s <.001). Results suggest that, although the intensity was not significantly different, the overall quality of participants' interest may have been somewhat different across the baseline, interesting, and sad epochs. As such, paired samples t-tests, adjusted for multiple comparisons with Bonferroni corrections, were conducted to compare other highly rated emotion terms during these epochs. Results indicated that the intensity of participants alertness did not differ across the baseline, interesting, and sad epochs [all *t*'s <.84, *p*>.40]; however, participants' excitement rating was higher during the interesting epoch (*M*=4.56, *SD*=2.04) than at baseline [*M*=3.75, *SD*=1.97, *t*(67)=2.88, *p*<.01]. Participants' also felt more upset during the sad epoch (*M=3.69*, *SD*=2.30) than during the baseline [*M=.44*, *SD*=1.07, *t*(67)=12.14, *p*<.001] or interesting [*M=.21*, *SD*=.51, *t*(67)=12.42, *p*<.001] epochs. There were no differences between upset ratings between the baseline and interesting epochs [*t*(67)=1.87, *p*>.05]. Taken together, these results suggest that participants felt equally interested during the baseline and interesting epochs, however the quality of their overall affect differed somewhat across these periods. At baseline, participants seemed to be more interested and alert but less excited than during the neutral epoch when they felt more interested and excited.

Boredom. There were significant differences in intensity of the boredom ratings on the SA questionnaire across epochs [$F(2.5,164.4)=125.32$, $p<.001$, $\eta^2=.65$; with Greenhouse-Geisser corrections]. Multiple comparisons, with Bonferroni corrections, revealed that boredom ratings during the boring epoch ($M=5.54$, $SD=2.37$) were significantly higher than during the baseline epoch ($M=1.50$, $SD=1.75$; *mean difference*=4.04, $p<.001$), the interesting epoch ($M=1.03$, $SD=1.47$; *mean difference*=4.52, $p<.001$), and the sad epoch ($M=1.03$, $SD=1.47$; *mean difference*=4.52, $p<.001$). There were no differences between the boredom ratings across the baseline, interesting, and sad epochs (all *mean differences*<.47, all *p*'s>.99). These findings indicate that the boring video successfully elicited boredom and that the intensity of participants' boredom was much higher during the boring epoch than during any other period.

Sadness. There were also significant differences in intensity of the sadness ratings on the SA questionnaire across epochs [$F(1.5,49.9)=97.4$, $p<.001$, $\eta^2=.86$]. Multiple comparisons revealed that sadness ratings during the sad epoch ($M=5.10$, $SD=1.85$) were significantly higher than during the baseline epoch ($M=.49$, $SD=1.03$; *mean difference*=4.62, $p<.001$), the interesting epoch ($M=.32$, $SD=.78$; *mean difference*=4.78, $p<.001$), and the boring epoch ($M=.40$, $SD=.98$; *mean difference*=4.71, $p<.001$). There were no differences between the sadness ratings across the baseline, neutral, and sad epochs (all *mean differences*<.16, all p's>.60). These findings indicate that the sad video elicited sadness and the intensity of this emotion was much higher during the sad epoch than during any other period.

Finally, to compare intensity of participants affect, regardless of which emotion was felt, across epochs, a repeated measures ANOVA, with epoch as the within-subjects factor, was carried out using the highest rated emotion term from each epoch. Comparing the interest rating during the baseline and interesting epochs, the boredom rating during the boring epoch, and the sadness rating during the sad epoch revealed that there were no differences in affect intensity across epochs [F(2.5,169.3)=2.51, p>.05, η^2=.04].

Valence. Results of a repeated measures ANOVA, with epoch as the within-subjects factor, indicated there were significant differences in the valence of participants' affect across epochs [F(3,117)=64.78, p<.001, η^2=.66; Table 3]. Multiple comparisons revealed that participants' pleasantness ratings on the SA questionnaire were highest during the baseline (M=5.87, SD=1.19) and interesting (M=6.18, SD=1.51) epochs and there was no difference in these ratings between the baseline and interesting epochs (*mean difference*=.31, p>.99). Participants pleasantness ratings on the SA questionnaire were lowest during the boring (M=3.24, SD=1.87), and sad (M=2.63, SD=1.51) epochs and, again, there was no difference in pleasantness between the boring and sad epochs (*mean difference*=.61, p>.99). Lastly, the pleasantness of participants' affect was significantly higher during the baseline and interesting epochs than during the boring and sad epochs (all *mean differences*<3.05, all p's <.05).