**Sleep and Emotion Processing in Individuals with Insomnia Symptoms and Good Sleepers**

by

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## Abstract

Despite complaints of deficits in waking socioemotional functioning by individuals with insomnia, only a few studies have investigated waking emotion processing performance in this group. Additionally, the role of sleep in socioemotional processing has not been investigated using quantitative measures of sleep. The thesis investigated sleep and behavioural processing of emotionally expressive faces in individuals with insomnia symptoms (n=14) compared to healthy, good sleepers (n=15). The primary aim was to investigate the degree to which sleep predicted emotion processing. Participants completed two nights of at-home polysomnography-recorded sleep, and sleep diaries, which was followed by an afternoon of in-lab performance testing on tasks measuring processing of emotional facial expressions with an emotional Stroop task and a face categorization and intensity rating task. The insomnia group reported less total sleep time on their diary but no other differences in subjective or objective sleep were observed. No behavioural differences in emotion processing were observed overall. Post-hoc analysis of the individuals with insomnia symptoms that had a poor night of sleep on the night prior to performance assessment (n=8) revealed that a poor night of sleep in insomnia was associated with reduced time in Stage 2, REM and NREM sleep, and, there was trending support for elevated Sigma and Beta activity throughout the night as well as performance deficits for identifying emotional face expressions. For individuals with insomnia symptoms, greater levels of Beta EEG activity throughout sleep was associated with greater intensity ratings of happy, fearful, and sad faces. In conclusion, the thesis identified that the hyperarousal phenomenon in insomnia was related to altered waking salience assessments and gives promise for a new stream of research that investigates the relationship between hyperarousal in sleep and waking emotion functioning in insomnia.

Key words: insomnia, emotion processing, socioemotional processing, face processing, hyperarousal, Beta EEG power, quantitative EEG, sleep

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**Sleep and Emotion Processing in Individuals with Insomnia Symptoms and Good Sleepers**

The capacity to function well in daytime life is dependent on a night of quality sleep. Unfortunately, approximately 10-15% of the population suffers from poor sleep due to insomnia, a chronic condition characterized by difficulty initiating and/or maintaining sleep (Morin, LeBlance, Belanger, Ivers, Merette & Savard; 2011; Morin, LeBlanc, Daley, Gregoire & Mérette, 2006; Pallesen, Sivertsen, Nordhus & Bjorvatn, 2014; Perlis, Smith & Pigeon, 2005). Insomnia leads to daytime consequences for cognitive abilities such as memory, attention, and concentration, and, several of these performance deficits have been linked to poor sleep (Bastien, Fortier-Brochu, Rioux, LeBlanc, Daley & Morin, 2003; Fernandez-Medoza et al., 2010; Ferrie, Shipley, Akbaraly, Marmot, Kivimäki & Singh-Manoux, 2011; Fortier-Brochu & Morin, 2014; Li et al., 2016; Shekleton et al. 2014). One of the recurring features of insomnia is reports of reduced social engagement (Carey, Moul, Pilkonis, Germain & Buysse, 2005; Endeshaw & Yoo, 2016; Silva, Chase, Sartorious & Roth, 1996), suggesting that a daytime consequence of insomnia is poor social functioning. Further, little research has examined the impact of insomnia on the processing of emotions and emotional content, despite complaints from insomnia patients of daytime impairment in these areas (Carey et al., 2005; Kyle, Crawford, Morgan, Spiegelhalder, Clark & Espie, 2013).

Poorer social functioning might stem from a reduced capacity for individuals with insomnia to process socioemotion cues such as emotional expressions in faces (Kyle, Beattie, Spiegelhalder, Rogers & Espie, 2014; Crönlein, Langguth, Eichhammer & Busch, 2016). Observations of waking brain processing in insomnia have shown differences in regions of affective processing, cognition, and face processing, suggesting that a characteristic of insomnia is altered emotion processing (Baglioni et al., 2014; Dai et al., 2014; Huang et al., 2012; Kay et

al., 2016). In insomnia, sustained wake-like neurophysiological processing during sleep (measured by quantitative EEG and brain imaging), a reduced amount of time spent in the deepest stages of sleep, sleep being non-restorative for waking function, as well as difficulties with maintaining sleep and misperceptions about sleep-states, suggest the possibly that poor sleep in insomnia is the result of continuous engagement of neurocognitive processes during sleep (Baglioni, Regen & et al., 2014; Buysse et al., 2008; Fernandez-Mendoza et al., 2016; Freedman, 1986; Kay et al., 2016, Kay et al., 2017; Krystal, Edinger, Wohlgemuth & Marsh, 2002; Merica, Blois & Gaillard, 1998; Perlis, Smith, Andrews, Orff & Giles, 2001; Perlis, Giles, Mendelson & Bootzin, 1997; Riedner et al., 2016; Spiegelhalder et al., 2012). Two recent studies have found that poor sleep was directly associated with differences in waking neurophysiological activation in emotion and face processing regions (Baglioni et al., 2014; Dai et al., 2014). The aim of the current thesis was to investigate sleep, waking socioemotional functioning, and the impact of sleep on waking socioemotional functioning in individuals with insomnia symptoms compared to healthy good sleepers.

### 1.1. The Problem of Insomnia

Insomnia is a clinically defined psychopathology related to persistent disruption of the quality and duration of sleep (Levenson, Kay & Buysse, 2015; Perlis, Smith & Pigeon, 2005). A formal diagnosis of insomnia requires meeting the criteria specified by the Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-5; American Psychiatric Association, 2013). The core symptomology of clinically defined insomnia includes trouble falling asleep, trouble remaining asleep (frequent awakenings and trouble falling back to sleep), and/or waking earlier than intended without being able to return to sleep. To distinguish insomnia from habitual short sleep, these sleep difficulties must be reported to have negative consequences for daytime

functioning and quality of life, and these difficulties must occur despite sufficient time spent in bed with the intention to sleep. Insomnia must be a chronic rather than acute condition for diagnosis, and therefore must occur for at least three months and for three or more nights of the week. Finally, insomnia symptoms cannot be better explained by being a by-product of any mental or medical conditions, nor be attributed to the effects of substances (e.g., drug or medication use). Clinically, insomnia may be diagnosed as comorbid with other medical and psychiatric conditions, but often for research purposes, insomnia is studied without the presence of comorbidities.

By most estimates, insomnia affects 10-15% of the population and is more common in the elderly and women (Morin et al., 2006; Morin et al., 2011; Pallesen, et al., 2014). Despite being prevalent and costly to individuals and society, few individuals with insomnia seek treatment (Daley, Morin, LeBlanc, Grégoire & Savard, 2009; Wade, 2010; Sarsour, Kalsekar, Swingle, Foley & Walsh, 2011), and those who do seek treatment do so because of the interfering effects it has on daytime functioning (Aikens & Rouse, 2005). Individuals with insomnia report a reduced quality of life, difficulty concentrating and managing worry, reduced attention and memory abilities, and struggles with daytime sleepiness (Ishak et al. 2012; Moul, Nofzinger, Pilkonis, Houck, Miewald & Buysse, 2002; Roth & Ancoli-Israel, 1999). They have also reported that their sleep quality negatively impacts daytime energy/motivation, cognitive functioning, social functioning, emotion regulation, and performance at work/study/daily activities (Kyle at al., 2013; Roth, Jaeger, Jin, Kalsekar, Stang & Kessler, 2006). Insomnia is also a condition of impaired emotional processing and regulation, evidenced by individuals with insomnia being at greater risk of developing depression and anxiety (Neckelmann, Mykletun, & Dahl, 2007; Franzen & Buysse, 2008). Daytime complaints with social functioning (Carey et al.,

2005, Kyle et al., 2013), and reports of reduced enjoyment in the company of loved ones (Silva et al., 1996), suggest that a core symptom of insomnia is reduced social functioning as well.

Research into waking impairment in insomnia has established a relationship between sleep and cognitive functioning in several cognitive domains where individuals with insomnia have complained of daytime difficulty (see Wardle-Pinkston, Slavish & Taylor, 2019, for a recent meta-analysis and review). For example, individuals with insomnia with short sleep durations (i.e., less than six hours) have demonstrated clear cognitive deficits in processing rate, attention switching, and visual memory ability, while healthy sleepers and those with insomnia with normal sleep durations did not (Fernandez-Medoza et al., 2010; Fortier-Brochu & Morin, 2014; Shekleton et al. 2014). Self-reported shorter sleep durations and longitudinal decreases in sleep duration (i.e., insomnia symptoms) have also been linked to cognitive impairments in reasoning, vocabulary, reaction time, numeric memory, visual memory and prospective memory, and, these deficits are similar to those found due to aging (Kyle et al., 2017; Ferrie, et al. 2011). Bastien and colleagues (2003) examined the relationship between subjective and objective sleep and several cognitive performance measures in good sleepers and those with insomnia (medicated and non-medicated). They discovered that for the unmedicated insomnia group, greater objective sleep maintenance difficulties related to reduced psychomotor speed, attention and concentration. In addition, poorer subjective sleep depth was related to poorer visual memory performance.

Li and colleagues (2016) used a comprehensive Attention Network Task to measure the executive attentional control ability of individuals with insomnia and good sleepers. Time spent in deep slow wave sleep was positively associated with attentional control ability for individuals with insomnia but not good sleepers. Wilckens and colleagues (2014) found that in the non-

insomnia population, poor sleep continuity, measured by greater time awake throughout the night, was related to worse performance in several cognitive domains (e.g., inhibitory control, working memory), and, for young adults these effects were also associated with lower total sleep times. Individuals with insomnia have self-reported poorer attention and memory ability during the day as a consequence of their poor sleep, which corroborates with the observations of poorer cognitive attention and memory performance linked to poor sleep (Li et al., 2016; Wilckens et al., 2014; Moul et al., 2002; Roth & Ancoli-Israel, 1999). While cognitive and attention performance deficits have been linked to markers of poor sleep, there has been insufficient research conducted thus far on the impact of poor sleep for socioemotional functioning in insomnia despite complaints of daytime impairment in this domain from this clinical population (Carey et al., 2005, Kyle et al., 2013; Silva et al., 1996).

### 1.2. How is Sleep Disrupted in Insomnia?

Polysomnography (PSG) has commonly been employed for measuring and characterizing basic objective sleep parameters in sleep research; PSG allows for discrete staging of sleep and distinguishing wake, stages of non-REM sleep (NREM), and REM sleep, through the measurement of brainwave activity, eye movements, and muscle tone (Rechtschaffen & Kales, 1968). However, the PSG has historically failed to accurately identify insomnia, and is therefore not employed for clinical diagnosis or research criteria, except to rule out other medical sleep disorders (Kushida et al., 2005; Littner et al., 2003). PSG has been an ineffectual tool for classifying insomnia mainly due to heterogeneity of sleep disturbances in insomnia (e.g., some individuals have trouble with sleep maintenance and others have trouble falling asleep), and the large amount of night-to-night variability in sleep observed during recording (Buysse et al., 2010; Frankel, Coursey, Buchbinder & Snyder, 1976; Reite, Buysse, Reynolds & Mendelson,

1995; Spinweber, Johnson & Chin, 1985; Thomas, June, Joel, Marchini, Hamilton & Carl, 1981). As well, there is a subtype of insomnia referred to as Sleep-State Misperception where PSG in the sleep clinic fails to find objective evidence of sleep disturbance when examining standard sleep architecture variables such as total sleep time and sleep latency (Edinger & Krystal, 2003; Fernandez-Mendoza et al., 2011). Finer examination of the EEG using quantitative methods of analysis reveals that this group has higher frequency EEG (in the beta and gamma frequencies; Krystal et al., 2002; Perlis et al., 2001). These individuals also have consistent misperceptions about sleep (i.e. underestimate the amount of sleep they get, and overestimate the time it takes to fall asleep; Krystal et al., 2002; Perlis et al., 2001). In addition, PSG recording of a single night of sleep has likely failed to be a useful tool for the identification of insomnia because of the night-to-night variability in sleep; due to the nature of homeostatic sleep pressure, even chronic insomniacs have some good nights of recovery sleep.

Despite these limitations, a recent meta-analysis of PSG data in insomnia research has revealed consistent differences for insomnia populations compared to good sleeper controls (Baglioni et al., 2014). The authors examined 23 studies of insomnia groups (some studies with mixed insomnia types), where participants met the DSM-IV criteria for insomnia and had no other diagnoses, and underwent consecutive nights of PSG recording. Findings from this meta-analysis revealed that, compared to good sleepers, individuals with insomnia consistently had a lower sleep efficiency (time asleep compared to time in bed), took more time to fall asleep, had a shorter total sleep times, and had an increased number of awakenings. This analysis also revealed that individuals with insomnia compared to good sleepers spent significantly less time in slow wave sleep (on average 20 minutes less) and REM sleep (on average 10 minutes less) across studies. Despite these findings the authors concede that differences in PSG data cannot address

questions about whether poor sleep in insomnia is related to differences in neurophysiological activation during sleep, and that answering questions about the nature of poor sleep in insomnia requires investigation by more sophisticated tools such as power spectral analysis.

Quantitative investigation of the EEG using power spectral analysis more thoroughly addresses differences in sleep by examining EEG power in different frequency bands in various stages of sleep. There have been several findings of greater power in the higher frequency beta (16-35 Hz) and gamma bands (40-70 Hz), which are normally predominant in waking activity (Niedermeyer & da Silva, 2005), during both sleep onset and non-REM sleep in individuals with insomnia compared to good sleepers (Buysse et al., 2008; Fernandez-Mendoza et al., 2016; Freedman, 1986; Krystal et al., 2002; Merica, Blois, & Gaillard, 1998; Perlis et al. 2001; Riedner et al., 2016; Spiegelhalder et al., 2012). However, other studies have failed to find elevated high-frequency EEG activity in drug-free insomnia groups (i.e. St-Jean, Turcotte, Perusse & Bastien, 2013 and Bastien, LeBlanc, Carrier & Morin, 2003) suggesting it may be particular to certain individuals with insomnia or depend on the methods of power spectral analysis. For individuals with insomnia, greater relative alpha and sigma EEG power and lower relative delta power have also been observed (Krystal et al., 2002), as well as greater alpha activity localized from sensory and sensorimotor regions during the deepest stage of sleep (Riedner et al., 2016). Elevated high-frequency EEG activity in insomnia has been thought to represent abnormal arousability from sleep, sustained information processing during sleep, and misperceptions about sleep-states, a well documented phenomenon which has come to be called hyperarousal (see Bonnet & Arand, 2010, Kay & Buysse, 2017, Perlis et al., 1997, Perlis, Smith & Pigeon, 2017, and Riemann et al., 2010 for comprehensive reviews on the topic). Supporting evidence for this conclusion is that greater high-frequency power during NREM sleep in insomnia has been associated with the size

of the discrepancy between objective and subjective measures of sleep durations and latency, as well as overall sleep complaints (Perlis et al., 2001; Krystal et al. 2002). And, more in-depth analysis of event-related potentials during sleep in insomnia have found indicators that sleep in insomnia, especially for those with greater misperceptions about sleep-states, is associated with elevated/uninhibited attention and information processing during sleep (Ceklic & Bastien, 2015, Bastien, Turcotte, St-Jean, Morin & Carrier, 2013, Kertesz & Cote, 2011; Turcotte, St-Jean & Bastien, 2011). Discussion of the mechanism of hyperarousal has brought forth differing opinions; however, the key models discuss hyperarousal as the result of sustained or uninhibited cortical arousal and information processing, abnormal co-activation of both sleep-promoting and wake-promoting circuitry, and/or increased conscious awareness, as potential psychopathological qualities of insomnia sleep (Buysse, Germain, Hall, Monk & Nozfinger, 2011; Kay & Buysse, 2017; Perlis et al., 1997; Perlis, Smith & Pigeon, 2017).

Recent neuroimaging research has shed light on specific regional differences in neurophysiological activity during insomnia sleep and sleep onset. Individuals with insomnia compared to good sleepers have smaller differences in regional glucose metabolism between wake and sleep in the left frontoparietal region, precuneus cingulate, posterior cingulate, left middle frontal regions, and the fusiform and lingual gyri (Kay et al., 2016). Functioning of these areas is associated with attention, cognition, and face processing (George et al., 1999; Leech & Sharp, 2013; Luckmann, Jacobs & Sack, 2014). Because these findings were relative comparisons between wake and sleep, the authors concluded that these findings may be indicative of either continuous regional activation during NREM or reduced engagement during wake. Further investigation into regional glucose metabolism differences in insomnia revealed that greater misperception of the time to fall asleep was correlated with greater regional glucose

metabolism in the right anterior insula and middle and posterior cingulate areas (Kay et al. 2017). These areas are part of the salience network, which is a distributed cortical network that serves to detect and coordinate neurophysiological responses to relevant environmental stimuli (see Uddin, 2015, for an overview of the salience network), and are also associated with social processing (Uddin, Nomi, Herbert-Seropian, Ghaziri & Boucher, 2017), as well as related to conscious awareness (Koubeissi, Bartolomei, Beltagy & Picard, 2014), and the generation of slow wave sleep (Dang-Vu et al., 2005). These studies indicate increased or uninhibited activation during sleep in specific areas of salience processing, social processing and sleep generation, as potential areas of pathological significance during sleep in insomnia.

In sum, measurement of quantitative EEG and regional glucose metabolism during PSG-defined sleep offer more sensitive measurements of sleep pathology in insomnia. Studies have found elevated high-frequency EEG activity and sustained regional metabolic brain activity during NREM in insomnia (Buysse et al. 2010; Kay et al., 2016; Kay et al., 2017; Krystal et al., 2002; Perlis et al. 2001; Riedner et al., 2016, Spielhalder et al., 2015). Both findings have been found to be associated with greater misperceptions about sleep durations and sleep onset (e.g., Perlis et al., 2001; Kay et al., 2017). And, studies have found evidence for sustained information processing in insomnia sleep, associated with paradoxical insomnia (i.e. misperceptions about sleep; Turcotte, St-Jean & Bastien, 2011; Ceklic & Bastien, 2015; Bastien et al., 2013). Individuals with insomnia frequently have nights of shallow sleep, indicated by difficulty falling asleep, maintaining, and returning to sleep, a greater number of awakenings throughout the night, and reduced time spent in the deepest stages of sleep (Baglioni, Regen & et al., 2014; Edinger, Ulmer & Means, 2013; Frankel et al., 1976; Kay et al., 2015; McCall & Edinger, 1992; Rezaie et al., 2018). Additionally, the regional investigation of neurophysiological activity in insomnia has

shown persistent activity remains in areas related to affect, social cognition, and the salience network (Kay et al., 2016; Kay et al., 2017). Sleep plays an integral role in maintaining the function of cognition-related signaling molecules, synaptic plasticity, and managing oxidative stress (i.e., managing neurobiological mechanism of cognitive functioning; Alkadhi, Zagaar, Alhaider, Salim, & Aleisa, 2013). Therefore, continuous information processing and/or a failure to inhibit neurophysiological activity in insomnia sleep may compromise the role of sleep in maintaining neurobiological functioning in these regions, lead to shallower sleep, and ultimately to alterations in next-day waking cognitive and socioemotional functioning.

### 1.3. Evidence for Differences in Waking Emotion Processing in Insomnia

In healthy, good sleepers the consequences of sleep deprivation on emotion processing have been well investigated, providing clear evidence that a night of sleep is required for optimal emotion functioning (Cote, Lustig & Macdonald, 2019; Krause et al., 2017; Tempesta, Socci, Gennaro & Ferrara, 2018; Walker, 2009; Watling, Pawlik, Scott, Booth & Short, 2017). For example, experimental sleep deprivation leads to reduced accuracy at identifying emotional facial expressions (Cote, Mondloch, Sergeeva, Taylor & Semplonius, 2014; Killgore, Balkin, Yarnell & Capaldi, 2017; Maccari et al., 2014; Van der Helm, Gujar & Walker, 2010). The basic emotional facial expressions are important cues for social and emotional functioning (Blair, 2002; Hess & Fischer, 2013; Marsh & Blair, 2008) and performance on face-emotion processing tasks has been found to be affected in disorders of mood impairment such as anxiety (Fox, 2002; Schwab & Schienle, 2018), and depression (Van Vleet et al., 2019). Experimental sleep deprivation has also lead to reduced emotional empathy (Guadagni, Burles, Ferrara & Iaria, 2014), increased amygdala activation to increasingly negative images (Yoo, Gujar, Hu, Jolesz & Walker, 2007), increased attention allocation for emotional pictures (Cote, Jancsar, & Hunt,

2015), and poorer ability to inhibit response to negative and neutral distractor stimuli (Anderson & Platten, 2011; Chuah, Dolcos, Chen, Zheng, Parimal & Chee, 2010; Simon et al. 2015).

The few studies that have investigated waking emotion processing in insomnia have found behavioural and neurophysiological differences from good sleepers, suggesting that emotion processing is affected by insomnia. Baglioni and colleagues (2010) first examined reactivity to emotional and sleep-related picture stimuli that varied on valence (positive, neutral, negative) by measuring facial electromyography, heart-rate, as well as participants' subjective assessments of the valance and arousal of each picture. Compared to healthy sleepers, individuals with insomnia reacted with increased physiological arousal to all stimuli, subjectively rated all stimuli as more arousing, could not inhibit facial reactions to positive sleep stimuli, and subjectively rated negative emotional and negative sleep-related stimuli as equally arousing and unpleasant. The authors concluded that insomnia patients had abnormal reactivity to sleep stimuli, which they interpreted as a sleep craving, and that individuals with insomnia showed no deficits in the processing of positive stimuli and therefore show clear differences from depression pathophysiology. Additionally, they suggested that greater subjective and physiological arousal in response to all images offers support for the hyperarousal model of insomnia that posits that insomnia is a condition of cortical, autonomic, cognitive and emotional hyperarousal and hyper-arousability during wake and sleep (Perlis et al., 1997, Perlis et al., 2017). However, the authors did not record sleep parameters the night before testing and therefore did not examine the contribution of sleep to altering arousal towards emotion stimuli.

Baglioni and colleagues (2014) continued this line of research and examined activity in the amygdala in response to neutral and negative emotional and sleep related picture stimuli of different salience (i.e., low, medium or high intensity). Individuals with insomnia had increased

BOLD response in the amygdala when presented with sleep-related pictures in the MRI scanner while good sleepers did not. More interestingly, individuals with insomnia also had blunted amygdala reactivity (similar to baseline) to negative non-sleep related pictures of medium intensity (e.g., picture of a crying individual), compared with good sleepers who had reactivity (greater than baseline) in the amygdala to these same images. For all participants, less total sleep time and lower sleep efficiency related to greater amygdala reactivity to negative non-sleep related emotional images. For individuals with insomnia and not good sleepers, poorer objective sleep, measured by less time spent in slow wave sleep and REM sleep was also found to be correlated with greater amygdala reactivity to the negative non-sleep emotional images. This suggests that differences in sleep (time in slow wave sleep and REM) in individuals with insomnia might specifically contribute to emotion processing differences for this group. However, PSG recording and fMRI sessions were 2-4 weeks apart, therefore conclusions about the contributions of sleep on emotion processing are difficult to draw. These findings provide preliminary evidence for emotion processing differences in insomnia in salience processing, evidenced by amygdala reactivity differences depending on the salience and valence of emotion stimuli. These differences appear also to be affected by sleep, but further investigation is required.

Based on the daytime complaints of socioemotional functioning difficulties in insomnia, Kyle and colleagues (2014) investigated the ability of insomnia patients to categorize emotional face expressions and investigated their assessments for the intensity of these stimuli. Static images of emotionally expressive faces of happiness, anger, fear and sadness, were presented until categorization and then participants rated the intensity of the face. While the insomnia patients were as capable as good sleepers in categorizing the emotion of the faces, they trended

towards lower intensity ratings. Post-hoc analysis of this trending effect at levels of emotion revealed that the insomnia group had significantly lower intensity ratings for faces of fear and sadness. Subjective sleep had no relationship to categorization and intensity judgements, but the authors did not examine or report the relationship between objectively measured sleep and face processing performance. They also did not observe any association between intensity ratings and measures of sleepiness during task performance. For the insomnia group only, lower intensity ratings were significantly associated with both greater anxiety and greater depression over the past week (Hospital Anxiety and Depression Scale). This study was the first to support face emotion processing differences in insomnia patients. For the association between depression and anxiety and intensity ratings the authors suggest that "… this association may reflect the daytime consequences of perceived sleep loss, perhaps suggesting a common mechanism linking subjective and objective daytime (emotional) dysfunction." The authors also suggest that reduced sensitivity to the intensity of faces may be explained by decreased emotion reactivity seen by a functional impairment in the amygdala and its connectivity to the prefrontal cortex after a night of poor sleep that has been reported in previous imaging research by Yoo et al. (2007), or may be affected by poor emotion regulation strategies common to insomnia.

Subsequently, Crönlein et al. (2016) examined face-emotion recognition capabilities in individuals with sleep apnea as well as insomnia patients to determine whether emotion processing differences were due to pathophysiological qualities of insomnia or could be attributed to chronic poor sleep experienced by both clinical samples. Participants in this study performed a Facial Expressed Emotion Labelling test, where a series of static images of emotional face expressions (anger, anxiety, surprise, sadness, happiness or disgust) were each presented for 300 milliseconds, with a 10 second window to categorize the emotion. Both

clinical groups (sleep apnea and individuals with insomnia) had lower categorization accuracy than good sleepers, and further analysis revealed that the lower categorization accuracy was specific to faces of happy and sad expressions. Objective measurement of sleep duration and time spent awake throughout the night had no significant relationship with categorization ability, but no indication was given whether behavioural testing followed the night of sleep recording in the clinic. The authors suggest that the reason measures of sleep did not significantly predict performance might be attributed to the poor ability of the polysomnography to capture objective sleep differences due to high variability between nights of recording. The authors also argued that the accuracy deficits for emotional faces being consistent for both individuals with insomnia and sleep apnea allude to a direct relationship between poor sleep and the processing of emotionally expressive faces. They conclude that the precise contributions of sleep for emotion processing warrants further investigation despite a lack of any significant association found in their study.

In insomnia, neurophysiological differences from healthy good sleepers have been observed in waking activity and functional connectivity of brain regions associated with emotion, face processing, affect, and the salience network, such as the amygdala, fusiform gyri, insula, anterior cingulate and frontal cortex (Baglioni et al. 2014; Dai et al., 2014; Kay et al. 2016, Huang et al. 2012, Nozfinger, Buysse, Germain, Miewald & Kuperfer, 2004). Huang and colleagues (2012) found that during resting-state fMRI recordings, individuals with insomnia had reduced functional connectivity between the amygdala and areas of the insula, striatum and thalamus. These areas have been identified as emotion processing circuitry in the salience network, which are employed during emotion perception, emotion reactivity, and emotion regulation (Phillips, Drevets, Rauch & Lane, 2003). Compared to good sleepers, individuals with

insomnia also have reduced resting-state glucose metabolism (FDG-PET analysis) during wake in several regions including the frontal cortex, insula, and the anterior cingulate cortex (Nozfinger at al., 2004). The function of the insula is thought to include empathy, social cognition, and salience processing (Uddin, Nomi, Herbert-Seropian, Ghaziri & Boucher, 2017), and the anterior cingulate cortex is involved in both emotion and attention (Bush, Luu & Posner, 2000). Dai and colleagues (2014) compared regional homogeneity (local synchronization in BOLD activity for neighbouring clusters) across the brain in good sleepers and those with insomnia. Abnormal regional homogeneity during wake has been previously linked to greater cognitive dysfunction in individuals with Alzheimer's and mild cognitive impairment (Zhang et al., 2012), and has been found to be altered in individuals with depression (Liang, Zhou & Yang, 2013), after experimental sleep deprivation (Dai et al., 2012) and affected by sleep apnea (Peng et al., 2014), suggesting that abnormal homogeneity might represent impaired cognitive functioning (i.e., poor neurophysiological resource coordination) and may also represents waking consequences of sleep loss/poor sleep. Dai and colleagues (2014) found that compared to good sleepers, individuals with insomnia had lower regional homogeneity in several brain regions including the bilateral cingulate gyrus and right cerebellum anterior lobe, as well as greater homogeneity in the left fusiform gyrus. Greater homogeneity in the left fusiform gyrus for insomnia participants was significantly correlated with self-reports of longer insomnia duration and poorer subjective sleep quality measured by the Pittsburgh Sleep Quality Index. These findings identified differences in regional homogeneity and activity in core regions of affect and emotion processing, which may be indicative of altered/dysfunctional neurophysiological emotion processing during wake related to the effects of chronic nights of poor sleep in insomnia.

### 1.4. Aims of Thesis and Study Hypotheses

From the literature several conclusions can be drawn. The objective measurements of sleep typically employed have often failed to measure the extent of sleep deficits reported by individuals with insomnia, due the lack of sensitivity and specificity of information gained from discrete sleep staging, as well as a lack of attention to types of sleep disruption in insomnia (Bianchi, Williams, Mckinney & Ellenbogen, 2013; Edinger et al., 2013; Feige et al., 2008; Frankel et al., 1976; Harvey, Stinson, Whitaker, Moskovitz & Virk, 2008; Manconi et al., 2010; Rosa & Bonnet, 2000). Both quantitative EEG and neurophysiological measurement of sleep with imaging techniques have been employed to identify abnormal neurophysiological activity in insomnia during sleep (Bastien et al., 2013; Buysse et al. 2010; Kay et al., 2016; Kay et al., 2017; Krystal et al., 2002; Perlis et al. 2001; Riedner et al., 2016, Spielhalder et al., 2015). In this study, sleep was measured with polysomnography in the participant's home, and was also measured through self-reported sleep quality using sleep diaries, and quantitative EEG, in order to further investigate possible markers of poor or abnormal sleep in insomnia as well as to examine which features of poor or abnormal sleep in insomnia might contribute to differences in waking emotion processing. Additionally, a novel and sensitive quantitative EEG measure of sleep depth and arousability called the Odds Ratio Product (ORP; Younes et al. 2015) was employed as a possible neurophysiological marker of impaired sleep in insomnia. The ORP has been used to characterize sleep depth in obstructive sleep apnea (Qanash, Giannouli & Younes, 2017), and the critically ill (Georgopoulos & Vaporidi, 2019). Details of the ORP measure are described further in the Methods section.

There is also a lack of research into waking socioemotional processing in insomnia despite evidence of daytime complaints in social and emotional functioning (Carey et al., 2005;

Silva et al., 1996; Kyle at al., 2013). A few studies have identified abnormal neurophysiological and behavioural reactivity and assessments of face and emotion stimuli for individuals with INS (Baglioni et al., 2010; Baglioni et al., 2014; Cronlein et al., 2016; Kyle et al., 2014), and some studies have identified waking neurophysiological differences in regions associated with emotion processing (e.g. Dai et al., 2014; Huang et al., 2012; Nozfinger et al., 2004), but there has still been few studies that have investigated this phenomenon and so there is a need for more research to elucidate the extent and types of emotion processing differences. One area of emotion processing that has not been investigated in insomnia is attention and inhibitory control with socioemotional cues in the presence of distracting emotional information. Insomnia and poor sleep have been shown to relate to poorer attention control (Li et al., 2016; Wilckens et al., 2014), and, experimental sleep deprivation has been shown to lead to reduced attention control for distracting emotion stimuli (Anderson & Platten, 2011; Chuah et al., 2010; Simon et al. 2015), but no research thus far has examined this type of processing with emotion stimuli in insomnia. Therefore, the current study set out to bolster research on waking emotion processing differences in individuals with insomnia, by first replicating a face-emotion perception and salience assessment task (face-emotion categorization and intensity; Kyle et al., 2014), as well as extending the investigating to attentional control for emotional stimuli using a face-emotion Stroop paradigm (requiring a classification of the category of emotional face expressions while ignoring distracting emotional words).

Basic measures of sleep/wake stages, polysomnography-measured sleep duration and, self-reported sleep duration, sleep onset and wake after sleep onset, have not been found to be related to behavioural emotion processing performance in preliminary studies (Cronlein et al., 2016; Kyle et al., 2014). However, measures of sleep architecture (time in slow wave sleep and

REM) and subjective sleep history (complaints of insomnia severity and duration) for individuals with insomnia has been found to be associated with differences in neurophysiological functioning and reactivity to emotional stimuli in areas associated with emotion and face processing (Baglioni et al., 2014, Dai et al., 2014). Therefore, it is possible that abnormal or poor sleep beyond simple disruption of sleep/wake stages may contribute to impairment in waking functioning. In addition, cognitive performance in non-emotional domains for individuals with insomnia and insomnia symptomology is negatively impacted by poor sleep (Bastien et al., 2003; Fernandez-Mendoza et al., 2010; Ferrie, et al. 2011; Fortier-Brochu & Morin, 2014; Kyle et al., 2017; Lie et al., 2016; Shekleton et al. 2014; Wilckens et al., 2014). Therefore, the main aim of the thesis was to examine the extent to which measures that have previously captured differences in sleep in insomnia, or are indicative of poor sleep generally, relate to emotion processing differences for individuals with insomnia.

**1.4.1. Hypothesis 1: Poorer sleep and sleep depth for individuals with insomnia.** A meta-analysis revealed that individuals with insomnia have lower sleep efficiency, take longer to fall asleep, have an increased number of awakenings throughout the night, and spend less time in slow wave sleep and REM (Baglioni et al., 2014). Additionally, individuals with insomnia have been reported to have greater power in high-frequency Beta and Gamma EEG bands during sleep (Buysse et al., 2008; Fernandez-Mendoza et al., 2016; Freedman, 1986; Krystal et al., 2002; Merica, Blois, & Gaillard, 1998; Perlis et al. 2001; Riedner et al., 2016; Spiegelhalder et al., 2012). Therefore, it was expected that individuals with insomnia compared to good sleepers would have greater power in Beta EEG bands during sleep, take longer to fall asleep, have more awakenings, less time in slow wave sleep and REM, would have subjective reports of poorer sleep quality, and, would have shallower sleep depth throughout the night measured by greater

ORP values during sleep. Other measures of objective (including quantitative EEG in each frequency band), subjective sleep, and the discrepancy between objective and subjective measures of sleep were also investigated to further characterize sleep disturbances in the sample.

**1.4.2. Hypothesis 2**: **Lower sensitivity for emotion faces and inhibitory control deficits for individuals with insomnia**. Based on findings by Crönlein et al. (2016), it was expected that individuals with insomnia compared to good sleepers would have deficits in the ability to identify face-emotion expressions, and, based on the findings by Kyle et al. (2014), would have lower intensity ratings on a face-emotion categorization and intensity task. Wilckens et al. (2014) found reduced inhibitory control on an Attentional Network Task correlated with greater insomnia symptomology, and, Li et al. (2016) reported that individuals with insomnia had lower executive attentional control ability compared to good sleepers. In addition, experimental sleep deprivation research has reported a reduction in the ability to ignore distracting neutral and negative emotion stimuli after sleep deprivation (Anderson & Platten, 2011; Chuah et al., 2010; Simon et al. 2015). Therefore, it was expected that compared to good sleepers, individuals with insomnia would have poorer inhibitory attention control on a face-word emotion Stroop task, represented by a greater difference in response time and accuracy between congruent and incongruent trial types.

**1.4.3. Hypothesis 3: Sleep predicts emotion processing performance differences for individuals with insomnia.** This hypothesis was the main focus to the thesis. Poor sleep has been linked to both abnormal amygdala reactivity to negative emotion stimuli and lower executive control ability in insomnia (Baglioni et al., 2014, Li et al., 2016). Waking differences in the activity of the fusiform gyrus, a region associated with the processing of faces, has also been linked to subjective reports of historic poor sleep quality and greater symptom duration of

insomnia (Dai et al., 2014). Therefore, it was predicted that measures of sleep in insomnia (sleep architecture, ORP, historic sleep quality, Beta EEG Power) would relate to behavioural emotion processing differences for individuals with insomnia.

## 2. Methods

### 2.1. Participants

This study was cleared through the Brock University Biosciences Research Ethics Board (see Appendix A). All participants were recruited from Brock University and from the surrounding community of the Niagara Region in Ontario, Canada, through radio, online, classroom, and poster advertisements. Criteria for all participants included: (1) age between 18 and 50; (2) no history of concussion or head injury; (3) no history of psychiatric condition including depression, anxiety, or schizophrenia; (4) no known medical or sleep disorder diagnosis or symptomology; (5) no recent (within 3 months) history of shift work or time zone adjustments; (6) no medication use that affects cognition or sleep, (7) have not gone through menopause or perimenopause for women; (8) non-smokers; and (9) right-handed. Individuals with insomnia symptoms were identified by meeting the DSM-5 criteria for poor sleep: (1) an average of 6.5 hours or less of sleep per night; (2) three or more nights of difficulty sleeping per week; (3) difficulty falling asleep (average >30 minutes to fall asleep) and/or maintaining asleep (average >30 minutes total wake time throughout the night); (4) three or more months of sleeping difficulties; (5) complaints that their sleep quality impacts their daytime functioning and/or quality of life; and (6) this poor sleep is not better explained by co-existing sleep disorders, medical conditions, mental disorders, or medication/drug use (American Psychiatric Association, 2013).

The insomnia group was also classified by an Insomnia Severity Index (ISI; Morin, Belleville, Bélanger & Ivers, 2011) score greater than 7 and a Pittsburgh Sleep Quality Index greater than 5 (PSQI; Buysse, Reynolds, Monk, Berman & Kupfer, 1989; see Appendix B for ISI and PSQI scores of each participant). The ISI assesses insomnia severity over the past 2 weeks; a score of 8-14 on the ISI indicates subthreshold insomnia and a score of 15 or greater represents clinical levels of insomnia (Morin et al., 2011). For the PSQI scores of greater than 5 indicate significant impairment in sleep quality over the past month (Buysse et al., 1989). These individuals were classified as having insomnia symptomology because they met the DSM-5 criteria for insomnia but PSG recording was not carried out to measure markers of sleep apnea, restless leg syndrome and periodic limb movement disorder to exclude these disorders.

Sixty-eight participants completed the online intake questionnaires following a preliminary telephone interview. Among those 68 participants, 11 were ineligible: two participants had shifted sleep (irregular bedtimes), one participant reported excessive marijuana use, two individuals with insomnia symptoms reported regularly sleeping a full eight hours, two individuals with insomnia symptoms had ISI scores less than 7 (indicating normal healthy sleep), three individuals reported good sleep but had an ISI score greater than 7, and one individual with insomnia symptoms had poor sleep hygiene (e.g., excessive pre-sleep phone use). Another 12 participants did not complete the orientation: eight had difficulties scheduling, one began taking medication for sleep, and three participants could not be contacted.

Of the 45 participants completing the orientation session, two participants withdrew due to technical difficulties with the sleep equipment during the nights of at-home sleep recording. Forty-three participants completed the full study. One participant was omitted from final analysis for a failure to comply with instructions to wake up by 8:00 am on the performance testing day,

two due to inability to remain awake during performance assessment, and one participant scored greater than 7 on the ISI despite initially qualifying as a good sleeper. Thirty-nine participants completed the protocol, 25 good sleepers (GS) and 14 individuals with insomnia symptoms (INS).

Inspection of polysomnography data the night before performance testing revealed that 9 of the 25 GS group did not comply with study instructions and had restricted their sleep to less than 6.5 hours, and one GS had a night of insufficient sleep despite ample time in bed (Appendix B). The GS were screened and recruited based on reports of normative sleeping hours (>6.5 hours). These ten individuals were excluded from final analysis, leaving 15 individuals in the GS group. Note: descriptive data supports that the sleep restricted good sleepers had impaired performance on emotion processing tasks (Appendix C). The final sample included 15 GS and 14 INS participants (see Table 1 for descriptives for age and sex).

Table 1.

*Descriptives of age, sex, and number of participants for each of the classifications.*

| Group | *N* | *Mean Age* | *SD Age* | *Men* | *Women* |
|---|---|---|---|---|---|
| Good sleeping good sleepers (GS) | 15 | 25.60 | 9.56 | 2 | 13 |
| Individuals with insomnia symptoms (INS) | 14 | 27.00 | 9.81 | 4 | 10 |
| Sleep restricted good sleepers | 9 | 24.89 | 5.78 | 3 | 6 |
| INS with a poor night of sleep | 8 | 26.13 | 10.91 | 3 | 5 |
| INS with a good night of sleep | 6 | 28.17 | 9.00 | 1 | 5 |

After analysing group differences between good sleepers and the entire INS sample (n=14), a post-hoc analysis comparing the good sleepers and the individuals with insomnia symptoms with a night of poor sleep was conducted. Research that shows individuals with insomnia with an objective poor night of sleep differ from those with a good night of sleep on waking neurocognitive functioning, sleep, and neurophysiological activity during sleep (e.g.,

Bastien, Fotier-Brochu, Rioux, Lebblanc, Daley & Morin, 2003; Fernandez-Mendoza et al., 2010; St-Jean, Turcotte, Pérusse & Bastien, 2013). Sleep was examined for each participant using total sleep time, sleep onset latency, number of arousals, diary sleep quality, and time in bed, for both nights of sleep recordings, to determine the quality of sleep (good or poor). It was determined that eight individuals with insomnia symptoms had a night of poor sleep typical of the insomnia symptomology.

## 2.2. Materials

**2.2.1. Phone interview**. For initial screening and to determine eligibility participants underwent a phone interview (Appendix D). The phone interview asked questions about demographics, sleep, health, medication use, and medical history, in order to ensure participants met eligibility criteria for participation.

**2.2.2. Intake questionnaires.** To further assess eligibility and characterize sleep and personality, participants completed a series of demographic, sleep, and medical history questionnaires (Appendix E, F, & G). The Circadian Rhythm questionnaire (Horne & Ostberg, 1976) was also completed to characterise sleep. Participants completed the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman & Kupfer, 1989) and Insomnia Severity Index (Morin et al., 2011), valid measures of subjective sleep quality for the past 4 or 2 weeks respectively. A higher score on either measure is indicative of poorer quality sleep. For the Pittsburgh Sleep Quality Index, scores of 5 or greater are indicative of poor sleep quality (Buysse et al., 1989). For the Insomnia Severity Index, scores below 8 are indicative of healthy sleep, scores from 8-14 are indicative of subthreshold insomnia, and scores of 15 or greater indicate clinically significant levels of insomnia (Morin et al., 2011). Both were used to assess the extent

of sleep impairment as well as eligibility and group classifications. For a full list of intake questionnaires including those not used in analysis of the current study see Table 2.

Table 2.

*List of Intake Questionnaires.*

| Questionnaire | Measures | Reference |
|---|---|---|
| Demographic Questionnaire | Collects general demographic information | Appendix E |
| Sleep and Wake Questionnaire | Health and sleep related questions to assess eligibility | Appendix F |
| Family and Personal Medical History | Additional questions about family and personal medical history in order to assess the presence of medical sleeping disorders | Appendix G |
| Circadian Rhythms Questionnaire | Morningness-Eveningness questions, sleep-wake questions used to determine chronotype (morning or evening) | Horne & Ostberg (1976) |
| Pittsburgh Sleep Quality Index | Assess subjective sleep quality through questions about the last 4 months of sleep conditions | Buysse, Reynolds, Monk, Berman & Kupfer (1989) |
| Depression Anxiety Stress Scale | Questions to gauge negative affect – depression, anxiety and stress. | Lovibond & Lovibond (1995) |
| State Trait Anxiety Inventory - Trait | Measures trait anxiety by rating frequency of different conditions | Spielberger, 2010 |
| Behavioural Inhibition-Activation Scale | Assesses behaviours related to action or inhibition | Carver & White (1994) |
| Barratt Impulsiveness Scale | Measures trait impulsivity by endorsement of feelings and actions | Patton, Stanford & Barratt (1995) |
| Interpersonal Reactivity Index | Multidimensional assessment of empathy | Davis (1980) |
| Buss-Perry Aggression Questionnaire | Assesses endorsement of aggressive behaviours and thoughts | Buss & Perry (1992) |
| Emotion Regulation Questionnaire | Questions that measure the employment of reappraisal and suppression emotion regulation strategies | Gross & John (2003) |
| Short Proneness Boredom Scale | Assesses ease of boredom and restlessness in individuals | Struk, Carriere, Cheyne & Dackert (2017) |

| | | |
|---|---|---|
| Insomnia Severity Index | Measures the degree of insomnia symptoms and the impact they have on self and social perceptions of functioning over the past 2 weeks | Morin, Belleville, Belanger & Ivers (2011) |

**2.2.3. Sleep measures**. Participants used an ambulatory polysomnography system called the Prodigy Sleep System (Cerebra Medical Inc., Winnipeg) for two consecutive nights at home (see Figure 1; Younes, Soiferman, Thompson & Giannouli, 2017). The Prodigy Sleep System has eight electrode channels: left-frontal (on the upper-left side of the forehead; see Figure 1), right-frontal (on the upper-right side of the forehead; see Figure 1), left-horizontal EOG, lower-vertical EOG, AFZ for ground, FPZ for reference, right mastoid (M2/A2), and left chin EMG. Recording of these channels produces a polysomnography data file which allows for sleep scoring. Scoring allows for discrete staging of sleep data and the computation of objective sleep measurements including total sleep time (TST), time to sleep (SOL – sleep onset latency), time spent awake throughout the night (WASO – wake after sleep onset), time spent in each sleep stage (1, 2, 3, NREM, REM), and number of awakenings and arousals. A sleep diary (Appendix H) was administered and completed for up to one week starting immediately after the first night of at-home recording. The sleep diary was used to capture subjective sleep quality, sleep duration, bed and wake times, circumstances that affected sleep, and daytime caffeine, medication, substance, and alcohol use, and exercise.

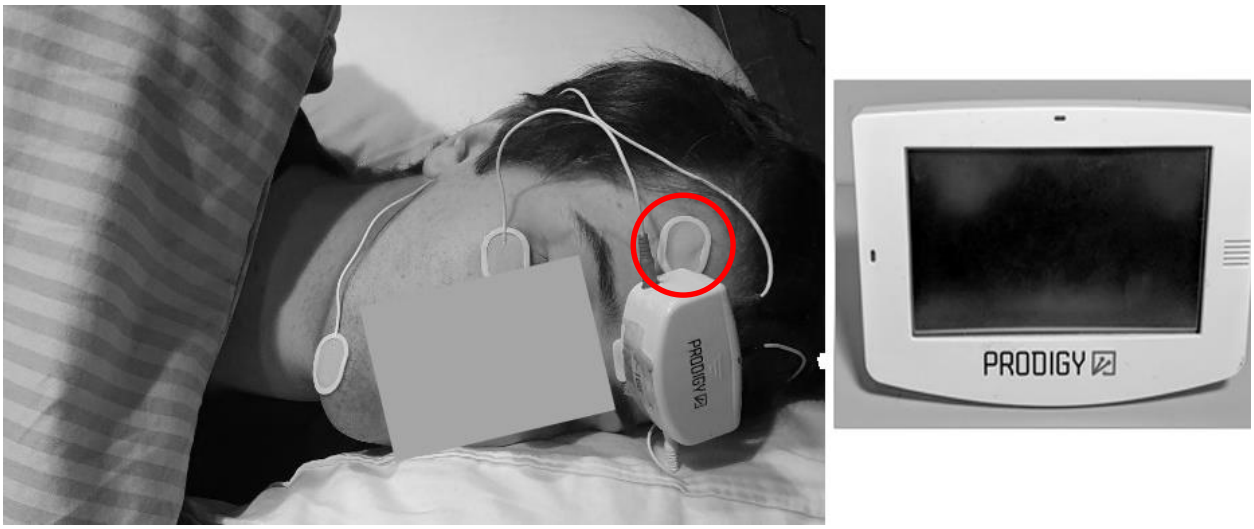


*Figure 1*. Prodigy sleep equipment (Cerebra Medical Inc, Winnipeg). Electrodes and head monitor applied (left). Prodigy monitor: interface and data storage (right). The right frontal channel is circled in red, the left frontal channel is mirrored on the other side of the forehead but is obscured here.

**2.2.4. Trait affect measures.** During intake participants completed the trait version of State-Trait Anxiety Index (STAI-Trait), a 20 item measure of trait anxiety with scores between 20 and 80, where greater scores indicate greater trait or state anxiety (Spielberger, 2010); the Depression Anxiety Stress Scale (DASS), a 42 items questionnaire that produces a score between 0 and 42 (greater scores indicate greater disturbance) for each subscale of trait depression (DASS – Depression), trait anxiety (DASS – Anxiety), and trait stress (DASS – Stress; Lovibond and Lovibond, 1995).

**2.2.5. Performance assessment battery**. For a full list of tasks descriptions and timings of the performance assessment see Table 3. Note that several measures were not included for the purpose of the thesis. Tasks requiring more than one keyboard input from the participant had two counterbalanced versions to account for finger-key response biases and facilitation.

Table 3.

*Performance Assessment Battery.*

| Task | Measure | Approx. Duration (min) | Approx. Total Time (min) |
|---|---|---|---|
| Positive and Negative Affect Schedule | Subjective ratings of current positive and negative affect | 1 | 1 |
| State-Trait Anxiety Index – State version | Subjective arousal and anxiety levels | 1 | 2 |
| Stanford Sleepiness Scale | Subjective current sleepiness ratings | 1 | 3 |
| Visual Analogue Scale - Mood | Subjective ratings of current positive and negative affect | 1 | 4 |
| Alpha Attenuation Task | Physiological alertness and processing | 6 | 10 |
| Face-Word Emotion Stroop Task | Inhibitory control for distracting emotion words to categorize face emotion expressions | 10 | 16 |
| Reaction Time Task | Sensorimotor reaction time to an auditory tone | 6 | 22 |
| NASA Effort | Subjective effort ratings on preceding tasks | 1 | 23 |
| BREAK 1 | | 5 | 28 |
| Face Emotion Morphing Task | Threshold of detection for emotional faces | 18 | 46 |
| Face Emotion Categorization & Intensity | Categorization ability and intensity ratings for emotion face expressions | 12 | 58 |
| NASA Effort | Subjective effort rating on preceding tasks | 1 | 59 |
| BREAK 2 | | 5 | 64 |
| Two-Target Visual Face-Emotion Oddball | Rapid detection of target sad and angry face stimuli among non-target expressions | 6 | 70 |
| NASA Effort | Subjective effort rating on preceding tasks | 1 | 71 |
| Stanford Sleepiness Scale | Subjective current sleepiness ratings | 1 | 72 |
| Visual Analogue Scale - Mood | Subjective ratings of current positive and negative affect | 1 | 73 |
| Menstrual Cycle Questionnaire | Administered to women only: menstrual cycle and the use of hormonal birth control | 2 | 75 |

**2.2.6. Mood and sleepiness measures.** At the beginning of the task battery participants completed four questionnaires related to mood and sleepiness. Specifically, participants completed 1) the Positive and Negative Affect Schedule (PANAS), where participants rate their current mood using a 5-point likert scale on 10 positive and 10 negative affect descriptors generating a positive and negative subscale score that range from 10 to 50 (Watson, Clark and Tellegen, 1988); 2) the State-Trait Anxiety Inventory (state subscale; STAI-S), 20 anxiety related items rated on a 4-point Likert scale generating an overall score from 20 to 80 (higher scores represents greater state anxiety; Spielberger, 2010); 3) the Visual-Analog Mood Scale (VAS-M), four gradient scales (each from 0 to 100) that represent the mood of participants from positive (0-50) to negative (51-100) states with scales of energetic to sluggish, calm to irritable, happy to sad, and tense to relaxed (Stern, Arruda, Hooper, Wolfner & Morey, 1997); and 4) the Stanford Sleepiness Scale (SSS), a 7-point scale related to subjective current sleepiness levels where 1 represents an absence of sleepiness and 7 indicates extreme sleepiness (Hoddes, Zarcone, & Dement, 1973). Participants also completed the VAS-M and SSS at the end of the task battery.

**2.2.7. Psychomotor vigilance task (PVT).** This 6-minute psychomotor vigilance task is a standard measure of vigilance employed to determine fatigue effects on cognitive performance (Dinges & Powell, 1985). The participant was instructed to press a key as quickly as possible in response to a 70 db auditory tone (1000 Hz, 50 ms, delivered by desktop speakers). The interval between tones varied at random between 2000ms to 10000ms. During the interval between tones participants were required to focus on a fixation cross in the center of the screen. Feedback of response time after each response was briefly presented on the screen to participants.

**2.2.8. Face-word emotion Stroop task.** This task was adapted from the study by Preston and Stansfield (2008). A variable inter-stimulus fixation point was displayed for 500-800ms

before a face of one of three emotions (happy, sad, angry) or neutral expressions was displayed for 400ms (Figure 2). Each face stimulus had the words “happy”, “sad”, “angry” or “neutral” displayed across the ridge of the nose in order to not obscure facial or eye cues and to appear in the center where the fixation point was previously located. After 400ms of stimulus presentation the stimulus was removed, and it did not proceed until the participant responded. The participants were instructed to respond as quickly and accurately as possible and responded by indicating (by hitting labelled keyboard keys: 0-3 on the numeric keypad) the emotion of the face, not the word, as this approximates the original Stroop task where processing of the semantics of the word is automatic and distracting, requiring inhibitory control (Stroop, 1935). There was a total of 36 congruent (face-word matched) and 36 incongruent trials (face-word did not match) for each face type (288 total trials) and the sequence of stimuli presented was randomized. Stimuli were greyscale images (17 cm high) of 18 different actors (9 women and 9 men) showing each facial expression, were taken from the Karolinska Directed Emotional Faces database (Lundwist, Flykt, & Ohman, 1998) and were cropped to remove clothing, background and hair. This task differed from Preston and Stansfield (2008) by using the prototypical emotion words (“happy”, “sad”, “angry”) instead of emotion adjectives (e.g. “blissful”, “hopeless”, “enraged”) as the distractor to reduce variability, and differed with the inclusion of the neutral condition (neutral word and face expressions), using different face stimuli, and limiting the duration of stimulus presentation to 400ms instead of until response in order to increase task difficulty.

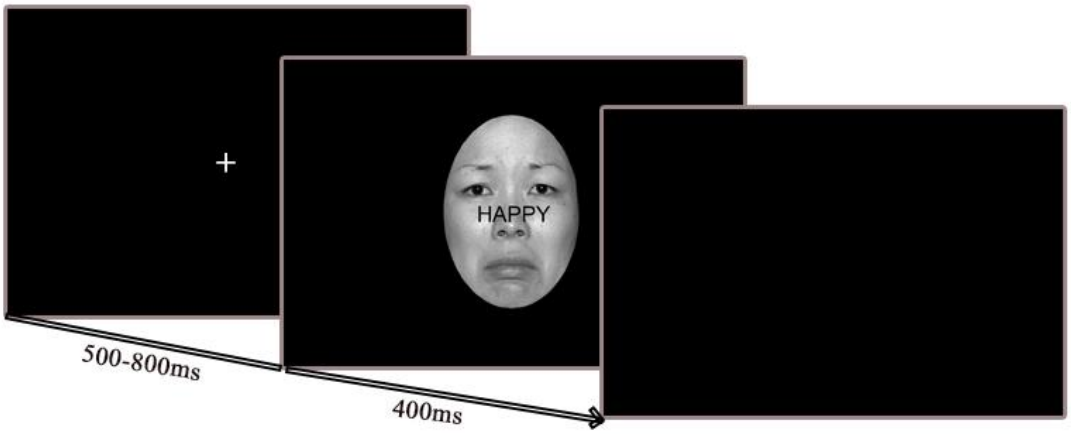


*Figure 2*. A single trial of the face-word emotion Stroop task. Next trial proceeds after choosing the face emotion category.

**2.2.9. Face emotion categorization and intensity task**. This task was adapted from the study by Kyle et al. (2014). A variable inter-stimulus fixation point was displayed for 500-800ms before a face of one of four emotions (happy, sad, fearful, angry) was presented for 400ms and then a blank screen continued until participant responded (Figure 3). Participants were instructed to respond as quickly and accurately as possible and responded by indicating (by pressing a corresponding labelled keyboard key) the category of the emotion of the face. Participants were then presented, until response, with a 5-point Likert scale to rate the intensity of the face (1 = "Not very intense" to 5 = "Extremely intense") without the face stimuli present. There was a total of 60 trials of each emotion (240 total trials) and the sequence of stimuli presented was randomized. Stimuli were static greyscale face images (17 cm high) of 12 different actors (6 women and 6 men) expressing each of the face emotions, taken from the NimStim face database (Tottenham et al., 2009) and were cropped to remove clothing, background and hair. This task differed from the one employed by Kyle et al. (2014); face stimuli were present for a short duration (400ms) instead of until response in order to increase difficulty, and the range of

intensity ratings was reduced from 1-7 to 1-5 as task piloting revealed a tendency for participants to not move the hand further along the keyboard to choose higher intensities.

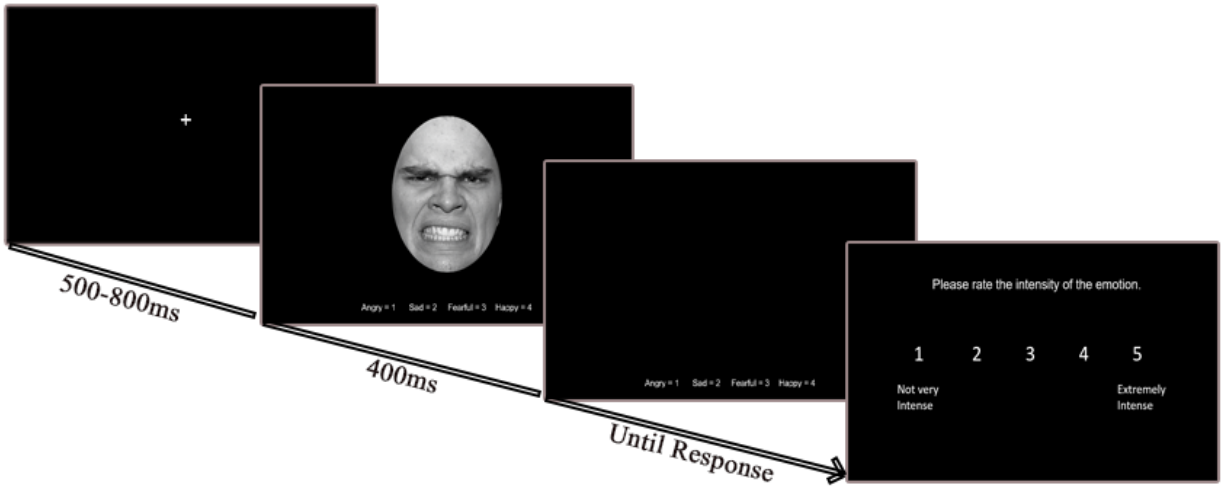


*Figure 3*. A single trial of the face-emotion categorization and intensity task. Next trial proceeds following intensity rating.

### 2.3. Procedure

Participants first underwent a screening phone interview (Appendix B) in order to ensure they met the research criteria. After the phone interview, participants that passed initial screening were given an online link hosted on Qualtrics (Qualtrics International Inc, Provo) to provide consent for participation and data collection (Appendix I) followed by the opportunity to complete the intake questionnaires (Table 2). Results from the demographic, sleep and health, medical history, the circadian rhythm questionnaire, Pittsburgh Sleep Quality Index and the Insomnia Severity Index were assessed to determine eligibility for full participation in the study, as well as to characterize sleep.

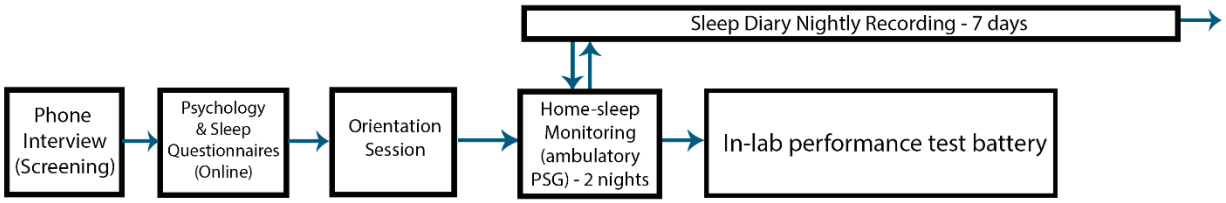


*Figure 4*. Procedure of study through screening interview to performance assessment.

Participants that completed the intake questionnaires and met the study criteria were scheduled for an orientation session (see Figure 4 for full study schedule). During the orientation session participants were given a tour of the lab facilities and written consent forms (Appendix J), and then practiced a short 10-minute version of the computerized task battery to be performed on the performance assessment day to become familiar with the tasks and keyboard inputs. The practice version was presented in the same sequence as in the full performance assessment battery, but had fewer trials (10-20) for each task, and the face-emotion practice tasks had trials with feedback on correct/incorrect response for the purpose of learning the appropriate keyboard inputs. Practice trials also used unique stimuli in order to account for potential practice effects on performance on the main task day.

Participants were then instructed on how to use and wear the Prodigy Sleep System. Participants watched an instructional video, and then went through a demonstration of proper use of the equipment with the experimenter. Participants were instructed to clean their skin for each electrode application area by using an alcohol swab, and then to apply electrodes one by one by removing the plastic backing and carefully attaching electrodes to each location outlined in the video and instructional booklet that was provided. Each electrode came with pre-applied conductive gel, and were one-time use, which allowed for ease of application. Participants were instructed on operation of the sleep monitor, head unit, and the application of electrodes, and were instructed to begin the recording when they intended to sleep and to end the recording

immediately upon wakening. Extra electrodes were included with the equipment to replace faulty electrodes, and the experimenter was on call for troubleshooting if any problems with the equipment occurred during use. Participants were instructed to follow normal bedtime routines while wearing the equipment, and, on the performance assessment day, to be out of bed no later than 8:00 am, refrain from recreational drug use, caffeine intake, vigorous exercise, and to eat breakfast and lunch to ensure adequate nutritional energy levels. Participants took this equipment and accessories home and wore it for two nights; the first night was intended as an adjustment night so that the second night recording would be more typical sleep (Thomas et al., 1981). Any error in the PSG recording for the second night of recordings was remedied by a repeat of the night of PSG recording, with troubleshooting of the equipment to ensure the error would not persist. In this case, performance assessment was rescheduled to follow immediately after the second night of PSG recording without error. During orientation participants were instructed to complete a sleep diary each night beginning immediately after the first night of PSG recording and for up to six days after (1 week total), participants were sent a link via email to an online sleep diary hosted on Qualtrics (Qualtrics International Inc, Provo; Appendix F).

The day after the second night of at-home PSG recording, participants returned to the lab in the afternoon at 13:00. For the first hour of the afternoon in the lab electrodes were applied for electrophysiological recording. Electrodes were applied to cites AFZ, FPZ, F3, F4, FZ, CZ, CPZ, PZ, PO7, PO8, OZ, M1/A1, M2/A1, EKG left/right, EMG left/right, vertical EOG upper/lower, and horizontal EOG left/right. Recording was performed using Neuroscan amplifiers and the Scan software (Neuroscan Inc, El Paso). Electrophysiological analysis was not included for the purposes of the current thesis. After adjustment to improve channel signal impedance to less than 5 Ohms, the task battery began at 14:00.

Refer to Table 3 for an overview of the full task battery with timings. Before each full task, participants were given instructions that there was a small number of practice trials (6-12) with novel stimuli and without feedback, in order to remind participants of correct keyboard inputs. After the reminder practice trials, the participants were instructed that practice had concluded and performance would start to be recorded. Participants were required to use only their right hand for practice and performance assessment. All tasks were completed on a 24-inch LED computer monitor (1080p resolution). After completion of the performance battery, participants were given the opportunity to remove conductive gel from their hair, receive feedback on the study, and provide personal information for a honourarium payment of $60 CAD. Individuals with insomnia symptoms also received a guide on improving sleep quality (Education Program for Getting a Good Night's Sleep; Charles Morin, 1996).

## 2.4. Data Analysis

**2.4.1. All data.** All variables were tested for violations of normality as well as outliers. Measures violating normality were square-root or log transformed and were tested again for normality. Measures violating normality after transformation were compared using non-parametric Mann-Whitney U tests. Outliers were identified by box-plots and by individual means greater than +/- 3 SD from the group mean. Each outlier case is indicated in the results, and data was analysed with and without outliers; any significant findings for a variable with an outlier are reported both with and without that participant included, otherwise the results reported include the outlier to retain sample size. Equality of variance was examined using Levene's Test and violations were corrected using the Welch-Satterthwaite adjustment. For tests of sphericity, violations were corrected using the Greenhouse-Geisser. Main effects were examined using

follow up *t* tests using Bonferroni corrections. Figure summaries are presented with error bars that represents +/- 1 standard error.

**2.4.2. Missing data.** Individuals with missing or compromised data were removed casewise for analysis relevant to that variable but were retained for all other measures and analysis. No behavioural data was missing from the study. Some questionnaires were missing answers to particular items. Two participants were missing a single answer on the STAI – Trait subscale; mean weighted rounded-up values were used based on questionnaire guidelines for handling missing data on the STAI (Spielgelhalder et al., 1983). For the DASS anxiety subscale, two participants did not answer one question; for DASS stress subscale, one participant did not answer one question; and for the DASS depression subscale, two participants did not answer one question. No specific convention for the handling of missing data was found with the DASS, therefore mean imputation for missing values (in consideration of reversed score items) for the relevant subscale was conducted, based on general recommendations for the handling of missing items in questionnaires including the DASS (Peyre, Leplege & Coste, 2011; Parent, 2013; Shrive, Stuart, Quan & Ghali, 2006; Siddiqui, 2015). With the Pittsburgh Sleep Quality Index , one GS did not answer one question, and one individual from the INS group did not answer four questions, these surveys were omitted from analysis as imputation could not be conducted (Buysse et al., 1989), thus comparisons on the Pittsburgh Sleep Quality Index included 14 GS and 13 INS.

For PSG sleep data, one GS and one INS participant had a large proportion (i.e. greater than 30 minutes) of bad EEG signal in their PSG recording compromising the validity of their sleep architecture data. Therefore, for group comparisons of sleep architecture, there were 14 GS and 13 individuals with INS. Two GS participant and one INS participant failed to complete the

sleep diary for the night preceding the afternoon of performance testing (sleep diary analysis included 13 GS and 13 INS). One GS and two INS participants did not give input on the question in the sleep diary asking the amount of time they spent awake throughout the night (13 GS and 12 INS in comparisons of this variable). One GS participant had an absence of Stage 3 sleep in their PSG recording and therefore an ORP value for Stage 3 sleep could not be processed (14 GS and 14 INS for ORP Stage 3 analysis). One GS and one INS had disruption to the signal quality of the right-frontal channel and power spectral analysis could not be conducted on these channels (right-frontal channel analysis included 14 GS and 13 INS), however, data of the left-frontal channel remained intact for all participants.

**2.4.3. State and trait characteristics.** Scores for the Stanford Sleepiness Scale, and each Visual Analog Mood Scale, were automatically generated from the task battery in E-PRIME (Psychology Software Tools). For the PANAS and STAI-State questionnaires, paper responses were transcribed into digital data and scored according to the guidelines for scoring (Watson, Clark and Tellegen, 1988; Spielberger, 2010). The DASS and STAI-Trait were first automatically scored using programming in R (R Core Team, 2013), and were checked for accuracy by the experimenter following guidelines for scoring (Carver and White, 1994; Spielberger, 2010; Lovibond and Lovibond, 1995). For the psychomotor vigilance task, five variables were calculated: mean response time overall (in milliseconds - ms), standard deviation of response times, the number of lapses in response (number of responses > 500ms), mean response time for the fastest 10% of trials, and mean response time for the slowest 10%. The mean 10% of the slowest trials were transformed by using the reciprocal value. To examine if the insomnia group had differences in mood, state or trait affect, sleepiness or psychomotor

vigilance levels that might impact performance, group difference were examined using independent samples *t* tests.

**2.4.4. Sleep.** The two nights of PSG-measured sleep were first scored by automatic sleep-scoring software (Michele software, Cerebra Medical Inc; Malhotra et al., 2013). For the second night of PSG data only, the automated scoring was verify by a trained human scorer following AASM Scoring Manual guidelines (Berry et al., 2012). Anomalous or bad EEG signals were marked within the files for their full durations and omitted from scoring. Interclass correlation coefficients between human-edited and automatically-scored files were calculated for stage times, and the coefficient was > 0.8 overall for all files. After editing for staging accuracy, objective sleep variables of total sleep time (TST), sleep efficiency (SE), wake after sleep onset (WASO), sleep onset latency (SOL), number of awakenings, number of stage shifts, time spent in each stage, and time to first 2 and 10 minutes of consolidated sleep were output by the Michele software, converted into tables using R (R Core Team, 2013) and entered into SPSS for analysis. The sleep diaries produced subjective reports of TST, SE, WASO, SOL, sleep quality (1-7), and number of awakenings. A discrepancy score between subjective and objective sleep times was calculated for TST, WASO, and SOL, by subtracting PSG values from the sleep diary values for each participant (subjective minus objective).

The ORP data as well as average EEG power values for each band were provided by Cerebra Medical Inc on the sleep-scored edited files. The ORP is a continuous measure of sleep depth (0-2.5, 0 = deepest sleep, 2.5 = awake) that represents the predictive value of relative rank power in each frequency band (Delta, Theta, Alpha-Sigma, and Beta) on an arousal or awakening occurring within a 30-second epoch (Younes et al., 2015). The ORP has been found to correlate strongly with Rchetschaffen and Kales's sleep staging (1968) and the likelihood of

an arousal or awakening occurring within a 30-second epoch (Younes et al., 2015). EEG measured power was calculated by averaging the squared microvolts of power over the entire sleep file for each band (Delta = 0.33-2.33 Hz, Theta = 2.67-6.33 Hz, Alpha = 7.33-12 Hz, Sigma = 12.33-14.00 Hz, Beta-1 = 14.33-20.0 Hz, Beta-2 = 20.3-35.00 Hz, Beta = average of Beta 1 and Beta 2) and separately for each EEG channel of the Prodigy equipment: left-frontal channel, right-frontal channel.

Although two nights of PSG data were collected, only sleep diary and objective sleep measures (sleep architecture, ORP, EEG Power derived from the computer and human-scored PSG files) for the second night, which preceded the afternoon of performance testing, were analysed in this thesis. As well, the first night of recording, even at home, was expected to show a typical First Night Effect (FNE), where people sleep poorer than usual due to adaptation to the equipment, and was therefore not analyzed. To address Hypothesis 1, group comparisons (GS vs INS) of subjective and objective sleep variables were conducted using independent samples *t* tests. Additionally, to investigate whether the INS group might show evidence of misperceptions about their sleep, the discrepancy between objective-subjective of total sleep time, sleep onset latency and wake after sleep onset were also compared.

**2.4.5. Emotion tasks.** For the Emotional Stroop Task, mean accuracy (only trials with response time within 100ms to 3000ms were included), and mean response time (correct trials only; within 100ms to 3000ms), were calculated separately for congruent and incongruent trials and for each face expression (Happy, Angry, Sad, Neutral). Additionally, mean accuracy (only trials with response time within 100ms to 3000ms were included) and mean response time (trials within 100ms to 3000ms) for each emotional word distractor (“Happy”, “Angry”, “Sad”, “Neutral”) and for each trial condition (congruent, incongruent) was also computed for each

participant. To address Hypothesis 2, response time and accuracy on the Emotional Stroop Task was examined using a three-way mixed-model analysis of variance (ANOVA) with the between-subjects factor as Group (INS, GS), and the within-subjects factors as Congruency (Congruent, Incongruent) and Face-expression (Happy, Angry, Sad, Neutral). A three-way mixed-model ANOVA with Group (INS, GS), Congruency (Congruent, Incongruent) and Distractor word ("Happy", "Angry", "Sad", "Neutral") was also used to examine the processing of the distractor stimuli. An interference effect for response time was calculated for the moderation regression (discussed below) by subtracting performance (response time) on incongruent trials from congruent trial performance.

On the Face Categorization and Intensity Rating task, mean accuracy (for trials within 100ms to 3000ms), response time (correct trials only, within 100ms to 3000ms), and intensity ratings (correct trials only, within 100ms to 3000ms) were calculated for each emotional face expression (Happy, Angry, Sad, Fearful) for each participant. To address Hypothesis 2 and to examine performance differences on this task, a two-way mixed-model ANOVA was employed with the between-subjects factor as Group (INS, GS) and within-subjects factor as face Emotion (Happy, Angry, Sad, Fearful).

**2.4.6. Regressions and correlations.** For descriptive and exploratory purposes, bivariate correlations between all sleep, subjective, affect, and behavioural variables were first run separately for GS and INS groups, as well as for all participants combined. These comparisons were done without correction for multiple comparisons and are presented in Appendix K. These analyses informed the regression strategy below.

In order to test the central hypothesis (Hypothesis 3) that abnormal/poor sleep in insomnia related to daytime emotion processing, moderation regression analyses were run with

group (GS, INS) as a categorical predictor, and sleep variables as the interaction term, to predict each measure of emotion processing performance as outcome variables (see Figure 5 for an illustration of the model). The measures of sleep for the interaction term were entered individually (i.e. one at a time) and included Stanford Sleepiness Scale scores, total sleep time, time in Stage 2, time in Stage 3 (SWS), time in REM, ORP Stage 2 sleep, ORP Stage 3 sleep, ORP REM, ORP NREM, Pittsburgh Sleep Quality Index scores, Insomnia Severity Index scores, and Beta power averaged over the two channels (left-frontal and right-frontal). Regressions were performed in SPSS Version 23 using the PROCESS 3.3 macro for SPSS (Hayes, 2012). For regressions violating heteroscedasticity, heteroskedasticity-consistent standard errors using Hinkley's method (1977) were employed in consideration of the small sample size (Hayes & Cai, 2007).

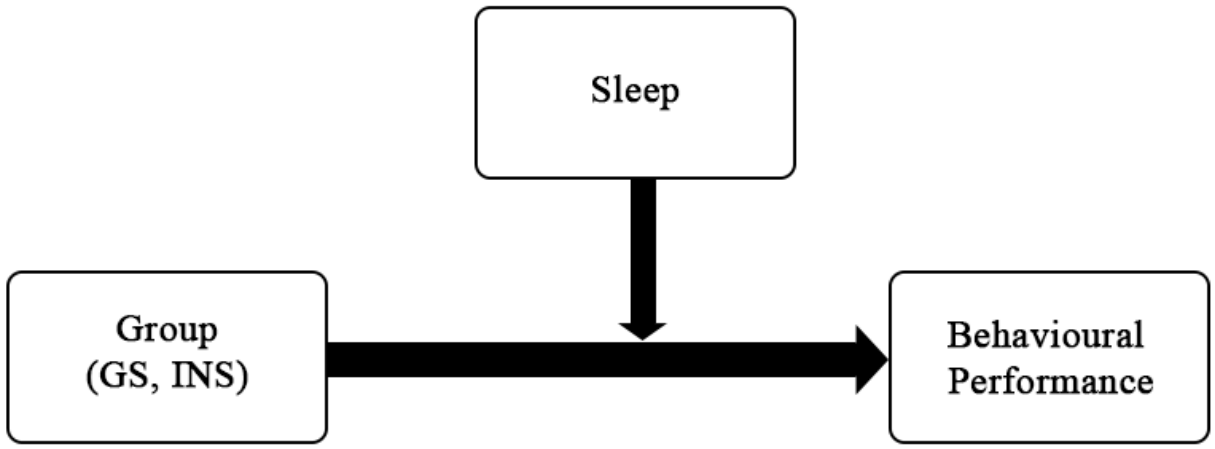


*Figure 5.* Moderation model employed in order to examine the role of sleep in the relationship between group and emotion processing performance.

# 3. Results

## 3.1. Participant characteristics.

**3.1.1. Demographics.** The GS group had 13 women and 2 men, and the INS group had 10 women and 4 men. The GS and INS groups did not significantly differ in age, $t(27) = -.39$, $p = .700$. The mean age of the GS group was 25.60 years ($SD = 9.56$), and the mean age of the INS group was 27.00 years ($SD = 9.81$). See Table 1 for demographics by group.

**3.1.2. Trait affect.** No differences were observed in trait depression, anxiety, or stress between GS and INS group (Table 4)**.** Normality was violated for DASS - Anxiety, but non-parametric tests were also non-significant. See Table 4 for descriptives and group comparisons in trait affect measures.

Table 4.

*Group comparisons and descriptives on personality measures.*

| | GS | | INS | | | | |
|---|---|---|---|---|---|---|---|
| Personality Measure | *M* | *SD* | *M* | *SD* | *t* | *df* | *Sig. (2-tailed)* |
| DASS - Anxiety | 2.60 | 2.29 | 3.71 | 4.34 | -.86 | 19.43 | .403 |
| DASS - Depression | 3.73 | 3.53 | 6.36 | 6.78 | -1.29 | 19.28 | .211 |
| DASS - Stress | 6.00 | 4.17 | 8.71 | 5.80 | -1.46 | 27 | .157 |
| STAI - Trait | 36.87 | 9.46 | 39.86 | 14.07 | -.68 | 27 | .505 |

*Note.* DASS = Depression Anxiety Stress Scale. STAI = State-Trait Anxiety Index – Trait Subscale.

**3.1.3. Sleepiness, mood and affective state during testing.** Group comparison revealed that the INS group ($M = 2.64$, $SD = .64$) had greater sleepiness scores on the SSS at the beginning of performance testing than the GS group ($M = 1.87$, $SD = .64$), $t(27) = -2.81$, $p = .009$. The INS group ($M = 34.64$, $SD = 23.79$) also reported greater sluggishness at the beginning of performance testing on the VAS-M Energetic-Sluggish scale compared to the GS group ($M = 18.53$, $SD = 14$), $t(27) = -2.24$, $p = .034$. Assumptions of normality were violated for

SSS, VAS-M Calm-Irritable, and PANAS - Negative, however, group differences on the SSS remained significant with non-parametric comparisons, $U = 158.5$, $p = .010$. See Table 5 for a summary of descriptives and group comparisons on sleepiness and mood.

Table 5.

*Group comparisons and descriptives on state mood and sleepiness measures.*

| | GS | | INS | | | | |
|---|---|---|---|---|---|---|---|
| Mood/State Measure | *M* | *SD* | *M* | *SD* | *t* | *df* | *Sig. (2-tailed)* |
| SSS | 1.87 | .64 | 2.64 | .84 | -2.81 | 27 | **.009*** |
| VAS-M Energetic-Sluggish | 18.53 | 14.12 | 34.64 | 23.79 | -2.24 | 27 | **.034*** |
| VAS-M Calm-Irritable | 9.67 | 13.00 | 13.71 | 12.04 | -.87 | 27 | .393 |
| VAS-M Happy-Sad | 11.07 | 16.06 | 15.00 | 20.10 | -.58 | 27 | .564 |
| VAS-M Relaxed-Tense | 18.47 | 14.44 | 20.29 | 20.20 | -.28 | 27 | .781 |
| STAI - State | 33.67 | 7.78 | 33.00 | 6.58 | .25 | 27 | .806 |
| PANAS - Positive | 32.00 | 8.88 | 31.43 | 5.67 | .21 | 23.97 | .837 |
| PANAS - Negative | 12.87 | 3.56 | 12.79 | 3.93 | .06 | 27 | .954 |

*Note.* * = significant at $p < .05$. SSS = Stanford Sleepiness Scale. VAS-M = Visual Analog Mood Scale. STAI = State-Trait Anxiety Index. PANAS = Positive and Negative Affect Schedule

**3.1.4. Psychomotor vigilance.** The INS and GS groups did not differ in psychomotor vigilance (Table 6). Normality was violated for the number of lapses (number of response times >500 ms) but non-parametric comparisons were also non-significant.

Table 6.

*Group comparisons in performance on the psychomotor vigilance task.*

| | Good Sleepers | | Insomnia | | | | |
|---|---|---|---|---|---|---|---|
| *Measure* | *Mean* | *SD* | *Mean* | *SD* | *t* | *df* | *Sig. (2-tailed)* |
| Response Time | 240.81 | 28.44 | 247.16 | 30.47 | -.58 | 27 | .567 |
| Response Time SD | 49.40 | 28.57 | 51.02 | 24.24 | -.51 | 27 | .613 |
| Fastest 10% RT | 190.71 | 19.17 | 193.65 | 18.68 | -.42 | 27 | .679 |
| Slowest 10% RT | 330.16 | 64.94 | 344.26 | 72.34 | .55 | 27 | .387 |
| Number of Lapses (>500ms) | .40 | .74 | .36 | .50 | .18 | 27 | .857 |

### 3.2. Were there Groups Differences in Sleep? (Hypothesis 1)

**3.2.1. Subjective historic sleep quality**. The GS on average scored 3.60 (*SD* = 2.56) on the Insomnia Severity Index, and 3.00 (*SD* = 1.52) on the Pittsburgh Sleep Quality Index, indicating healthy sleep. The INS group had an average score on the Insomnia Severity Index of 14.21 (*SD* = 5.44), and 11.39 (*SD* = 2.14) on the Pittsburgh Sleep Quality Index indicating significant sleep impairment. For the INS group, six individuals scored greater than 14 indicating clinical levels of insomnia, and eight scored between 8-14 indicating subclinical levels of insomnia. Group comparisons revealed that the INS group had significantly greater complaints of poor historic sleep quality indicated by greater scores on the ISI ($t(18.20) = -6.65$, $p < .001$), and PSQI ($t(25) = -11.80$, $p < .001$) than good sleepers.

**3.2.2. Sleep architecture.** Descriptives and *t* test comparisons between groups are presented in Table 7. No significant differences in sleep architecture were observed between INS and GS. Assumptions of normality were violated for sleep onset latency, time to first 2 minutes of consolidated sleep, time to first 10 minutes of consolidated sleep, wake after sleep onset, wake time, wake proportion, and Stage 1 proportion; non-parametric comparisons were also non-significant. Differences in sleep between GS and INS appeared in the expected directions (Table 7), for example, the INS group appeared to have less total sleep time, take longer to enter consolidated sleep and spent more time awake throughout the night, but differences were likely not robust due to a small sample size in conjunction with non-normal distributions (i.e. a lack of power), and inclusion of INS with a good night of sleep.

Table 7.

*Group comparisons and descriptives for sleep architecture.*

| | Good Sleepers | | Insomnia | | | | |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *t* | *df* | *Sig. (2-tailed)* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TST | 432.82 | 33.42 | 393.42 | 78.27 | 1.68 | 15.99 | .113 |
| SOL | 12.39 | 7.70 | 16.69 | 14.79 | -.96 | 25 | .347 |
| 2Min SOL | 13.21 | 9.58 | 20.77 | 28.26 | -.95 | 25 | .354 |
| 10Min SOL | 13.89 | 9.64 | 22.39 | 28.13 | -1.07 | 25 | .297 |
| WASO | 19.43 | 10.18 | 28.08 | 36.89 | -.82 | 13.69 | .428 |
| Wake Time | 29.83 | 21.07 | 40.28 | 39.20 | -.87 | 25 | .392 |
| Stage 1 Time | 46.94 | 19.74 | 42.92 | 17.84 | -.10 | 24 | .923 |
| Stage 2 Time | 232.90 | 47.52 | 203.01 | 45.81 | 1.66 | 25 | .109 |
| Stage 3 Time | 80.48 | 33.76 | 88.69 | 30.30 | -.66 | 25 | .514 |
| REM Time | 74.22 | 18.20 | 62.42 | 33.88 | 1.14 | 25 | .265 |
| NREM Time | 362.65 | 36.95 | 336.72 | 53.71 | 1.47 | 25 | .154 |
| Wake Proportion | 6.48 | 4.73 | 9.19 | 8.99 | -.99 | 25 | .332 |
| Stage 1 Proportion | 10.11 | 3.96 | 9.63 | 3.64 | .33 | 25 | .745 |
| Stage 2 Proportion | 50.08 | 8.27 | 46.08 | 6.19 | 1.41 | 25 | .170 |
| Stage 3 Proportion | 17.46 | 7.27 | 21.08 | 9.73 | -1.10 | 25 | .281 |
| REM Proportion | 16.04 | 3.98 | 13.86 | 6.84 | 1.02 | 25 | .316 |
| NREM Proportion | 78.17 | 4.44 | 77.23 | 7.41 | .40 | 25 | .690 |
| Total Number of Awakenings | 16.07 | 6.04 | 14.69 | 7.86 | .51 | 25 | .612 |
| Total Stage Shifts | 129.21 | 24.95 | 126.31 | 35.12 | .25 | 25 | .805 |
| Number of Arousals (REM) | 12.36 | 7.41 | 12.38 | 8.09 | -.01 | 25 | .993 |
| Number of Arousals (NREM) | 73.43 | 19.64 | 76.15 | 33.38 | -.26 | 19.13 | .801 |

*Note.* TST = Total sleep time (minutes). SE = Sleep efficiency (sleep time/time in bed). SOL = Sleep onset latency (minutes to first sleep staging). 2Min SOL = minutes until first 2 minutes of consolidated sleep. 10Min SOL = minutes until first 10 minutes of consolidated sleep. WASO = wake after sleep onset (number of minutes awake throughout the night after first sleep staging).

**3.2.3. Sleep Diary.** The INS group ($M$ = 389.23, $SD$ = 70.14) reported lower self-reported total sleep time (TST) than the GS group ($M$ = 475.85, $SD$ = 50.67), $t(26) = 3.77$, $p = .001$. No other differences were observed. Self-reported SOL, WASO and number of awakenings violated normality assumptions but non-parametric comparisons were also non-significant. While not significant, poorer sleep quality appeared to be reported for most measures in the sleep diary in the INS group (Table 8); the small sample size and non-normal distributions, as well as inclusion of INS with a good night of sleep may have hindered the ability to detect

statistical differences. Descriptives and group comparisons in sleep diary reports are reported in Table 8.

Table 8.

*Group comparisons and descriptives in sleep diary reports of sleep.*

| | Good Sleepers | | Insomnia | | | | |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *t* | *df* | *Sig. (2-tailed)* |
| Total Sleep Time (min) | 475.85 | 50.67 | 389.23 | 70.14 | 3.61 | 24.00 | **.001*** |
| Sleep Onset Latency (min) | 12.89 | 6.60 | 27.69 | 35.51 | -1.48 | 12.83 | .163 |
| Wake After Sleep Onset (min) | 6.38 | 8.20 | 17.85 | 20.80 | -1.64 | 11.33 | .128 |
| Sleep Quality Rating (1-7) | 4.54 | 1.51 | 3.92 | .95 | 1.24 | 20.29 | .228 |
| Number of Awakenings | 1.92 | 1.88 | 3.42 | 4.42 | -1.08 | 22.00 | .291 |

*Note.* * = significant at $p < .05$

**3.2.4. Subjective-Objective Discrepancy.** GS and the INS group did not differ in the discrepancy between PSG recorded and sleep diary reports of total sleep time, minutes to fall asleep, or the number of minutes spent awake throughout the night. Subjective-objective discrepancy for sleep onset latency and wake after sleep onset violated assumptions of normality but non-parametric tests were also non-significant. Descriptives and group comparisons for subjective-objective discrepancy are presented in Table 9.

Table 9.

*Group comparisons in subjective-objective sleep discrepancy.*

| | Good Sleepers | | Insomnia | | | | |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *t* | *df* | *Sig. (2-tailed)* |
| TST Discrepancy (min) | 32.38 | 31.95 | -4.19 | 92.12 | 1.35 | 14.85 | .196 |
| SOL Discrepancy (min) | 2.08 | 4.59 | 11.00 | 29.18 | -1.09 | 12.59 | .297 |
| WASO Discrepancy (min) | -12.21 | 12.27 | -14.35 | 43.42 | .20 | 13.76 | .847 |

*Note.* TST = Total sleep time. SOL = Sleep onset discrepancy WASO = Wake after sleep onset.

**3.2.5. Odds ratio product (ORP).** A GS participant was a statistical outlier on Right/Left ORP Correlation and was omitted for comparisons for that variable. No differences

between groups in ORP parameters were observed, indicating there was no evidence for group differences in sleep depth in this sample. ORP REM and R/L ORP Correlation violated normality and non-parametric tests were also non-significant. Descriptives and group comparisons for all ORP parameters are presented in Table 10.

Table 10.

*Group comparisons of ORP variables.*

| | Good Sleepers | | Insomnia | | | | |
|---|---|---|---|---|---|---|---|
| Measure | *M* | *SD* | *M* | *SD* | *t* | *df* | *Sig. (2-tailed)* |
| ORP NREM | .50 | .17 | .51 | .18 | -.23 | 27 | .905 |
| ORP REM | .67 | .30 | .74 | .40 | -7.08 | 27 | .638 |
| ORP Stage 1 | .84 | .26 | .89 | .25 | -1.06 | 27 | .609 |
| ORP Stage 2 | .53 | .18 | .54 | .17 | -.33 | 27 | .869 |
| ORP Stage 3 | .24 | .11 | .25 | .13 | -.18 | 26 | .883 |
| R/L ORP Correlation | .87 | .09 | .87 | .12 | 1.03 | 26 | .560 |
| ORP Max During Arousal | 1.99 | .21 | 2.00 | .18 | -.38 | 27 | .925 |
| ORP Baseline Before Arousal | .63 | .22 | .61 | .21 | .01 | 27 | .786 |
| Number of Arousals with ORPMax-ORPBaseline > 0.5 | 45.27 | 16.95 | 48.50 | 26.92 | .66 | 27 | .886 |
| ORP-9 Post Arousal | .81 | .20 | .80 | .23 | .03 | 27 | .700 |

*Note.* ORP values range from 0-2.5 where 0 represents the deepest sleep and 2.5 represents wake/arousal.

**3.2.6. Power spectral analysis.** One INS participant had extreme values in the Delta, Theta and Alpha bands and was omitted from analysis for those variables. Descriptives and group comparisons for power spectral analysis for both left-frontal and right-frontal channels for each band are presented in Table 11. No group differences were observed between INS and GS. left-frontal Beta-1 and left-frontal Beta-2 violated normality assumptions, non-parametric comparisons were also non-significant. When inspecting the means (Table 11) the insomnia group appeared to have Delta and Beta power in the expected direction (less Delta power and

more Beta power), but differences may not have been observed due to a small sample including individuals with insomnia with a night of good sleep.

Table 11.

*Descriptives and group comparisons for average power during sleep recordings in each band.*

| | Good Sleepers | | Insomnia | | | | |
|---|---|---|---|---|---|---|---|
| *Measure* | *M* | *SD* | *M* | *SD* | *t* | *df* | *Sig. (2-tailed)* |
| LF Delta | 227.26 | 132.69 | 208.15 | 85.48 | .45 | 26 | .660 |
| RF Delta | 263.67 | 153.41 | 226.53 | 113.74 | .51 | 24 | .618 |
| LF Theta | 13.87 | 4.78 | 13.82 | 3.78 | .03 | 26 | .975 |
| RF Theta | 15.58 | 4.90 | 15.29 | 3.82 | .17 | 24 | .870 |
| LF Alpha | 5.00 | 2.60 | 4.37 | 1.18 | .80 | 26 | .430 |
| RF Alpha | 5.99 | 2.85 | 5.08 | 1.40 | 1.00 | 24 | .327 |
| LF Sigma | .71 | .23 | .93 | .45 | -1.68 | 27 | .104 |
| RF Sigma | .85 | .29 | 1.09 | .49 | -1.56 | 25 | .132 |
| LF Beta-1 | .87 | .27 | 1.04 | .40 | -1.36 | 27 | .186 |
| RF Beta-1 | .95 | .30 | 1.17 | .50 | .51 | 25 | .181 |
| LF Beta-2 | .57 | .36 | .63 | .26 | -.54 | 27 | .594 |
| RF Beta-2 | .60 | .32 | .74 | .44 | -1.08 | 25 | .279 |
| LF Beta Average | .71 | .31 | .84 | .32 | -1.10 | 27 | .277 |
| RF Beta Average | .78 | .30 | .96 | .46 | -1.27 | 25 | .216 |

*Note.* LF = Left frontal channel. RF = Right frontal channel.

### 3.3. Were there Behavioural Performance Differences Between Groups? (Hypothesis 2)

**3.3.1. Behavioural differences: Face Categorization & Intensity Rating Task.** For the Face Categorization and Intensity Rating Task, a two-way ANOVA with Group (GS, INS) and Face (Happy, Angry, Fearful, Sad) was conducted separately for response time, accuracy, and intensity ratings.

For response time on the Face Categorization and Intensity Rating Task, there was a non-significant interaction between Face and Group, and no main effect of Group, but there was a significant effect of Face on response time ($F(2.10,56.78) = 25.95$, $p < .001$, $\eta^2 = .485$). Post-hoc

analysis of Face with Bonferroni corrections revealed participants were fastest to classify Happy faces compared to Angry ($t(26) = -4.90$, $p < .001$), Fear ($t(26) = -8.10$, $p < .001$) and Sad ($t(26) = 9.64$, $p < .001$). For descriptives see Table 12.

The Face x Group ANOVA for accuracy yielded a non-significant Face emotion x Group interaction and no main effect of Group, but a significant main effect of Face emotion was observed ($F(1.91,51.52) = 22.92$, $p < .001$, $\eta^2 = .459$). Post-hoc comparisons of accuracy of the different Face-expressions revealed participants were more accurate for Happy faces than Angry ($t(26) = 6.00$, $p < .001$), Fearful ($t(26) = 7.68$, $p < .001$), and Sad faces ($t(26) = 7.25$, $p < .001$), and more accurate for Angry faces than Fearful faces ($t(26) = 4.72$, $p < .001$); descriptives are presented in Table 12.

With intensity ratings, there was again a significant effect of Face emotion, $F(2.12,57.11) = 13.75$, $p < .001$, $\eta^2 = .337$, but there was no significant effect of Group or significant sleep Group x Face emotion interaction. Post-hoc analysis with Bonferroni corrections of Face revealed that participants rated Angry faces as more intense than Happy ($t(26) = 3.20$, $p = .020$) and Sad faces ($t(26) = 4.92$, $p < .001$), and also rated Fearful faces as more intense than Happy ($t(26) = 4.64$, $p < .001$) and Sad faces ($t(26) = 6.60$, $p < .001$); see Table 12 for descriptives.

In summary, no group differences were observed on this task. Participants were faster and more accurate identifying Happy faces compared to the other face emotions, and, participants rated Angry and Fearful faces as more intense than Happy and Sad faces.

Table 12.

*Group descriptives for the face categorization and intensity rating task on mean response time, accuracy and intensity rating for each face-emotion expression.*

| | Good Sleepers | | Insomnia | | All | |
|---|---|---|---|---|---|---|
| Response Time | *M* | *SD* | *M* | *SD* | *M* | *SD* |

| | | | | | | |
|---|---|---|---|---|---|---|
| Happy | 402.46 | 113.92 | 367.48 | 92.97 | 385.57 | 104.01 |
| Angry | 480.93 | 120.49 | 448.98 | 103.10 | 465.51 | 103.10 |
| Fear | 496.34 | 115.62 | 488.87 | 87.28 | 492.73 | 101.17 |
| Sad | 487.78 | 128.46 | 460.18 | 89.03 | 474.46 | 110.13 |
| Accuracy | | | | | | |
| Happy | .99 | .01 | .98 | .03 | .98 | .02 |
| Angry | .90 | .08 | .90 | .08 | .90 | .08 |
| Fear | .84 | .12 | .79 | .12 | .82 | .12 |
| Sad | .86 | .09 | .82 | .13 | .84 | .11 |
| Intensity Rating | | | | | | |
| Happy | 2.87 | .49 | 2.96 | .75 | 2.91 | .62 |
| Angry | 3.30 | .51 | 3.23 | .48 | 3.26 | .48 |
| Fear | 3.39 | .48 | 3.29 | .41 | 3.34 | .44 |
| Sad | 2.92 | .56 | 2.99 | .55 | 2.95 | .55 |

**3.3.2. Behavioural differences: Emotional Stroop Task**. A three-way ANOVA with Group (GS, INS) x Face (Happy, Angry, Sad, Neutral) x Congruency (Congruent, Incongruent) was conducted to investigate how group, face-emotion and congruency impacts response time and accuracy performance on the Emotional Stroop Task. The three-way interaction for response time was not significant, nor were the two-way interactions of Group x Face, Group x Congruency, or Congruency x Face. There was no main effect of Group. There was a main effect of Congruency on response time, $F(1,27) = 155.31$, $p < .001$, $\eta 2 = .852$, and post-hoc pairwise comparison using Bonferroni correction found that all participants were slower for incongruent trials compared to congruent trials, $t = -12.46$, $p < .001$. There was also a significant main effect of Face on response time, $F(3,34) = 49.04$, $p < .001$, $\eta^2 = .812$; post-hoc pairwise comparisons with Bonferroni corrections revealed that participants were significantly faster for Happy faces compared to Angry ($t(26) = 9.90$, $p < .001$), Sad ($t(26) = 9.95$, $p < .001$), or Neutral faces ($t(26) = 10.52$, $p < .001$). In summary, participants were slower for incongruent trials compared to congruent trials, and were faster for trials with target Happy faces than any other face, and there

were no detectable differences in response times by individuals with INS compared to GS. Descriptives are presented in Table 13.

Table 13.

*Mean congruent and incongruent response time, and interference effect on response time by group when identifying the emotion of the face on the emotion Stroop task.*

| | Good Sleepers | | Insomnia | | All | |
|---|---|---|---|---|---|---|
| Congruent Response Time (ms) | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Happy | 770.85 | 164.57 | 742.75 | 145.55 | 757.28 | 153.56 |
| Angry | 911.91 | 204.60 | 876.19 | 174.58 | 894.67 | 174.58 |
| Sad | 945.40 | 224.19 | 893.01 | 149.36 | 920.11 | 190.26 |
| Neutral | 893.24 | 95.49 | 896.68 | 146.56 | 894.90 | 120.56 |
| Incongruent Response Time (ms) | | | | | | |
| Happy | 866.60 | 174.56 | 827.90 | 153.63 | 847.91 | 163.03 |
| Angry | 1037.98 | 226.98 | 1009.84 | 197.08 | 1024.39 | 197.08 |
| Sad | 1054.95 | 188.31 | 1012.62 | 159.70 | 1034.52 | 173.31 |
| Neutral | 1030.75 | 145.07 | 1019.61 | 144.58 | 1025.37 | 142.34 |
| Interference (Incongruent – Congruent; ms) | | | | | | |
| Happy | 95.75 | 58.77 | 85.15 | 61.47 | 90.63 | 59.25 |
| Angry | 126.06 | 91.91 | 133.65 | 86.48 | 129.73 | 86.48 |
| Sad | 109.55 | 100.90 | 119.61 | 76.94 | 114.41 | 88.69 |
| Neutral | 137.52 | 95.87 | 122.94 | 101.22 | 130.48 | 96.99 |

For the three-way ANOVA for accuracy on the Emotional Stroop Task, the interaction between Group, Face and Congruency was not significant. Assumption of sphericity for Face was violated and a Greenhouse-Geisser correction was used. For two-way interactions, there was no significant interaction between Group and Congruency, and no significant interaction between Group and Face. The interaction between Congruency and Face proved significant, $F(3,81) = 4.92$, $p = .003$, $\eta^2 = .175$, indicating that the effect of congruency differed between faces. Post-hoc analysis with Bonferroni corrections for face at the level of congruent trials found that participants were significantly more accurate for Happy faces than Angry ($t(26) = 5.08$, $p < .001$), Sad ($t(26) = 4.10$, $p < .001$) or Neutral faces ($t(26) = 6.17$, $p = .003$). Post-hoc analysis

of the face for incongruent trials also found that participants were more accurate for Happy faces than Angry ($t(26) = 5.75$, $p < .001$), Sad ($t(26) = 4.6$, $p < .001$), or Neutral ($t(26) = 7.05$, $p < .001$; see Table 14). There was no main effect of Group, $F(1,27) = .05$, $p = .832$, $\eta^2 = .002$.

Table 14.

*Descriptives for accuracy (proportion correct – hits/total trials) for face expressions on congruent and incongruent trials on the emotion Stroop task.*

| | Good Sleepers | | Insomnia | | All | |
|---|---|---|---|---|---|---|
| Congruent Accuracy | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Happy | .99 | .02 | .99 | .01 | .99 | .02 |
| Angry | .94 | .06 | .91 | .06 | .93 | .06 |
| Neutral | .91 | .08 | .91 | .06 | .92 | .07 |
| Sad | .94 | .04 | .93 | .08 | .95 | .05 |
| Incongruent Accuracy | | | | | | |
| Happy | .94 | .05 | .95 | .03 | .95 | .04 |
| Angry | .86 | .12 | .78 | .12 | .84 | .12 |
| Neutral | .84 | .10 | .79 | .09 | .83 | .09 |
| Sad | .85 | .09 | .79 | .15 | .84 | .12 |

To investigate group, emotion and congruency effects on response time and accuracy for the distractor words on the Emotional Stroop Task, a three-way ANOVA with Group (GS, INS), Distractor word (“Happy”, “Angry”, “Sad”, “Neutral”) and Congruency (Congruent, Incongruent) was conducted.

The three-way interaction between Group, Distractor, and Congruency for response times for distractors was non-significant. The two-way interactions between Group and Congruency, and Group and Distractor were also non-significant. There was a significant interaction between Congruency and Distractor for response time on the Emotional Stroop Task, $F(3,81) = 30.80$, $p < .001$, $\eta^2 = .533$. Post-hoc analysis with Bonferroni corrections of distractors at the level of incongruent trials corrections found that participants were significantly slower for incongruent

trials with a Happy distractor than Angry ($t(26) = 4.65$, $p < .001$), Neutral ($t(26) = 5.37$, $p < .001$) or Sad ($t(26) = 4.53$, $p = .001$) distractors. No significant main effect of Group was observed, $F(1,27) = .213$, $p = .648$, $\eta^2 = .008$. In sum, the distractor word of "Happy" slowed response times more than any other distractors for incongruent trials (see Table 15), and the INS group did not differ from GS in response times.

Table 15.

*Descriptives for response time for word-distractors on incongruent trials on the emotion Stroop task.*

| | Good Sleepers | | Insomnia | | All | |
|---|---|---|---|---|---|---|
| | M | SD | M | SD | M | SD |
| Happy | 1048.60 | 178.36 | 1029.85 | 162.81 | 1039.55 | 168.24 |
| Angry | 994.90 | 144.24 | 977.89 | 158.19 | 986.69 | 148.15 |
| Sad | 1000.10 | 180.46 | 956.92 | 148.14 | 979.25 | 164.18 |
| Neutral | 997.75 | 207.40 | 951.96 | 161.64 | 975.13 | 184.82 |

Accuracy for distractor words was also examined using a three-way ANOVA with Group, Distractor and Congruency. The three-way interaction with Group, Distractor and Congruency on accuracy for distractor words was non-significant. The two-way interactions of Group and Congruency, and Group and Distractor were also non-significant. The interaction between Congruency and Distractor on accuracy was significant, $F(2.35,63.40) = 6.99$, $p = .001$, $\eta^2 = .206$. Post-hoc analysis of distractors at the levels of incongruent trials with Bonferroni corrections found that participants had no significant differences in accuracy between any word distractors for incongruent trials (all comparisons $p > .05$; see Table 16), while participants were more accurate for Happy faces on congruent trials (see earlier analysis with Face-emotions). There was no significant main effect of Group, $F(1,27) = .049$, $p = .826$, $\eta^2 = .002$. See Table 16 for descriptives of accuracy for each word distractor on incongruent trials. In conclusion, there

appeared to be no differences between distractors for accuracy, and particular distractors did not have a different effect for INS and GS groups.

Table 16.

*Descriptives for accuracy (proportion correct – hits/total trials) for word-distractors on congruent and incongruent trials on the emotion Stroop task.*

| | Good Sleepers | | Short sleep INS | | All | |
|---|---|---|---|---|---|---|
| Word-distractor | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Happy | .87 | .06 | .87 | .07 | .87 | .06 |
| Angry | .88 | .08 | .89 | .07 | .88 | .07 |
| Sad | .85 | .11 | .82 | .10 | .84 | .10 |
| Neutral | .90 | .08 | .86 | .11 | .88 | .10 |

### 3.4. What were the Differences in Sleep and Emotion Processing for the Insomnia Subgroup with a Poor Night of Sleep?

A separate exploratory analysis comparing the GS group and a subgroup of INS that had objective evidence of poor sleep on the night prior to performance assessment (n = 8; for details on how these poor sleepers were identified see Methods section 2.1) was carried out to see if the hypothesized differences in sleep and performance might be evident after a night of poor sleep in insomnia. The same comparisons were run with this subgroup as they were above with the full INS sample (comparing GS and INS groups on sleep and behavioural performance), however, only significant or relevant findings are presented here for the sake of brevity.

The INS group with a night of poor sleep reported being sleepier than GS, $t(21) = -2.97$, $p = .007$, and no differences in trait affect or state mood were observed between groups. No differences were observed for this group in psychomotor vigilance performance. Despite the smaller sample, significant group differences were found in sleep as expected. The INS group with a night of poor sleep subjectively reported less total sleep time, $t(19) = 3.77$, $p = .001$, and

differences in objective sleep architecture were found in less total sleep time ($t(19) = 3.68$, $p = .006$), less time in Stage 2 sleep ($t(19) = 2.63$, $p = .017$), less time in REM sleep ($t(19) = 2.99$, $p = .007$), a smaller portion of time in REM, $t(19) = 2.24$, $p = .038$, and less time in NREM sleep overall ($t(19) = 3.23$, $p = .004$) than GS. For quantitative EEG measures of sleep, the individuals with INS and a poor night of sleep trended towards greater power in the left-frontal Sigma band, $t(21) = -1.96$, $p = .064$, and left-frontal Beta-1 band, $t(21) = -2.07$, $p = .052$, compared to the GS group. No differences in ORP parameters were observed.

Some indices of impaired accuracy were found for the INS group with a night of poor sleep on the emotion tasks. From the three-way ANOVA (Group x Congruency x Face) for accuracy on the Emotional Stroop Task, group differences were not significant but were in the expected direction, $F(1,21) = 1.935$, $p = .179$, $\eta^2 = .084$ (see Table 17 for descriptives). On the Face Categorization and Intensity Rating Task, the two-way ANOVA with Group and Face on accuracy performance yielded a trending main effect of Group in the hypothesized direction (1-tailed), $F(1,21) = 2.90$, $p = .052$, $\eta^2 = .121$, such that the INS group with a night of poor sleep trended towards poorer accuracy overall on this task. Refer to Table 17 for descriptives of accuracy on emotional tasks for these two groups. These findings may suggest that accuracy for emotional faces could be impaired after a poor night of insomnia but there may have been a lack of power given the small sample size to detect statistical differences.

Table 17.

*Descriptives for accuracy performance identifying the emotion of faces on the emotional Stroop task (EST) and face categorization and intensity task (FCI) for both good sleepers and the subset of individuals with insomnia symptoms that were identified to have a night of poor sleep.*

| | Good Sleepers (N = 14) | Insomnia with a night of poor sleep (N = 8) |
|---|---|---|

| EST Congruent Accuracy | *M* | *SD* | *M* | *SD* |
|---|---|---|---|---|
| Happy | .99 | .02 | .99 | .01 |
| Angry | .94 | .06 | .91 | .06 |
| Sad | .93 | .08 | .93 | .08 |
| Neutral | .91 | .07 | .91 | .06 |
| EST Incongruent Accuracy | | | | |
| Happy | .94 | .05 | .95 | .03 |
| Angry | .86 | .12 | .78 | .12 |
| Sad | .85 | .09 | .79 | .15 |
| Neutral | .84 | .10 | .79 | .09 |
| FCI Accuracy | | | | |
| Happy | .99 | .01 | .98 | .01 |
| Angry | .90 | .08 | .87 | .09 |
| Fear | .84 | .15 | .76 | .15 |
| Sad | .86 | .09 | .81 | .14 |

### 3.5. How Did Sleep Relate to Emotion Processing? (Hypothesis 3)

A full exploration of possible relationships between mood, affect and sleep and emotion performance was conducted using bivariate correlations for the full sample and each group and is presented in Appendix K. Note: these analyses were uncorrected for multiple comparisons but were investigated and are presented in an Appendix for exploratory purposes.

The results in the following sections is a presentation of the moderated regressions investigating the central hypothesis of group differences in the relationship between sleep and behavioural performance. These regressions included the full sample (n = 29) of good sleepers (n = 15) and individuals with insomnia symptoms (n = 14). Separate analyses were conducted for each moderation variable for each behavioural outcome and these analyses were uncorrected for multiple comparisons (see Methods section 2.6 for a list of sleep variables used as moderators). Only models with significant interactions are presented below, and significant interactions were followed by simple slopes tests between the measure of sleep and performance outcome

separately for each group (GS, INS) and at high (1 SD above the mean) and low (1 SD below the mean) levels of the moderator.

**3.5.1. The associations between group and sleep on the Face Categorization and Intensity Rating task performance.** Overall, significant interactions between Group and Beta activity and follow up simple slopes analysis found that greater Beta activity at frontal sites was associated with greater intensity ratings for emotional faces of Happy, Fearful and Sad (trending), for the insomnia group. For the good sleepers, greater Beta activity was associated with poorer accuracy identifying Happy faces, and lower intensity ratings for Happy, Angry, Fearful (trending) and Sad faces; for good sleepers, greater sleepiness levels were associated with poorer accuracy for Fearful faces, and less time in stage 3 (slow wave) sleep was associated with greater intensity ratings of Angry faces. These findings are reported in detail below.

The moderation model predicting accuracy for Happy faces on the Face Categorization and Intensity rating task was significant, $F(3,23) = 5.79$, $p = .004$, $R^2 = .103$. There was a significant interaction between Group and right-frontal Beta on accuracy for Happy faces, $b = .033$, $t = 2.83$, $p = .010$. Analysis of simple effects at levels of Beta power revealed that there was a trend for an association between high levels of right-frontal Beta and greater accuracy for Happy faces for the INS group compared to GS, $b = .01$, $t = 2.05$, $p = .052$. Simple slopes analyses for each group seperately revealed a significant negative relationship between right-frontal Beta and accuracy for Happy faces for good sleepers, $b = -.02$, $t = -3.99$, $p < .001$, but no significant relationship for the INS group, $b = .01$, $t = 1.04$, $p = .309$ (Figure 6).

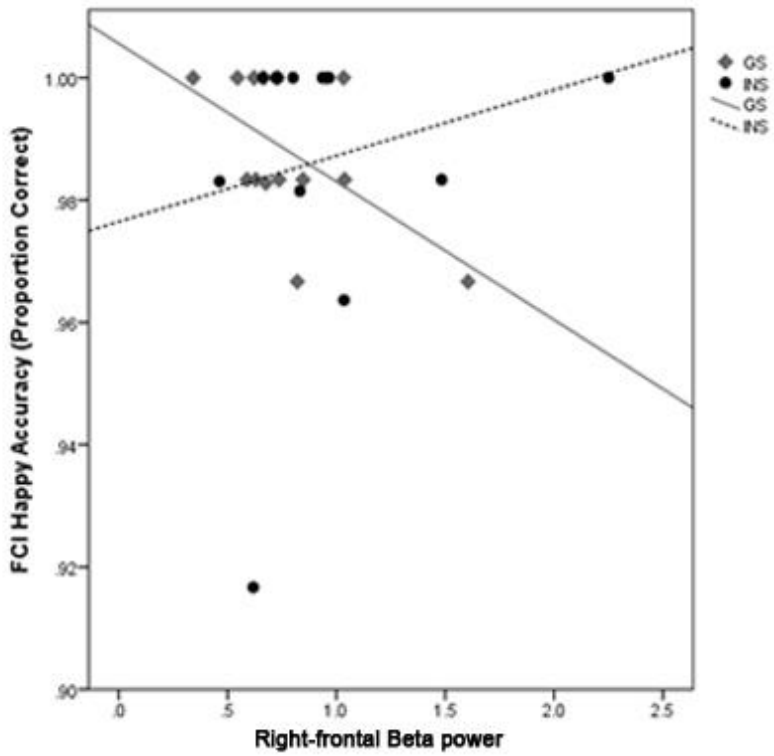


*Figure 6.* The correlation between right-frontal Beta power and Happy accuracy by Group on the Face Caterogization and Intensity Rating Task. A night of high levels of Beta activity was associated with poorer accuracy for good sleepers for happy faces.

The model predicting Happy intensity ratings on the Face Categorization & Intensity Rating task with Group and left-frontal Beta power was significant, $F(3,25) = 8.81$, $p < .001$, $R^2 = .19$. There was a significant interaction between Group and left-frontal Beta power over the night on Happy intensity ratings, $b = 1.61$, $t = 4.16$, $p < .001$. Simple effects at low and high levels of left-frontal Beta power revealed that a night of high levels of left-frontal Beta was associated with greater intensity ratings of Happy faces by the INS group compared to GS, $b = .55$, $t = 2.88$, $p = .008$ (Figure 7). Simple slopes at the level of Group revealed a significant negative relationship between left-frontal Beta and Happy intensity ratings for good sleepers, $b = -.47$, $t = -2.32$, $p = .029$, but a significant positive relationship for the INS group, $b = 1.13$, $t$

= .3.46, $p$ = .002. The model with Group and right-frontal Beta was also significant, $F(3,23)$ = 7.20, $p$ = .001, $R^2$ = .16, with a significant interaction between Group and right-frontal Beta power on intensity ratings for Happy faces, $b$ = 1.12, $t$ = 3.19, $p$ = .004. Analysis of the simple effects at levels of right-frontal Beta did not reveal any significant differences between groups in Happy intensity ratings. However, analysis of the simple effects for each Group revealed a significant relationship between greater right-frontal Beta and greater Happy intensity ratings for the INS group, $b$ = .76, $t$ = 4.22, $p$ < .001.

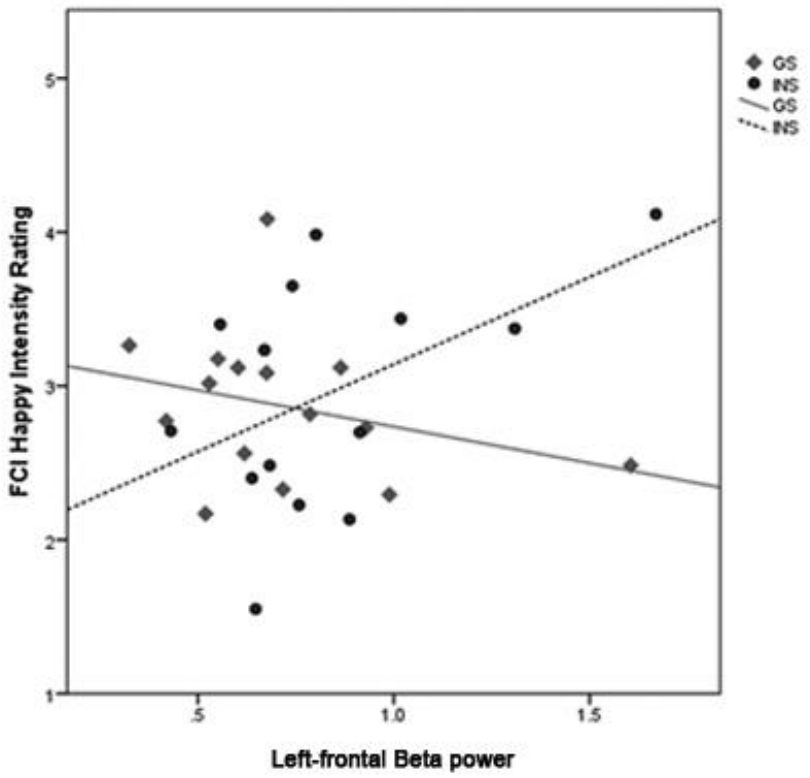


*Figure 7.* The correlation between left-frontal Beta power and Happy intensity ratings by Group on the Face Caterogization and Intensity Rating Task. A night of greater Beta activity was associated with greater intensity ratings for Happy faces for the insomnia group and lower intensity ratings for good sleepers.

The moderation model for Angry intensity ratings on the Face Categorization & Intensity Rating Task employing Group and right-frontal Beta as predictors was significant, $F(3,23) = 5.50$, $p = .005$, $R^2 = .19$. There was a significant interaction between Group and right-frontal Beta power on intensity ratings of Angry faces, $b = .98$, $t = 3.15$, $p = .004$. Simple effects analysis at levels of right-frontal Beta power revealed that high levels of right-frontal Beta activity was associated with greater intensity ratings by the INS group compared to GS, $b = .43$, $t = 2.56$, $p = .017$. Simple slopes analysis at level of Groups revealed a significant relationship between greater right-frontal Beta and lower Angry intensity ratings for good sleepers, $b = -.99$, $t = -3.81$, $p < .001$, but no significant relationship was found for the INS group, $b = -.01$, $t = -.08$, $p = .941$ (Figure 8).

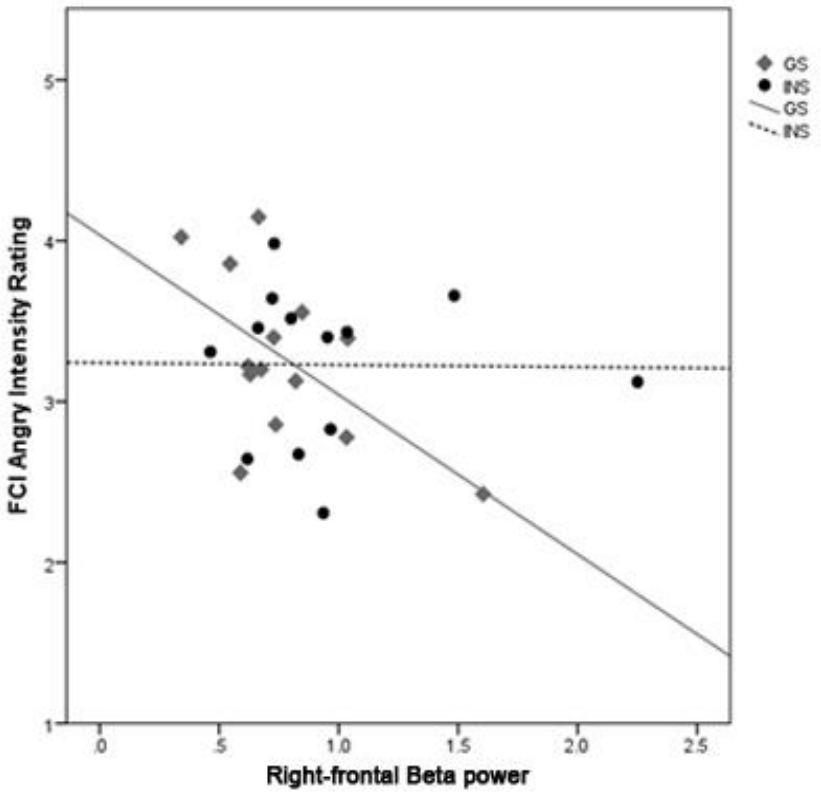


*Figure 8*. The correlation between right-frontal Beta power and Angry intensity ratings by Group on the Face Caterogization and Intensity Rating Task. A night of greater Beta activity was associated with lower intensity ratings for Angry faces for the good sleeper group.

The model predicting Fearful face intensity ratings with Group and right-frontal Beta was also significant, $F(3,23) = 14.29$, $p < .001$, $R^2 = .20$. There was a significant interaction between Group and right-frontal Beta on intensity ratings for Fearful faces, $b = 1.09$, $t = 2.97$, $p = .007$. Simple effects at levels of right-frontal Beta revealed a night of low levels of Beta activity was associated with lower intensity ratings for the INS group compared to GS, $b = -.47$, $t = -2.13$, $p = .045$, and there was a trend for high levels of right-frontal Beta to be associated with greater intensity ratings by the INS group compared to GS, $b = .37$, $t = 1.79$, $p = .087$. Analysis of simple effects for each Group found a significant positive relationship between right-frontal Beta and Fear intensity ratings for the INS group, $b = .45$, $t = 6.12$, $p < .001$, and a trend for a negative relationship for good sleepers, $b = -.64$, $t = -1.77$, $p = .089$ (Figure 9).

For predicting Fearful intensity ratings there was also a significant regression model with Group and left-frontal Beta power, $F(3,25) = 4.27$, $p = .015$, $R^2 = .15$, with a significant interaction, $b = .96$, $t = 2.33$, $p < .028$. No significant simple effects were observed at high and low levels of left-frontal Beta, but analysis of simple effects for each group revealed a significant relationship between greater left-frontal Beta and greater Fearful intensity ratings for the INS group, $b = .67$, $t = 3.40$, $p = .002$, but no relationship between these variables for good sleepers, $b = -31$, $t = -.84$, $p = .411$.

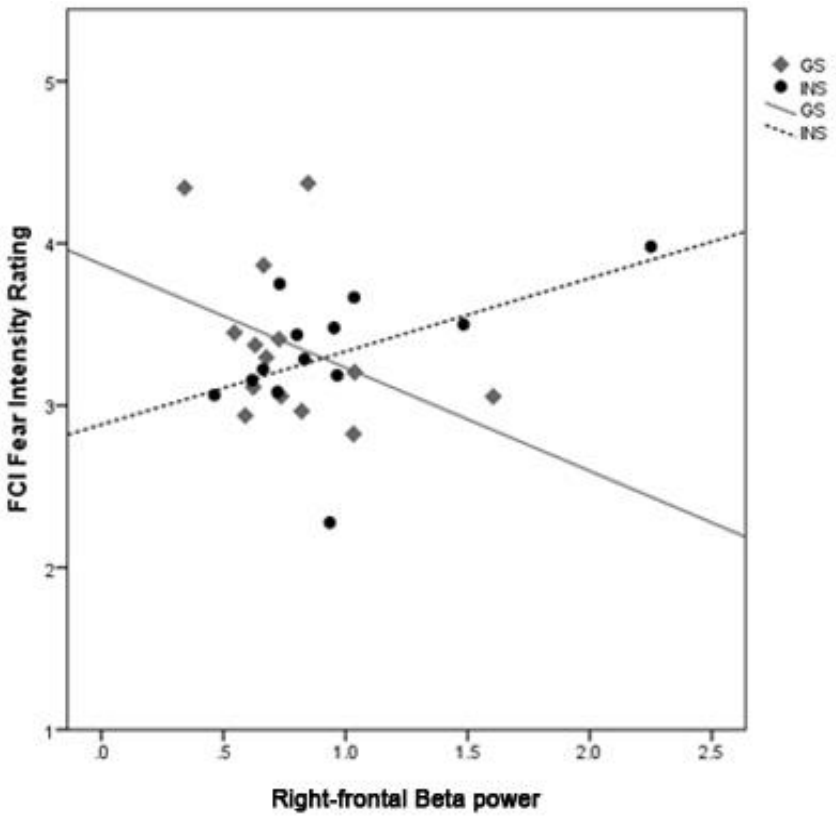


*Figure 9*. The correlation between right-frontal Beta power and Fear intensity ratings by Group on the Face Caterogization and Intensity Rating Task. Greater right-frontal Beta was related to greater intensity ratings for Fearful faces for the insomnia group.

The moderation model predicting Sad intensity ratings on the Face Categorization & Intensity Rating Task was also significant, $F(3,23) = 5.05$, $p = .008$, $R^2 = .20$, with a significant interaction between Group and right-frontal Beta, $b = 1.40$, $t = 3.65$, $p = .001$. Simple slopes analysis at low and high levels of right-frontal Beta power revealed that a night of high levels of right-frontal Beta activity was associated with greater intensity ratings for Sad faces for the INS group compared to GS, $b = .69$, $t = 2.98$, $p = .007$. Simple slopes analysis at levels of Group revealed a significant relationship between greater right-frontal Beta and lower Sad intensity ratings for good sleepers, $b = -.98$, $t = -3.03$, $p = .006$, but a positive relationship between right-

frontal Beta and Sad intensity ratings approaching significance for the insomnia group, $b$ = .42, $t$ = 2.04, $p$ = .053 (Figure 10).

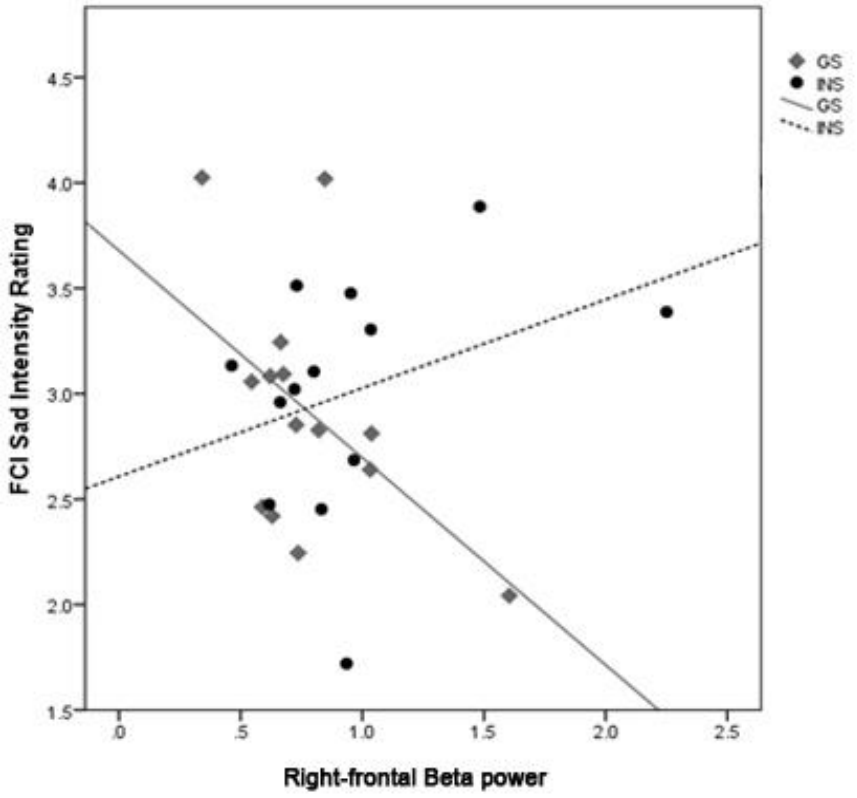


*Figure 10*. The correlation between right-frontal Beta and Sad intensity ratings by Group on the Face Caterogization and Intensity Rating Task. A night of high levels of Beta activity was associated with a trend for greater intensity ratings for Sad faces for the INS group.

The model predicting accuracy for Fearful faces on the Face Categorization & Intensity Rating task with scores on the Stanford Sleepiness Scale and Group was significant, $F(3,25)$ = 4.23, $p$ = .015, $R^2$ = .30. There was a significant interaction between Group and scores on the Stanford Sleepiness Scale on accuracy for Fearful faces, $b$ = .15, $t$ = 2.89, $p$ = .008. Simple effects at high and low levels of sleepiness revealed that low levels of sleepiness was associated with significantly lower accuracy identifying Fearful faces for the INS group compared to GS, $b$ = -.13, $t$ = -2.18, $p$ = .039. Simple effects at the levels of Group found that sleepiness scores were

negatively associated with Fearful accuracy for good sleepers, $b$ = -.13, $t$ = -3.08, $p$ = .005, but not significantly associated in the INS group, $b$ = .01, $t$ = .55, $p$ = .590 (Figure 11).

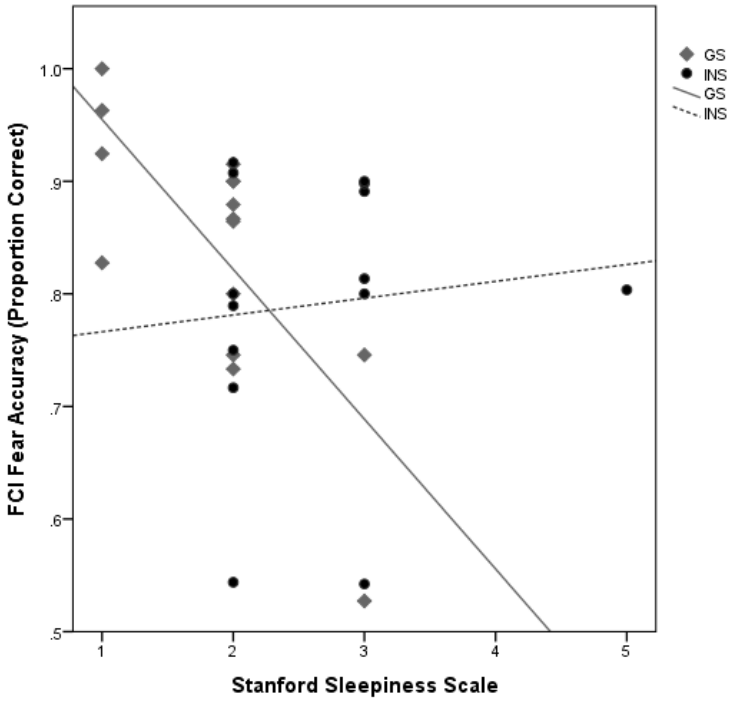


*Figure 11*. The correlation between Stanford Sleepiness Scale scores and Fear accuracy by Group on the Face Catergorization and Intensity Rating Task. Greater sleepiness during task performance related to poorer accuracy for fearful faces for good sleepers.

There was a significant moderation model with time spent in SWS sleep and Group for predicting Angry intensity ratings on the Face Categorization and Intensity Rating Task, $F$(3,25) = 3.70, $p$ = .025, $R^2$ = .17. There was a significant interaction between Group and time in SWS sleep on intensity ratings of Angry faces, $b$ = .01, $t$ = 2.97, $p$ = .007. Analysis of the simple effects at low and high levels of time in SWS revealed an association between a low amount of time spent in SWS and lower intensity ratings of Angry faces for the INS group compared to GS, $b$ = -.44, $t$ = -2.16, $p$ = .041. Simple slopes analysis for each Group revealed a significant

negative relationship between time spent in SWS sleep and Angry face intensity ratings for good sleepers, $b$ = -.01, $t$ = -2.99, $p$ = .006, but no relationship was detected for the INS group, $b$ = .004, $t$ = 1.39, $p$ = .177 (Figure 12).

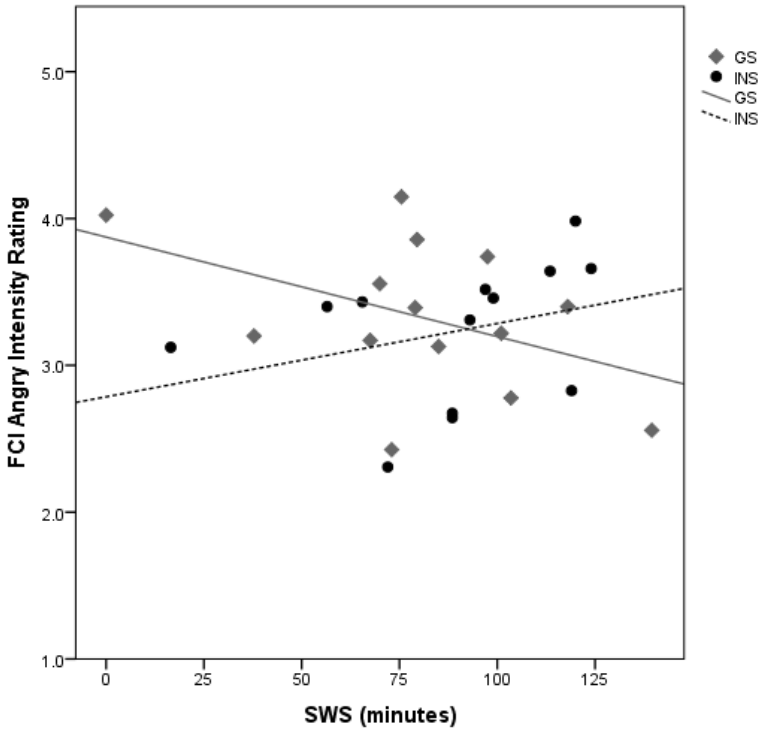


*Figure 12*. The correlation between time in slow wave sleep and Angry intensity ratings by Group on the Face Caterogization and Intensity Rating Task. A night of less time spent in SWS was associated with greater Angry intensity ratings for good sleepers.

### 3.5.2. The associations between group and sleep on emotional Stroop performance.

Two significant models and interactions were found for the Emotional Stroop Task, revealing that for good sleepers, but not individuals with insomnia symptoms, greater Beta power at the right-frontal channel during sleep was related to greater interference for response times on angry trials and poorer accuracy for happy faces on incongruent trials. These findings are reported in full detail below.

A moderation analyses found a significant regression model for Group and right-frontal Beta levels on the interference effect (congruent – incongruent trial response time) for Angry trials on the Emotional Stroop Task, $F(3,23) = 9.88$, $p < .001$, $R^2 = .34$. There was significant interaction between Group and right-frontal Beta, $b = -283.27$, $t = -4.38$, $p < .001$. Simple effects analysis at low and high levels of right-frontal Beta revealed that for those with a night of high levels of right-frontal Beta activity, the INS group had significantly less interference for Angry trials than GS, $b = -116.33$, $t = -3.29$, $p = .003$, and at low levels of right-frontal Beta, the INS group had significantly more interference than the GS, $b = 104.42$, $t = 2.30$, $p = .031$. Simple slopes analysis at the levels of Group revealed a significant positive correlation between right-frontal Beta and Angry interference scores for the good sleepers, $b = 224.40$, $t = 5.31$, $p < .001$, but no significant relationship for the INS group, $b = -58.87$, $t = -1.20$, $p = .242$ (Figure 13).

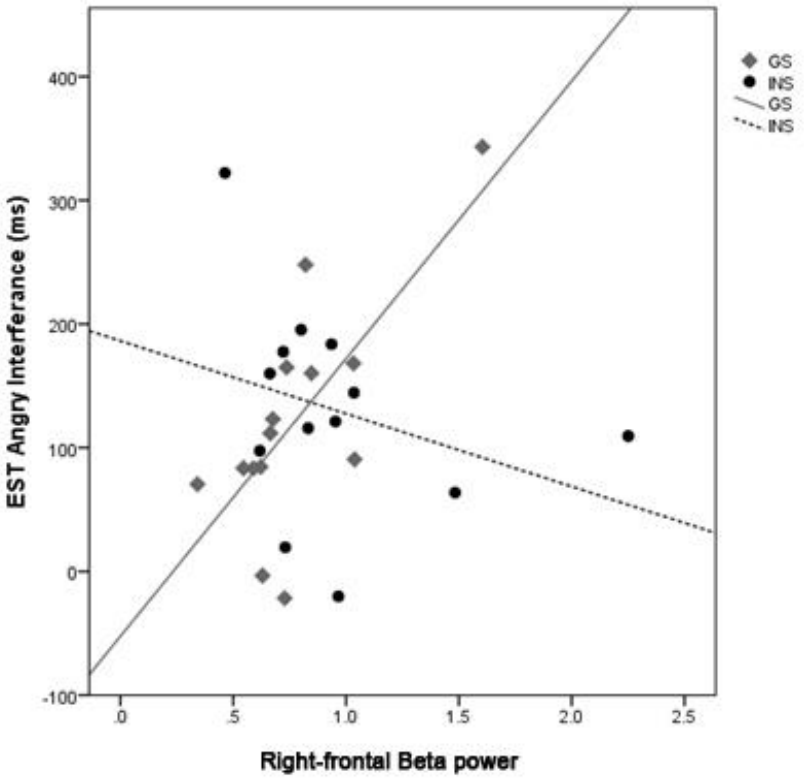


*Figure 13.* The correlation between right-frontal Beta power and the size of the interference effect on response time for Angry trials for each group on the Emotional Stroop task. A night of

greater Beta activity was associated with a greater intereference effect for Angry trials for the good sleeper group.

The regression model when entering Group and right-frontal Beta as predictors for accuracy on incongruent Happy trials was significant, $F(3,23) = 6.22$, $p = .003$, $R^2 = .31$. There was a significant interaction between Group and right-frontal Beta on accuracy for incongruent Happy trials, $b = .03$, $t = 3.00$, $p = .006$. Simple slopes analysis at high and low levels of right-frontal Beta revealed that a night of elevated right-frontal Beta was associated with better accuracy for the INS group, $b = .07$, $t = 3.92$, $p < .001$. Simple slopes analysis at levels of Group revealed a significant relationship between greater right-frontal Beta power and poorer accuracy for Happy faces on incongruent trials for good sleepers, $b = -.08$, $t = -3.77$, $p = .001$, but no relationship was found for the INS group, $b = .00$, $t = .01$, $p = .996$ (Figure 14).

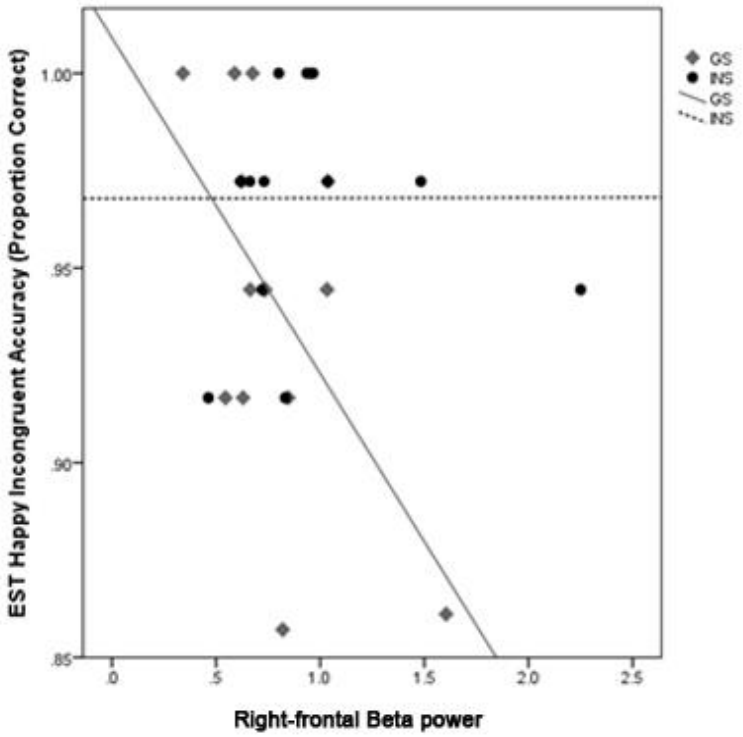

*Figure 14*. The correlation between right-frontal Beta power and accuracy for incongruent Happy trials for each group on the Emotional Stroop task. A night of greater Beta activity was associated with worse accuracy for happy faces on incongruent trials for the good sleeper group.

## 4. Discussion

The current thesis was designed to investigate emotion processing differences in waking functioning for individuals with insomnia symptoms compared to good sleeper controls. Several subjective, objective and quantitative EEG measures of sleep were employed to examine sleep differences in insomnia and good sleepers, as well as to examine the relationship between sleep and daytime socioemotional stimulus processing. Healthy good sleepers and individuals meeting the DSM-V criteria of insomnia (American Psychiatric Association, 2013) were recruited and underwent recording of their sleep for two nights at home using ambulatory PSG equipment. Participants completed an afternoon of performance testing including subjective ratings of mood and sleepiness, and tasks measuring psychomotor vigilance and emotion processing performance. The insomnia group subjectively reported shorter sleep times overall. Findings from the study did not offer support for differences in sleep architecture, quantitative EEG measures of sleep, or emotion processing between the INS group and good sleepers generally. However, investigation of the insomnia individuals with an objective night of poor sleep showed some support for differences from good sleepers in each of these areas. Specifically, the insomnia group with a night of poor sleep spent less time spent in Stage 2, and REM, and also showed trending support for elevated Beta and Sigma EEG power throughout the night. Additionally, this subgroup of insomnia with poor sleep showed some evidence in the expected direction of poorer accuracy identifying facial expressions. Investigation of the relationship

between sleep and emotion processing performance in the full sample of individuals with insomnia revealed evidence for a relationship between greater Beta EEG power during sleep and greater sensitivity to the intensity of happy, fearful and sad emotional face expressions the following day. In contrast, greater Beta EEG power during sleep for good sleepers was associated with poorer accuracy identifying happy faces, greater interference for angry faces, and a blunted sensitivity for happy, angry, fearful and sad faces.

### 4.1. The Sample

The final sample was small and heterogeneous in nature in that there were mixed types of insomnia subtypes (sleep onset versus sleep maintenance difficulties) and we captured both good and poor nights in the insomnia group. A large portion of good sleepers (nine individuals) were removed due to non-compliance with sleep; it was not anticipated that good sleepers would restrict their sleep on nights of recording, as they were instructed to get a normal night's sleep and were recruited based on self-reports of normative sleeping patterns. We also set out to capture poor nights of sleep in insomnia in order to look at the effects of poor sleep in insomnia on emotion processing, but captured a nearly equal number of good and poor nights of sleep in insomnia, which is a common problem in insomnia research with polysomnography measurement of sleep (e.g., Frankel et al., 1976; Newell, Mairesse, Verbanck & Neu, 2012; Reite et al., 1995; Spinweber, Johnson & Chin, 1985). It is also important to note that only six of the 14 insomnia participants reported clinical levels of insomnia symptomology on the Insomnia Severity Index. In conclusion, capturing a small sample, with a mixed and predominantly sub-clinical insomnia group likely affected power to find the expected group differences in gross sleep architecture as well as emotion processing performance. These limitations were partially mitigated by additional investigation of sleep and emotion processing in the subgroup of

individuals with insomnia symptoms with a night of objectively poor sleep. Given these limitations and especially the size of the sample, interpretations are offered with caution. It is expected that more robust findings will be found with a larger and more homogenous sample. Nevertheless, little research has been conducted to answer the questions of whether individuals with insomnia have emotion processing difficulties, or the degree to which sleep might impact next-day emotion processing and functioning in insomnia. The results of the current study are intended to inform future directions in research on these topics.

### 4.2. Sleep Differences in Insomnia and Good Sleepers

Except for diary reports of subjectively less total sleep time, no significant differences between good sleepers and individuals with insomnia symptoms were observed in the full sample of individuals with insomnia symptoms. The finding that individuals with insomnia symptoms subjectively reported less total sleep time than good sleepers in their sleep diaries, despite no observable differences in polysomnography (PSG) measure of total sleep time, was consistent with the extant literature, as it has been frequently reported that individuals with insomnia report poor sleep quality despite no detectable differences in objective PSG measurement (e.g., Frankel et al., 1976; Reite et al., Spinweber, Johnson & Chin, 1985). Subjective reports of poor sleep may therefore be capturing sleep debt from consecutive nights that are generally poor, or aspects of sleep not reflected in PSG. A lack of support for a difference in objective total sleep time and sleep architecture despite subjective reports of sleep may also be attributed to the inclusion of individuals with a good night of sleep in the larger insomnia sample. Indeed, when examining the subset of insomnia individuals with a night of poor sleep, differences from good sleepers were observed; they had less total sleep time, less time in Stage 2 sleep, less time in REM, and a smaller proportion of the overall night in REM

sleep. Interestingly, there was no significant difference in the amount of time spent in slow wave sleep (Stage 3) as expected based on the findings from Baglioni and colleagues (2014). Instead, the average 70 minutes less of total sleep experienced by the poor sleeper insomnia group was related to a reduction in Stage 2 sleep and REM. Importantly, slow wave sleep occurs predominantly in the beginning third of the night, there is a larger portion of Stage 2 sleep for each subsequent sleep cycle, and, episodes of REM most frequently occur in the last third of the night (Carskadon & Dement, 2017). Therefore, the group differences may be largely accounted for by the extra cycles of sleep obtained by the good sleeper group because they slept longer.

The reduction in time in REM was consistent with group differences observed in the meta-analysis of PSG measurement of insomnia sleep by Baglioni and colleagues (2014), who suggest that REM deficits may be linked to emotion processing differences as well. Research on REM sleep has shown that it plays a role in both reactivity in response to emotional information as well as the consolidation of emotional memory (see Goldstein & Walker, 2014 for a review). In the current study, only response time to angry faces on the Face Categorization and Intensity Rating Task significantly related to time in REM, and only for the insomnia group (Appendix K, Table 24). REM has been shown to serve a role in restoring reactivity to threatening angry and fearful faces (Gujar, McDonald, Nishida & Walker, 2011), thus a lack of REM may contribute to abnormal processing of angry faces. However, in the current study, REM only related to response time and not intensity ratings or accuracy for angry faces. And, less total sleep time and less time in NREM was also related to a slowing in angry face detection for the insomnia group (Appendix K, Tables 20 and 24). Thus, the relationship with REM could also be the artifact of individuals with insomnia symptoms requiring longer to detect angry faces due to the employment of poor visual identification strategies specifically for angry faces (Zhang et al.,

2018), and further suggests the possibly that poor visual identification of angry faces may be a property of poor sleep in insomnia due to similar relations with less REM, total sleep time and NREM time.

For the insomnia group overall, we observed a large degree of variability in all objective and subjective measures of sleep architecture, including but not limited to important markers of insomnia sleep such as total sleep time, time it took to fall asleep, and time spent awake throughout the night. Examination of individual characteristics of sleep in the insomnia sample indicated that only two individuals had trouble staying asleep (>30 min WASO), and only one had difficulty falling and staying asleep (>30 min SOL and WASO). Therefore, sleep impairment was mostly seen in sleep durations. It is possible that the shorter sleep reported by the insomnia group was due to the study protocol where they were instructed to get out of bed no later than 8:00 in order to control for hours awake for performance testing, but under normal conditions they may have slept longer to compensate for a delayed sleep initiation. A great amount of variability for the full insomnia group was also observed in the objective-subjective discrepancy of total sleep time, the time it took to fall asleep, and the amount of time spent awake throughout, suggesting that the sample included those with misperceptions of sleep as well. Upon further examination of the individual characteristics of the insomnia sample, four individuals (three in the good night of sleep insomnia subgroup) underestimated their total sleep time by greater than 30 minutes, while five (four in the poor sleep insomnia subgroup) overestimated their total sleep time by more than 30 minutes. In comparison, two good sleepers overestimated their total sleep time by more than 30 minutes, and only one good sleeper overestimated the time spent awake throughout the night by more than 30 minutes. Thus, over half the insomnia sample appeared to have misperceptions about their sleep duration, while good

sleepers appeared to be generally accurate, which is consistent with past literature (e.g., Edinger & Krystal, 2003). Unfortunately, due to the nature of the at-home PSG recording (a lack of control and ability to determine whether participants remained in bed and tried to sleep during recording), a reliable measure of sleep efficiency could not be gathered. And therefore, we could not determine overall impairment in sleep efficiency. In conclusion, no predominant pattern of sleep disruption was observed in the insomnia group, therefore it appears that the insomnia sample was mixed in the extent and types of sleep disruptions as well as in good and poor nights of sleep, which may have ultimately contributed along with the sample size to a lack of findings in subjective and objective sleep differences from good sleepers.

Beyond subjective and objective reports of sleep architecture it was predicted that the insomnia group would have shallower sleep, indicated by a novel measure of sleep-depth, the Odds Ratio Product. The current study failed to find any differences in ORP parameters for both the full insomnia group and for the subset that had a night of poor sleep. There was also no significant difference in markers of sleep depth or arousability from sleep from the PSG and sleep diary data, including no differences in the number of awakenings, number of arousals, time spent awake throughout the night, time spent in slow wave sleep, alongside no difference in diary reports of time spent awake throughout the night or number of awakenings. These findings suggest that for this study sample, insomnia was not associated with shallow sleep. It is important to consider that the lack of findings may again be attributable to a heterogeneous and predominantly subclinical sample. The ORP measure may also be more suitable to characterizing the sleep of individuals with insomnia that have been specifically identified to have difficulty remaining and/or maintaining sleep and whom have frequent awakenings (i.e. issues with sleep depth and arousability). In the present study, only three individuals with insomnia symptoms

(two with a night of poor sleep) had difficulties remaining asleep (i.e., >30 minutes WASO). Additionally, the ORP was initially developed and validated primarily on PSG recordings of patients with sleep apnea (Younes et al., 2015), therefore it may be particularly calibrated to detect or anticipate arousals associated with hypopnea events and not as accurately detect other forms of sleep disruption. Further testing on appropriate samples of individuals with insomnia symptoms with complaints of shallow non-restorative sleep and/or repeated awakenings throughout the night is required to determine the validity of the ORP for assessing the extent of shallow sleep in relevant insomnia populations.

For EEG power during sleep, no differences between good sleepers and individuals with insomnia were observed in the full sample. However, the subsample of individuals with insomnia symptoms that had poor sleep showed a trend for greater Sigma and Beta EEG activity across the night compared good sleepers. Higher Sigma and Beta activity is consistent with the literature of power spectral analyses of insomnia sleep (Buysse et al., 2008; Fernandez-Mendoza et al., 2016; Freedman, 1986; Krystal et al., 2002; Merica, Blois, & Gaillard, 1998; Perlis et al. 2001; Riedner et al., 2016; Spiegelhalder et al., 2012). The fact that trending support for elevated Beta and Sigma power during sleep was found only with the individuals with insomnia and a night of poor sleep offers some evidence for the idea that increased Sigma and Beta may be a property of a night of objectively impaired sleep for individuals with insomnia symptoms. Possible evidence for the conclusion that a hallmark of objectively disrupted sleep in insomnia is represented by elevated Sigma and Beta is suggested and elaborated on by Spiegelhalder and colleagues (2015). They found both increased Sigma and Beta activity in an insomnia sample and suggested that the presence of both increased Sigma power, which is thought to represent the activity of sleep stability mechanisms (Dang-Vu, Schabus, Desseilles, Sterpenich, Bonjean &

Maquet, 2010), and Beta power, which is thought to represent sensorimotor and cognitive processing (Engel & Fries, 2010), represents "further evidence for a simultaneous activation of sleep-promoting and wake-promoting areas in [insomnia], a pattern that has been previously found in a rat model of insomnia (Cano et al., 2008)." Fernandez-Mendoza and colleagues (2016) found that in adolescent insomnia groups, NREM Beta levels were highest in those with short-sleep durations, and the short-sleep insomnia group and not the normal-sleep insomnia group also had greater activation in neurological regions related to stress and the regulation of arousal and sleep. Thus, elevated Sigma and Beta power in insomnia may represent a disruption in sleep-regulation leading to an increase in information processing and/or arousability for this group. The trending findings in the small subgroup of the present study offer some tentative evidence that this type of sleep disruption is prominent in those with insomnia and a night of poor sleep, but ultimately, more investigation with larger and clinically significant insomnia populations are required.

### 4.3. Behavioural Performance for the Insomnia Group Compared to Good Sleepers

Despite a recent observation of poorer accuracy identifying emotional faces in insomnia (Cronlein et al., 2016), the current study did not support these findings. However, the individuals with insomnia and a night of poor sleep before testing had some evidence for poorer accuracy identifying facial expressions, suggesting the null findings here may also result from the small sample size. Specifically, although not significant or trending, we observed that the insomnia group with a night of poor sleep had evidence for accuracy deficits expected direction (lower than good sleepers) on the Emotional Stroop task. We also observed a trend in the expected direction for poorer accuracy overall on the Face Categorization and Intensity Rating task, so the null effects here may also result from the small sample size. Cronlein and colleagues (2016)

found accuracy deficits for happy and sad faces with a larger sample of individuals with insomnia (25 insomnia patients), but importantly found the same deficits in accuracy for individuals with sleep apnea (who suffer from chronic poor sleep) as well within the same study. Research on the effects of experimental sleep deprivation has also found accuracy deficits for emotional faces after a night of total or partial sleep deprivation (Cote et al. 2014; Lustig, Stoakley, MacDonald, Geniole, McCormick & Cote, 2018, Killgore et al., 2017; Maccari et al., 2014; Van der Helm, Gujar & Walker, 2010). The effects of sleep loss on accurately identifying facial emotions could be related daytime dysfunction of the emotion circuit seen in brain imaging research after a night of sleep loss (Yoo et al., 2007). Specifically, after a night of total sleep deprivation, individuals have been reported to have greater amygdala reactivity to "increasingly negative picture stimuli" but not neutral images, as well as a functional disconnect between the amygdala and the medial prefrontal cortex (Yoo et al., 2007). Baglioni and colleagues (2014) also found amygdala activity differences for individuals with insomnia in response to negative images, where less slow wave sleep and REM sleep related to greater amygdala reactivity for this group, but also found that for all participants (good sleepers and individuals with insomnia), less total sleep time and lower sleep efficiency were both related to greater amygdala reactivity. The amygdala has been found to have direct and indirect modulation of areas of face and emotion processing (see Haxby & Gobbini, 2000 and Vuilleumier & Pourtois, 2007 for a review). Thus, the provisional evidence for poorer accuracy detecting emotional face expressions after a night of poor sleep in insomnia in the current sample could provide some further evidence for a conclusion that sleep loss or poor sleep in general leads to negative consequences for identifying emotional face expressions, possibly through dysfunction of the amygdala and its associated networks. As individuals with insomnia chronically suffer from insufficient sleep,

and, accuracy identifying emotionally expressive faces appears to be compromised by sleep loss, these effects may be a major contributing factor to the reports of social impairment for this group (Carey et al., 2005, Kyle et al., 2013, Silva et al., 1996). And, it is possible that chronic nights of poor or insufficient sleep lead to further exacerbation of these functional impairments; further investigation is required.

For intensity judgements of emotional faces, no differences in intensity ratings of emotional faces were found for the insomnia group in the present study in both the full insomnia group and for those with a night of poor sleep. Kyle and colleagues (2014) found that their insomnia sample had lower intensity ratings for faces of sadness and fear expressions, but they also had greater anxiety and depression scores. Importantly, they also found that both greater anxiety and depression levels, but not poor sleep, were significantly correlated with reduced intensity ratings. Individuals with comorbid anxiety and depression have been reported to have a reduced sensitivity to emotion faces, as they require greater intensities of expressions to identify happy and sad faces (Berg, Ballard, Luckenbaught, Nugent, Ionescu, & Zarate, 2016). Individuals with high levels of trait anxiety have also found to have a reduction in cognitive processing of fearful faces (Holmes, Nielsen, & Green, 2008), and, depression (in children) has been linked to a blunted amygdala response to fearful faces as well (Thomas et al., 2001). These findings suggest that elevated depression and anxiety may alter salience sensitivity to emotionally expressive faces, especially of sadness and fear. As insomnia has been found to be a risk factor for comorbid depression and anxiety (Neckelmann, Mykletun, & Dahl, 2007), mood disorders comorbid with insomnia may contribute to socioemotional complaints observed in the population. The current study specifically recruited participants who had no signs of affective disturbance and did not find any evidence for differences in state or trait measures of depression

or anxiety for individuals with insomnia symptoms compared to good sleepers, and therefore the lack of observed differences in intensity ratings for individuals with insomnia symptoms may be largely attributed to the absence of affective disturbance in the sample and/or possibly to the issues with the sample size.

For the Emotional Stroop task, it was predicted that individuals with insomnia symptoms would have poorer inhibitory control than good sleeper controls (i.e., slower response times and reduced accuracy for incongruent trials compared to congruent trials). A consistent slowing of response time and reduced accuracy for all participants when comparing incongruent trials to congruent trials validates that the task was effective in generating cognitive interference requiring inhibitory control for supressing the distracting emotion information. The study failed to find evidence for the hypothesized greater interference for accuracy or response time for individuals with insomnia symptoms overall, as well as for the insomnia subgroup with a night of objectively poor sleep. A recent meta-analysis of 13 studies of inhibitory control in insomnia found a small to moderate slowing in reaction times but no differences in accuracy for this population (Ballesio, Aquino, Kyle, Ferlazzo & Lombardo, 2019). Only six of the 13 studies found significant differences between individuals with insomnia and healthy sleeper controls, with larger effects for insomnia groups that had poorer objective total sleep time and sleep efficiency (Ballesio et al., 2019). While these studies did not employ inhibitory control tasks with emotion distractors or stimuli, it alludes to the possibility that there is only a marginally small deficit in inhibitory control for insomnia groups due to sleep loss. Given that the insomnia sample in the current study was primarily subclinical in symptomology and small, it is possible that the effects require larger samples to identify, and/or, that the extent or types of sleep

impairment observed in the study's sample were not sufficient to impact inhibitory control. Additional research with larger clinical populations is required.

### 4.4. Hyperarousal was Associated with Greater Sensitivity to Socioemotional Face Stimuli for Individuals with Insomnia Symptoms

The examination between sleep and emotion processing found evidence for an association between greater Beta power during sleep and greater sensitivity for happy, fearful, and sad (trending) faces for individuals with insomnia symptoms. In contrast, for the good sleeper group, an association between greater Beta power and poorer accuracy identifying happy faces (both tasks), more interference in response time for distractors when identifying angry faces, and lower sensitivity for happy, angry, fearful (trending) and sad faces were observed. For good sleepers but not individuals with insomnia, greater sleepiness levels were associated with poorer accuracy identifying fearful faces, and, less time in slow wave sleep was associated with greater angry intensity ratings. These findings were based on multiple, uncorrected regressions with a small sample size and therefore are interpreted with caution. However, the diverging directions of these associations suggest the possibility that a night of hyperarousal is associated with alterations in the salience processing of emotional face expressions for individuals with insomnia, but in contrast both blunts sensitivity and leads to emotion processing accuracy deficits in good sleepers. This points to the possibility for a potential maladaptation or alteration in socioemotional salience processing directly linked to neurophysiological activity throughout sleep for individuals with insomnia.

Possible explanations for these contrasting findings are 1) the source (i.e., neurological regions) of elevated neurophysiological activity during hyperarousal may differ for good sleepers and individuals with insomnia, 2) the chronicity of poor sleep in insomnia may play a role, and

3) maladaptation in emotion-reactivity during wake in insomnia may result in both greater sensitivities to emotional faces and a predisposition for hyperaroused sleep. Neurophysiological examination of both GABA and regional differences in activity in sleep in insomnia provide evidence that hyperarousal in insomnia may be specific to altered activity in emotion processing regions. GABA is the primary neurotransmitter related to inhibition of the CNS and plays a critical role in sleep initiation, sleep onset and sleep maintenance (Gottesmann, 2002). Critically, several studies have identified lower GABA levels overall in insomnia, but one study specifically identified lower levels of morning GABA in the anterior cingulate cortex which is a key structure in emotion information processing including the processing of emotion faces (Winkelman et al., 2008; Plante, Jensen, Schoerning & Winkkelman, 2012; Klump, Post, Angstadt, Fitzgerald & Phan, 2013). Research examining neurophysiological activity differences in insomnia sleep has discovered smaller differences in activity between wake and sleep in regions of affect and face processing, including the left fusiform gyrus and posterior cingulate cortex (Kay et al., 2016). Further evidence is provided by Nozfinger and colleagues (2006) who found that greater objective or subjective time spent awake throughout the night (i.e. difficulties with sleep maintenance and arousability) was associated with increased activity in the anterior cingulate cortex, and regions associated with emotional awareness, anxiousness and fear (temporal poles). Event-related potential analysis of insomnia sleep has revealed markers of sustained/uninhibited information processing (e.g., Ceklic & Bastien, 2015). Thus, hyperarousal may represent either the continuous activation or a failure to inhibit the activation of emotional information processing regions during sleep in insomnia, and this may ultimately lead to alterations in the functioning of salience processing during wake.

It is also possible that the chronicity and regularity of poor sleep and/or hyperarousal in insomnia might be an important contributing factor to emotion processing differences in insomnia. Some evidence suggests that multiple nights of poor sleep is related to greater waking impairment in cognitive functioning (e.g. Fortier-Brochu & Morin, 2014; Hansen, Layon, Riedy & Van Dongen, 2019). Unfortunately, the effects of chronic nights of poor sleep on emotion processing has not yet been investigated. And, there has not been longitudinal examination of the stability of hyperarousal in insomnia (e.g., whether it occurs consistently across nights of poor sleep) and the impact that may have on waking functioning). However, several findings of hyperarousal during insomnia sleep (Buysse et al., 2008; Fernandez-Mendoza et al., 2016; Freedman, 1986; Krystal et al., 2002; Merica, Blois, & Gaillard, 1998; Perlis et al. 2001; Riedner et al., 2016; Spiegelhalder et al., 2012) suggest it could be a consistent pathological quality of this clinical population. It has been suggested that sleep plays an integral role in restoring or resetting emotional circuits to correctly react and process emotional information the following day (van der Helm & Walker, 2009), thus repeated nights of poor sleep and/or neurophysiological engagement (hyperarousal insomnia) might disrupt the restorative properties of sleep, and chronic disruption could lead to structural/functional changes (e.g. Zhao et al., 2015, Kay et al., 2016) and to abnormal or maladaptive sensitivities to emotional information.

What is also not yet clear is whether hyperarousal during sleep leads to greater socioemotional sensitivity during waking functioning, or that socioemotionally sensitive or reactive individuals are predisposed to nights of hyperarousal. Kalmbach et al., (2018) suggest that insomnia may be a condition of dysregulated cognitive-emotion reactivity to stress, ultimately leading to increased reactivity to sleep and thereby longer periods of sleep onset, greater pre-sleep ruminations and worry, and sleep disruption (i.e., insomnia symptomology).

Intervention with stimulus control and relaxation training for individuals with insomnia has been shown to lead to a reduction in elevated Beta EEG activity at sleep-onset, supporting the notion that elevated Beta may represent maladaptive cognitive-emotion reactivity (Jacobs, Benson, & Friedman, 1993). It is possible that dysregulated or maladaptive cognitive-emotion reactivity in insomnia extends beyond the processing of stressors and negatively conditioned sleep stimuli into the processing of emotional stimuli such as faces as well, which are important cues for socioemotional functioning (Blair, 2002; Hess & Fischer, 2013; Marsh & Blair, 2008). A link between hyperarousal and altered waking cognitive-emotion reactivity might be drawn out by EEG examination during wake; increased physiological and subjective arousal in reaction to sleep and non-sleep related emotion stimuli reported in individuals with insomnia (Baglioni et al., 2010) has already demonstrated an increase of reactivity to emotion stimuli as a potential feature of this clinical group, but has not been linked to hyperarousal. If hyperarousal in insomnia manifests as a condition of altered cognitive-emotion reactivity during wake, then inconsistent findings in waking hyperarousal (see Kay & Buysse, 2017, for an overview) may be due to physiological measures predominantly taken while research participants are in resting states rather than in response to emotional stimulation and/or task engagement.

For the good sleeper group, greater Beta EEG activity was associated with blunted emotion processing: poorer accuracy identifying happy faces, more interference by emotional distractors identifying angry faces, and lower intensity ratings of emotional faces. It is possible that high levels of Beta activity for good sleepers represents a rare night of light, non-restorative sleep (e.g., experiencing a night of light/disrupted sleep due environmental factors such as the sleep-recording equipment, or temperatures, noise, bed-partner activity, novel sleeping environment, dream content, etc). Sleep plays an integral role in the maintenance and functioning

of key areas of cognitive-emotion functioning including attention, working memory, and the sensitivity and processing abilities for emotion expressions and signals (see Krause et al., 2017, for a review). Ultimately, a night of light sleep in good sleepers may tax cognitive resources and functionality for the processing of emotional faces, but also more generally lead to fatigue effects on performance. Some evidence in support of this suggestion was found in the current study: less slow wave sleep affected angry intensity ratings and greater sleepiness impacted accuracy for fearful stimuli. And, for good sleepers but not the insomnia group, subjective reports of poorer sleep quality the night before testing were related to slower response times for identifying all faces, and both worse accuracy and lower intensity ratings of fearful and angry faces (Appendix K, Table 25), and, greater levels of subjective sleepiness were related to faster response times (i.e., impulsivity) for happy and sad trials, and also poorer accuracy for angry and fearful faces, and lower intensity ratings of angry faces (Appendix K, Table 38). Therefore, for good sleepers and not individuals with insomnia symptoms, elevated Beta EEG activity, poor subjective sleep quality, and afternoon sleepiness all related to poorer sensitivity for emotion faces (and sleepiness specifically to a potential impulsivity of responses). In conclusion, it is possible that the relationship between elevated Beta activity and a blunting in sensitivity for emotion faces in good sleepers may be due to effects of light, non-restorative sleep, and the results of fatigue effects on waking emotion processing. Critically, the contrasting findings that elevated Beta EEG activity in good sleepers relates to a blunting emotion processing but for individuals with insomnia relates to greater sensitivity for emotional faces illustrates that the nature and/or impact of this neurophysiological activity in insomnia is both abnormal and has specific implications for socioemotional functioning.

### 4.5. Limitations

The small and heterogeneous sample and the number of analyses in the present study means the current findings should be interpreted with caution and considered tentative pending further examination. It is suggested that future investigations of the effects of sleep (and hyperarousal) in insomnia on waking function include sufficient numbers to better identify effects, as well as to account for variability in sleep, insomnia subtypes, and the presence or absence of hyperarousal. The sample in the study was also predominantly a convenience sample from the student body of Brock University due to difficulty in initial attempts at collecting a primarily community sample. As a result, the sample collected was predominantly women and young adults. Therefore, there was no opportunity to examine the effects of sleep and emotion processing between sex, and it is cautioned that any particular effects observed here may be generalizable only to women. Insomnia is also more prevalent in older adults (e.g., Morin et al., 2011) and the findings here may not extend to other age cohorts. A larger sample of participants with increased diversity is required in order to fully contribute to the literature and account for the contributors of sex and age on emotion processing and sleep in insomnia. Given the difficulty in obtaining a sizeable community sample of individuals with insomnia, it is suggested for future recruitment efforts to gain access to individuals with insomnia complaints from clinics or medical centers through referrals or advertisement, and before any treatment, although insomnia is a condition that many do not seek treatment and there are few treatment centers in Canada.

There were also limitations to the employment of ambulatory polysomnography to record sleep. Sleep was recorded in participants' own homes in order to increase the ecological validity of the findings which is particularly useful with the insomnia sample who tend to sleep well away from their home environment. However, without strictly enforced bed times, a large

portion of healthy good sleeper participants were lost to sleep restriction. Where possible, researchers employing ambulatory sleep-measuring equipment should use more explicit instruction or enforcement of bed times in accordance with a common standard or participants own self-reported normative bedtimes. In addition, without constant monitoring, some elements of the data such as data from an EEG channel or sleep diaries were lost for some participants. And, participants were able to begin sleep recordings without actually going to sleep, thus compromising the validity of sleep efficiency and sleep onset latency, two key measures of measuring insomnia sleep. Additionally, for ease of use of the equipment at home, ambulatory EEG only employs a few EEG channels, therefore topographic analysis of how EEG changes across the scalp cannot be carried out. Future researchers should consider whether the employment of ambulatory recording for increased ecological validity of sleep measurement is worth the trade-off of an increase in missing or compromised data and a lack of opportunity for more thorough monitoring and quantitative EEG analysis. Alternatively, home monitoring may be achieved with increased controls and measures of compliance.

A very important limitation to the ambulatory polysomnography employed in this study was the absence of the ability to detect and rule out sleep apnea and restless leg syndrome. Both conditions were screened for during the intake process by interview and by questionnaire, however, it is possible that participants who are unaware of underlying medical sleep conditions entered the study. Further research employing ambulatory polysomnography without equipment for measuring RLS/sleep apnea should consider an in-lab night of sleep recording for screening purposes. Another limitation was that the first night of polysomnography was automatically scored but did not receive corrective scoring by a human scorer, thus was employed only for characterizing sleep in the insomnia group but could not be included in analyses to allow for an

investigation of consistent effects between nights that might contribute to emotion processing. However, a strength of the current study was that sleep recordings were taken the night preceding the afternoon of performance testing, therefore the proximal relationship between sleep and next-day functioning was directly addressed where it did not appear to be accounted for in other studies of emotion processing in insomnia (e.g. Baglioni et al., 2014; Cronlein et al., 2016; Kyle et al., 2014). Future studies investigating the relationship between sleep and waking functioning must employ sleep measurement the night before testing in order to determine these relationships.

There were also some possible limitations to the task battery. The battery included several tasks not included in the current thesis, and took approximately an hour and a half to complete, therefore performance could by impacted by motivation or fatigue, especially for tasks such as the face categorization and intensity rating task which occurred later in the task battery. Additionally, specific cognitive components of emotion processing such as perceptual sensitivity, attention, inhibitory control, or recognition could not be identified due to an absence of ERP analysis coinciding with behavioural performance. Therefore, the current thesis could not address which aspects of cognitive emotion processing might be impacted by hyperarousal and sleep. A main limitation to the face categorization and intensity rating task was that the face stimuli were presented only during identification, and then participants rated the intensity of the faces without the face present; judgements of the face stimuli were made based on the image held in working memory. Thus, individual differences in working memory ability and functioning may have contributed to intensity ratings on this task. Psychomotor vigilance was tested to determine whether sleep impacted simple reaction time and sustained attention generally. However, no non-emotion cognitive processing tasks that were equivalent in

complexity to the emotion tasks employed were included to detect whether sleep impacted behavioural responses to complex non-emotion stimuli as well. Future research should employ complex non-emotion tasks for comparison alongside ERP data analysis, in order to address the specificity of cognitive differences and to identify more precisely how emotion processing is impacted by sleep and hyperarousal in insomnia.

### 4.6. Summary, Contributions to Insomnia Research, and Future Directions

This study offers some evidence that accuracy for emotional faces is impaired after a night of objectively poor sleep in individuals with insomnia symptomology. Insomnia with a poor night of sleep was associated with elevated Beta and Sigma EEG activity, and reduced time in Stage 2, REM and NREM sleep, and a smaller proportion of the night in REM. This study was the first to examine the impact of quantitative EEG-measured sleep on next-day socioemotional processing in insomnia. We found evidence that greater levels of Beta EEG activity (i.e., hyperarousal) during sleep related to greater sensitivity to emotionally expressive faces of happiness, fear and sadness for individuals with insomnia symptomology on the following day. In contrast, healthy good sleepers had poorer performance and a blunting in sensitivity after a night of elevated Beta EEG activity; however, poorer sensitivity was also related to greater sleepiness, less time in deep sleep, and subjective reports of poorer quality sleep, suggesting the possibility that light/non-restorative sleep generally leads to poorer emotion processing abilities in good sleepers. The contrasting associations of elevated Beta EEG activity on emotion processing between the two groups suggests that hyperarousal in insomnia may represent alterations in waking salience processing which could represent the consequences of abnormal and likely chronic neurophysiological activation in emotion regions during sleep, and/or that impaired emotion-reactivity in insomnia may also predispose individuals with insomnia to nights

of hyperaroused sleep. Given the limitations of the sample and the exploratory analyses conducted, and that this study was the first to report these relationships, further studies must be conducted.

The following research questions are recommended to be addressed by future research efforts: are emotion processing areas engaged during hyperarousal sleep; are the same areas engaged during hyperarousal in both healthy good sleeper and individuals with insomnia; are there differences in the degree or the extent of regional neurophysiological activation during hyperarousal; is hyperarousal a reliable marker of impaired sleep in insomnia; does hyperarousal have functional significance for good sleepers as well; and finally, is hyperarousal associated with abnormal neurophysiological reactivity to emotional cues during wake? Future research should also investigate which aspects of emotion processing (e.g., cognitive components and emotion processing beyond emotional face processing) are affected in insomnia populations exhibiting hyperarousal.

Clinically, the findings suggest that a poor night of sleep and hyperarousal in insomnia may relate to abnormal sensitivity to emotionally expressive faces, which could contribute to the experience of poorer social functioning in this clinical population. Interventions which restore or curtail neurophysiological activity during sleep to normative levels may also serve to improve socioemotional functioning by restoring appropriate sensitivity to emotionally expressive faces. Further investigation of the impact of interventions such as Cognitive Behavioural Therapy for insomnia or relaxation therapy on both hyperarousal and emotion processing are warranted. Further confirmation of the impact of hyperarousal and a night of poor sleep on emotion processing in insomnia could also inform possible treatments or inventions for the development of comorbid social deficiencies, anxiety and/or depression. The findings of the current study

provide a preliminary investigation into an essential and novel avenue of research for both hyperarousal and emotion processing in insomnia.

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# Appendix A

Brock University

Research Ethics Office Tel:
905-688-5550 ext. 3035

Email: reb@brocku.ca

Bioscience Research Ethics Board

## Certificate of Ethics Clearance for Human Participant Research

| | | | |
|---|---|---|---|
| DATE: | 3/28/2018 | | |
| PRINCIPAL INVESTIGATOR: | COTE, Kimberly - Psychology | | |
| FILE: | 17-332 - COTE | | |
| TYPE: | Faculty Research | STUDENT: | Reuben Howlett |
| | | SUPERVISOR: | Kimberly Cote |

TITLE: How Sleep Quality Impacts Emotion and Cognition

**ETHICS CLEARANCE GRANTED**

Type of Clearance: NEW Expiry Date: 3/1/2019

The Brock University Bioscience Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from **3/28/2018** to **3/1/2019**.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 3/1/2019. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at https://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable

implications for participants;

c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved: _____

Stephen Cheung, Chair
Bioscience Research Ethics
Board

**Note:** Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

Brock University

Research Ethics Office Tel:
905-688-5550 ext. 3035

Email: reb@brocku.ca

Bioscience Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

| | | | |
|---|---|---|---|
| DATE: | May 22, 2018 | | |
| PRINCIPAL INVESTIGATOR: | COTE, Kimberly - Psychology | | |
| FILE: | 17-332 - COTE | | |
| TYPE: | Faculty Research | STUDENT: | Reuben Howlett |
| | | SUPERVISOR: | Kimberly Cote |

TITLE: How Sleep Quality Impacts Emotion and Cognition

**ETHICS CLEARANCE GRANTED**

Type of Clearance: MODIFICATION Expiry Date: 3/1/2019

The Brock University Bioscience Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement.

Modification: Participant age range changed to18-50 with the rationale that 1) the first few participants may be taken from the Brock student populace for protocol training for the principal investigator before taking in members from the community; 2) may need to use the university convenience sample if recruitment from the community proves insufficient by later times of the data collection phase.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before **3/1/2019**. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at https://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Stephen Cheung, Chair
Bioscience Research Ethics
Board

**Note:** Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

Appendix B

Table 18.

*Classification criteria for the four groups for analysis based on sleep the night before testing alongside ISI/PSQI scores during initial screening.*

| ID# | TST Hrs | TST Min | SE | TRT Hrs | TRT Min | SQ | ISI | PSQI | Classification |
|---|---|---|---|---|---|---|---|---|---|
| Good sleepers | | | | | | | | | |
| 11 | 7 | 38 | 94 | 8 | 15.5 | 7 | 2 | 2 | **GS** |
| 16 | 7 | 15 | 92.5 | 7 | 50.5 | 6 | 0 | 1 | **GS** |
| 17 | 7 | 9.5 | 93.8 | 7 | 46.5 | 6 | 6 | 3 | **GS** |
| 45 | 6 | 51 | 92.4 | 7 | 26 | 6 | 2 | 1 | **GS** |
| 36 | 7 | 10 | 97.4 | 7 | 21.5 | 6 | 3 | 4 | **GS** |
| 39 | 7 | 24 | 95.4 | 7 | 45.5 | 6 | 3 | 3 | **GS** |
| 47 | 7 | 46 | 89.3 | 8 | 42 | 5 | 7 | 4 | **GS** |
| 51 | 8 | 59.5 | 97.2 | 9 | 5 | 3 | 4 | 4 | **GS** |
| 62 | 6 | 38.5 | 91.6 | 7 | 15 | 4 | 0 | 0 | **GS** |
| 69 | 7 | 19 | 98.5 | 7 | 26 | 5 | 2 | 4 | **GS** |
| 70 | 9 | 1 | 97.7 | 9 | 13 | 5 | 2 | 3 | **GS** |
| 73 | 7 | 34 | 97 | 7 | 48 | 3 | 7 | 5 | **GS** |
| 78 | 6 | 33.5 | 92 | 7 | 7.5 | 4 | 2 | 3 | **GS** |
| 75 | 7 | 11 | 98.7 | 7 | 16 | 5 | 7 | NA | **GS** |
| 79 | 7 | 2 | 99.2 | 7 | 5.5 | 3 | 7 | 5 | **GS** |
| 24 | 5 | 25 | **66.3** | 8 | 10.5 | 7 | 1 | 1 | **PS** |
| 2 | 5 | 13.5 | 91 | 5 | 34.5 | 5 | 4 | 2 | **SR** |
| 7 | 6 | 18.5 | 92.2 | 6 | 41.5 | 6 | 0 | 2 | **SR** |
| 31 | 3 | 53.5 | 90.2 | 4 | 8.5 | 5 | 6 | 3 | **SR** |
| 29 | 4 | 40 | 90.6 | 5 | 9 | 5 | 2 | 4 | **SR** |
| 41 | 5 | 52.5 | 92.1 | 6 | 16 | 4 | 2 | 5 | **SR** |
| 52 | 5 | 33 | 89.4 | 6 | 12.5 | 4 | 1 | 3 | **SR** |
| 55 | 6 | 23.5 | 91 | 6 | 56 | 4 | 0 | 1 | **SR** |
| 59 | 4 | 25 | 91.4 | 4 | 50 | 4 | 4 | 1 | **SR** |
| 68 | 6 | 17.5 | 90.6 | 6 | 57 | 5 | 6 | 5 | **SR** |
| Individuals with insomnia symptoms | | | | | | | | | |
| 3 | 7 | 26.5 | 91.1 | 8 | 10 | 3 | 8 | 9 | **GSI** |
| 15 | 8 | 55.6 | 96.1 | 9 | 20.5 | 4 | 17 | 12 | **GSI** |
| 33 | 6 | 58.5 | 95.5 | 7 | 18.5 | 5 | 10 | 11 | **GSI** |
| 50 | 7 | 14 | 87.2 | 8 | 17.5 | 4 | 12 | 11 | **GSI** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 54 | 7 | 18.5 | 95 | 7 | 31.5 | 5 | 13 | 10 | **GSI** |
| 46 | 7 | 34.5 | 95.5 | 7 | 56 | 5 | 17 | 8 | **GSI** |
| 6 | 6 | 2 | 95.5 | 6 | 19 | 3 | 12 | 12 | **PSI** |
| 12 | 6 | 19 | 94.4 | 6 | 41.5 | 4 | 25 | 17 | **PSI** |
| 22 | 3 | 6 | 84.5 | 3 | 40 | 4 | 10 | 12 | **PSI** |
| 26 | 6 | 26 | 95.4 | 6 | 41.5 | 4 | 14 | 10 | **PSI** |
| 44 | 5 | 49 | 72.8 | 7 | 59.5 | 4 | 8 | 12 | **PSI** |
| 61 | 4 | 12 | 62.7 | 6 | 42 | 3 | 16 | 9 | **PSI** |
| 63 | 5 | 40 | 79.2 | 7 | 9.5 | 4 | 15 | NA | **PSI** |
| 80 | 4 | 36 | 98.9 | 4 | 39 | 5 | 24 | 12 | **PSI** |

*Note.* Sleep data is based on PSG recordings the night before testing, and sleep quality questionnaires (ISI and PSQI) were online taken during the screening procedure. TST = Total sleep time. TRT = Total recording time. Hrs = hours. Min = minutes. SQ = Diary sleep quality (1-7, 1 = very poor quality sleep, 7 = very good quality sleep). ISI = Insomnia Severity Index. PSQI = Pittsburgh Sleep Quality Index. GS = Good sleepers who slept well. SR = Good sleepers that sleep restricted. PS = Good sleeper that had a night of poor sleep. GSI = Individual with insomnia symptoms that had a good night of sleep. PSI = Individual with insomnia symptoms that had a poor night of sleep.

# Appendix C

Performance behavioural outcomes comparing four groups are shown in Figures 15-23. Statistically comparisons were not performed. Sleep restriction (SR) for healthy sleepers appeared to reduce performance, while a night of normal sleep INS sleep in individuals with insomnia symptoms lead to restored performance (INS-G). The SR group appeared to generally have slower response times and a greater interference effect on the Emotional Stroop task (Figures 16-18) and slower responses on the Face Categorization and Intensity Rating Task (Figure 21); they also appeared to have greater intensity ratings on the Face Categorization and Intensity Rating Task (Figure 23).

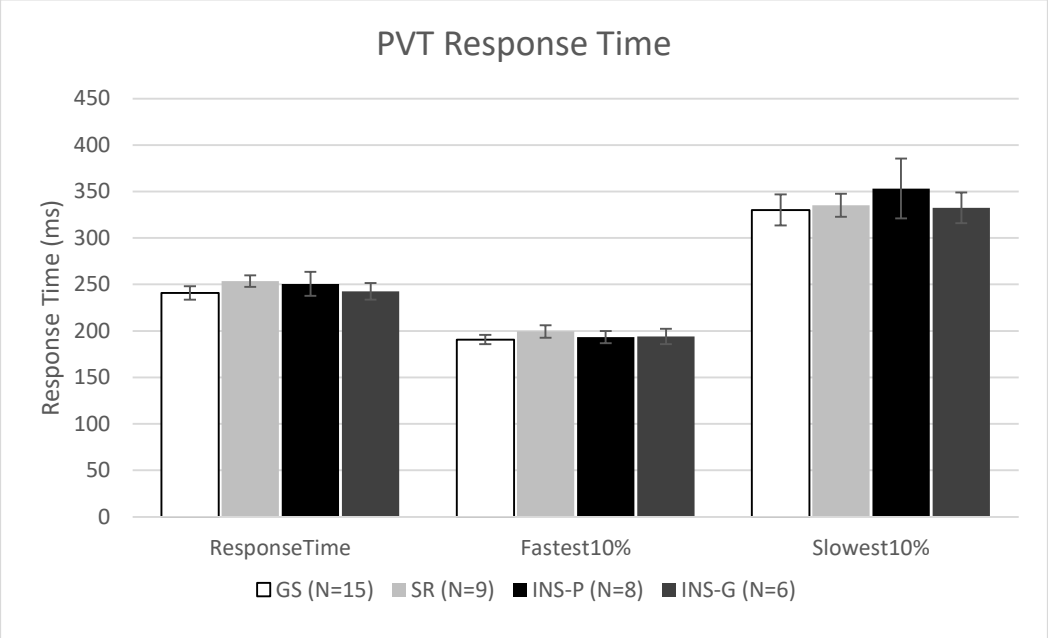



*Figure 15.* Performance of the four groups on the psychomotor vigilance for the four groups.

*Note.* Error bars represent +1/-1 SE.

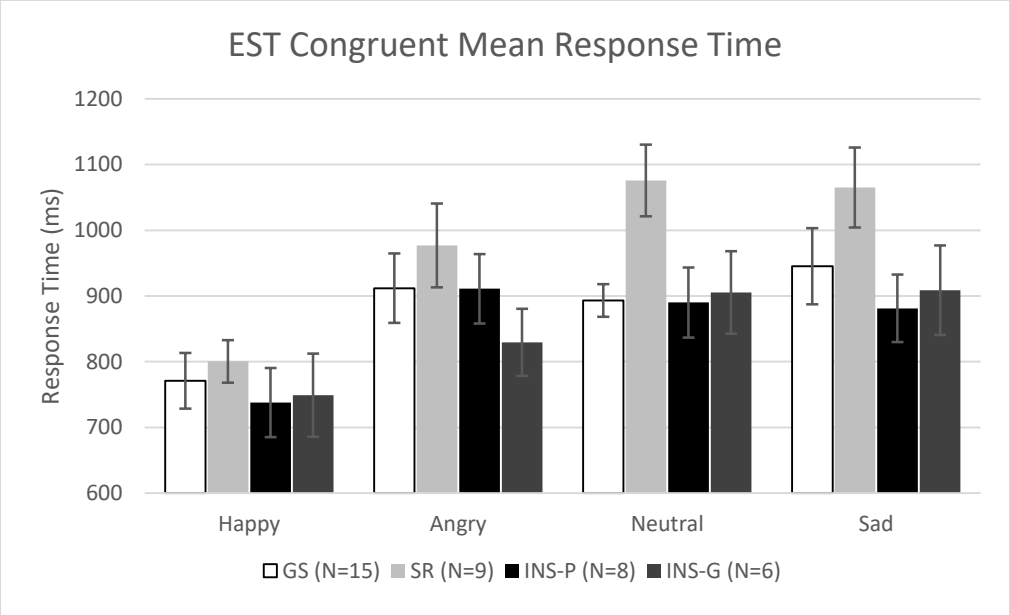



*Figure 16*. Mean response time for congruent trials for the four groups on the emotion Stroop task. *Note*. Error bars represent +1/-1 SE.

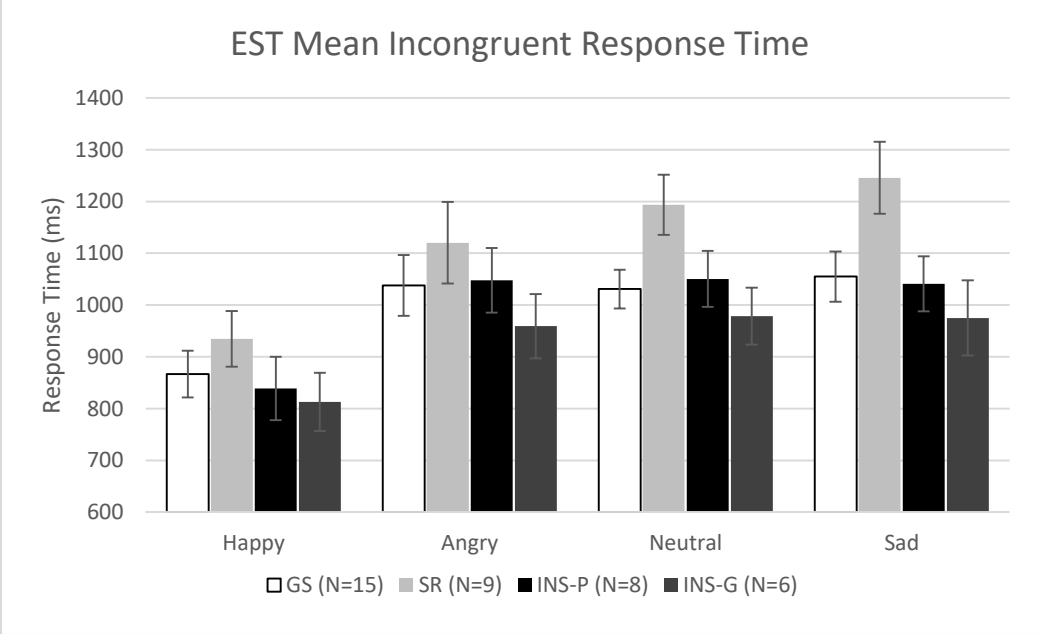



*Figure 17*. Mean response time for incongruent trials for the four groups on the emotion Stroop task. *Note*. Error bars represent +1/-1 SE.

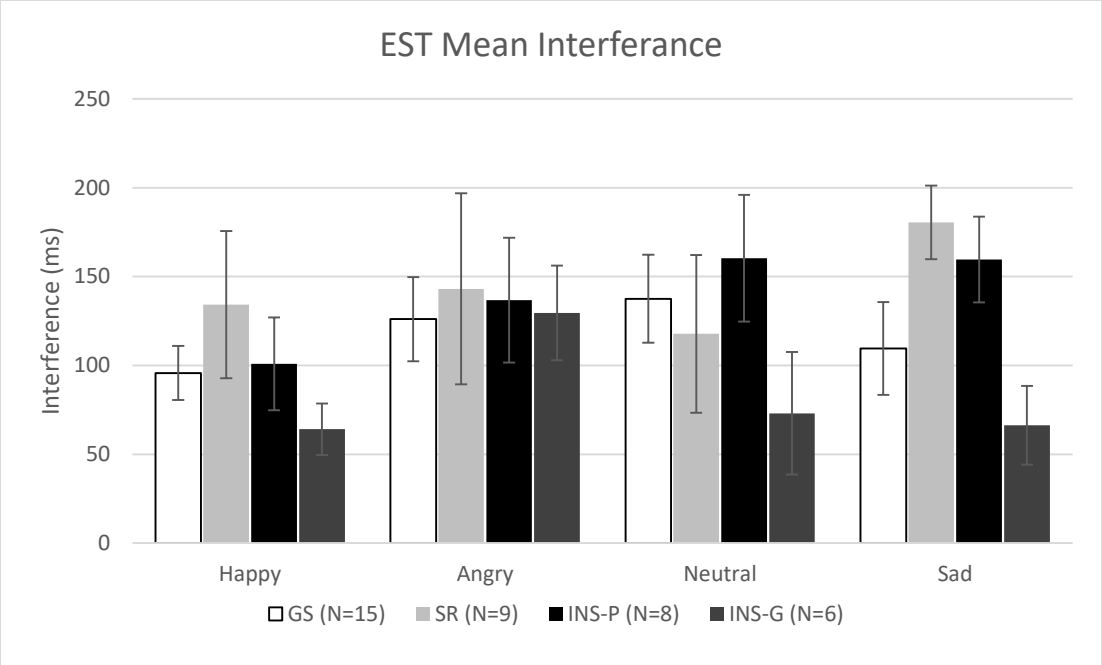



*Figure 18*. Mean interference effect of the four groups on the emotion Stroop task. *Note.* Error bars represent +1/-1 SE.

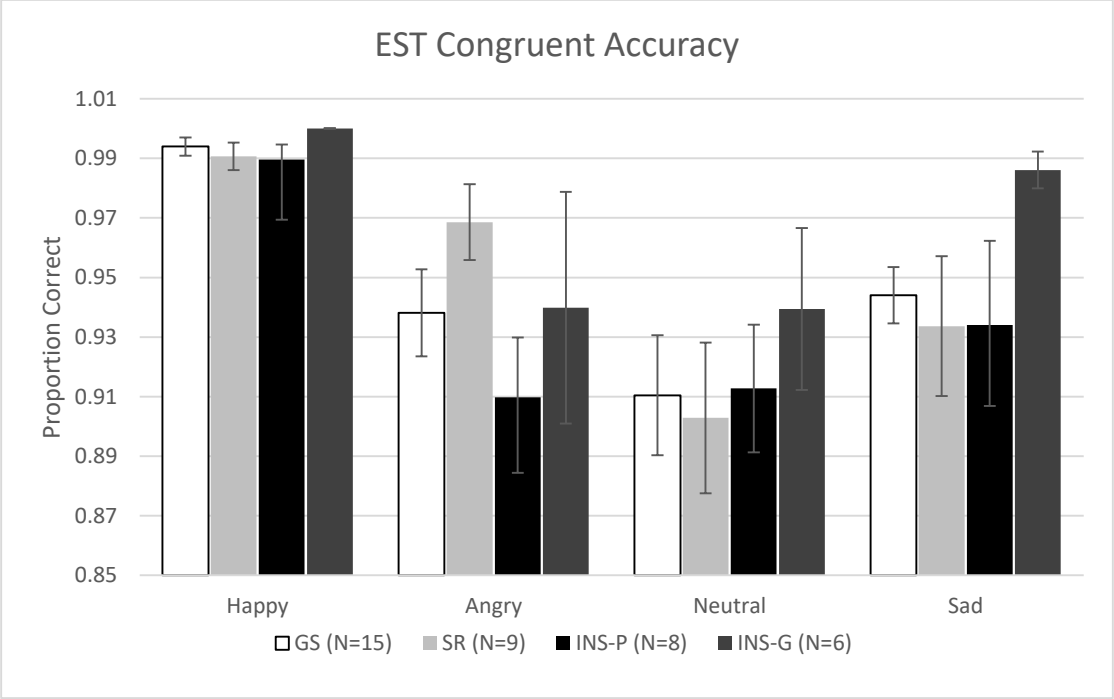



*Figure 19*. Mean accuracy for congruent trials for the four groups on the emotion Stroop task. *Note.* Error bars represent +1/-1 SE.

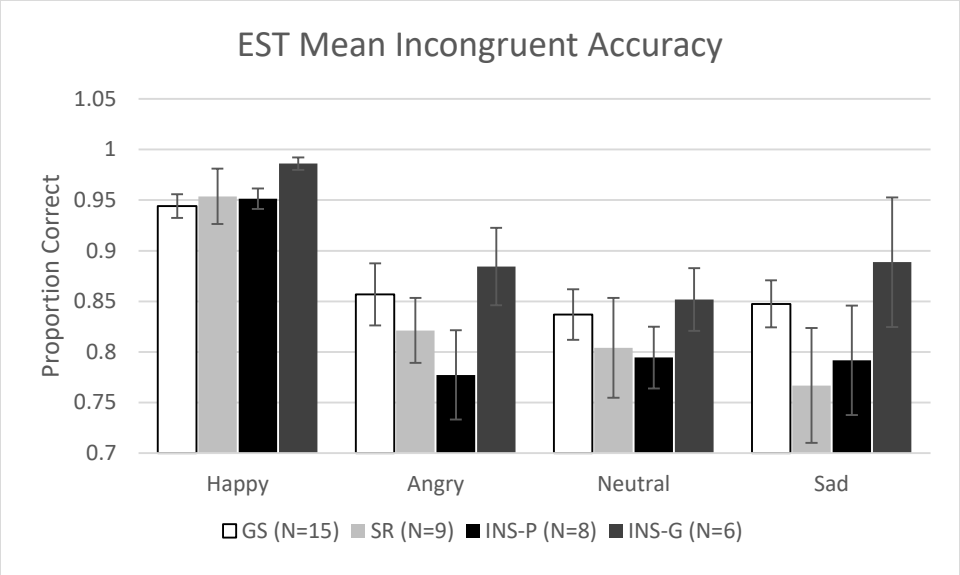



*Figure 20*. Mean accuracy for incongruent trials for the four groups on the emotion Stroop task.

*Note.* Error bars represent +1/-1 SE.

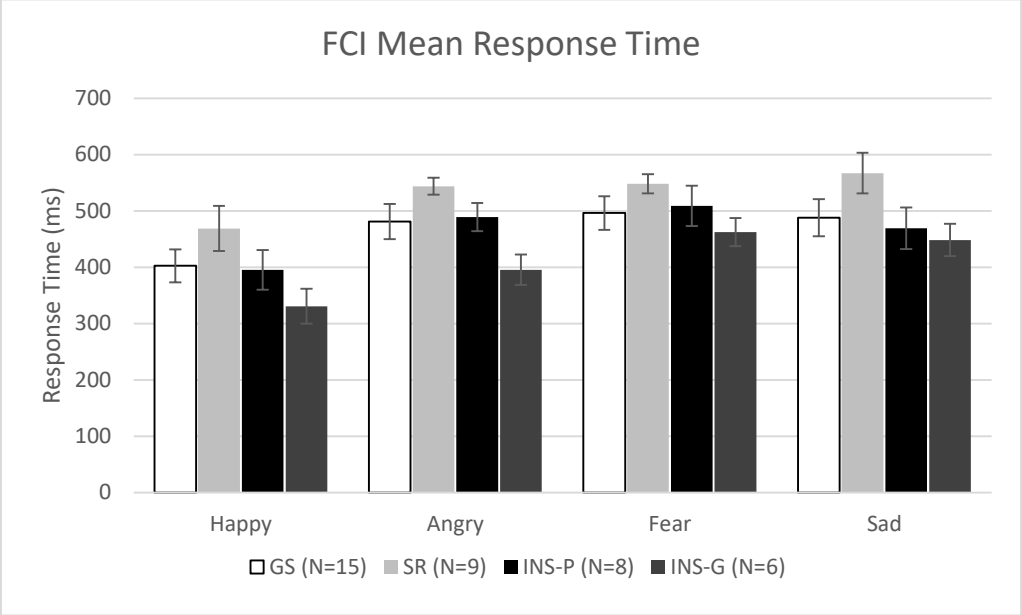



*Figure 21*. Mean response time of the four groups on the face-categorization and intensity task.

*Note.* Error bars represent +1/-1 SE.

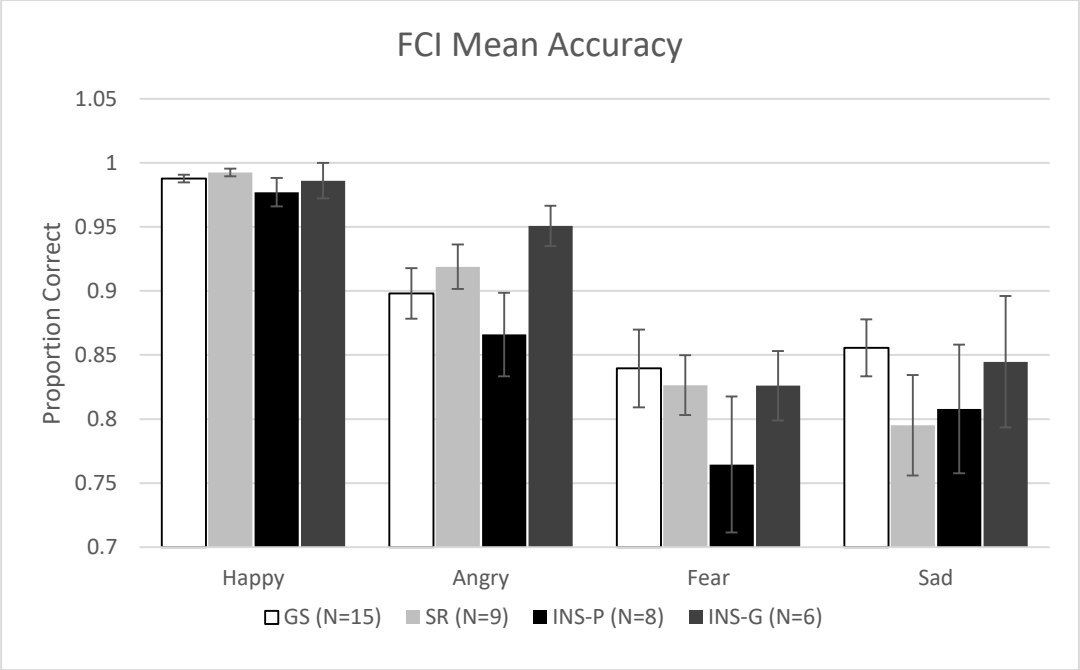



*Figure 22*. Mean accuracy for the four groups on the face-categorization and intensity task. *Note.* Error bars represent +1/-1 SE.

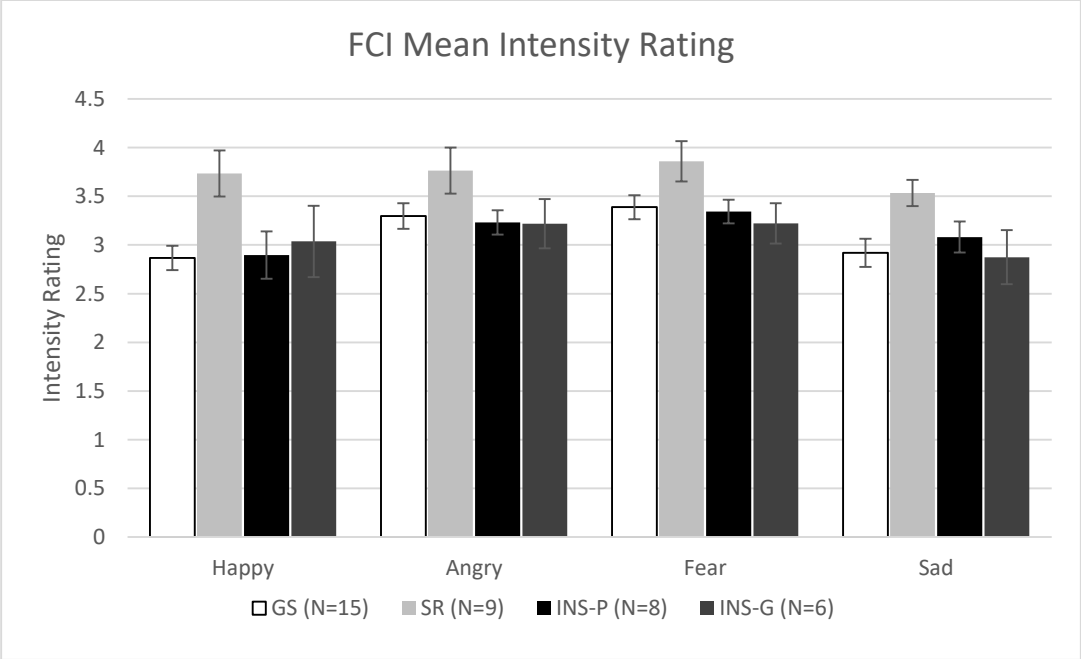



*Figure 23*. Mean intensity ratings of the four groups on the face-categorization and intensity task. *Note.* Error bars represent +1/-1 SE.

# Appendix D

## Phone Interview

**I. DESCRIBE STUDY:**

We are interested in studying the role of sleep quality in daytime alertness, attention, and emotion. To do this, we are looking for both good and poor sleepers to participate in this study. You will be asked to record your sleep at home for 2 nights using equipment we provide; after which you will come to the Brock Sleep Lab for an afternoon to complete computerized performance tasks.

More specifically, participation in the study would include 5 parts:

Part 1. A brief PHONE INTERVIEW today where I will ask you questions in order to assess eligibility. These questions are about your general demographics, sleep habits, and health, and takes approximately 15 minutes.

Part 2. You will then be asked to complete some ONLINE FORMS including a study consent form and questionnaires that will further assess sleep and well-being (1 hour total). You will also fill out a daily sleep diary for a week (5 minutes a day, 35 minutes total).

Part 3. If eligible, you will then be scheduled for a 1-hour ORIENTATION SESSION at the Brock Sleep Lab where the study procedures will be fully explained. At this session, you will also sign a study consent form, practice the performance tasks, and be shown how to use the sleep-recording equipment.

Part 4. You will record your sleep in the comfort of your own home for 2 nights using the equipment provided. Putting on or taking off the equipment takes 15 minutes each time for a total of 1 hour.

Part 5. You will return the equipment and spend an afternoon in the Sleep Lab from 1:00pm until 4:00pm following the second night of home-recording. During this session you will perform computerized tasks while wearing electrodes attached to your head and face, and fill out a few questionnaires.

You will receive an honorarium of $60 for completion of the full study. Poor sleepers will also receive a guide to home treatment of sleep. Note that there is no compensation for study screening procedures.

**Do you have any questions about the study?**
**Are you interested in participating in this study?**

[yes] – OK, now we will complete the phone interview (PART1) to make sure you are eligible. It will take about 15 minutes. Your answers will be kept confidential and will not be used for any purpose outside of the study. Please note that you are free to say "I do not wish to respond" to any question or stop the interview at any time. If you meet study criteria, I will get contact information from you, and follow-up to arrange Part 2 of the study.

[no] – Thank you for calling.

## TELEPHONE INTERVIEW QUESTIONS

**Date:** _____ **Time**:_____ ID CODE:_____

What days of the week would you be free to participate in an afternoon session from 1-4PM?:___

# Demographics

1) What is your age? [25-50] _____

2) Are you left or right handed? [right] _____

3) Is English your first language? _____

   If no: did you learn English before age 8? [yes] _____

4) What's your approximate weight? _____

5) Do you smoke tobacco/cigarettes? [no] _____

6) If you smoke marijuana, how often do you smoke it? [occasional only] _____

7) Do you have normal vision or wear glasses/contacts to correct? [yes] _____

8) Do you have normal hearing ability? [yes] _____

9) Do you have any motor deficits that would prohibit you from using a computer keyboard or mouse? [no] _____

10) How many caffeinated drinks do you typically have in a day? _____

    What are they?_____
    [1 one morning coffee/tea per day, and minimal use of other caffeinated beverages/energy drinks]

11) Do you have a recent history of working shifts that are overnight or late into the night? [no] _____

    If yes: Currently, or how long ago? _____; Shifts / week? _____; For how long? _____

12) Have you traveled over multiple time zones in the past 3 months? _____

    If yes: Get time zone hour difference: [<3] ____

# Sleep

13) Do you consider yourself to be a good or poor sleeper? _____

14) What are your usual sleeping times at night? [within 21:30-09:30]_____; on weekends? ___

Total average hours of actual sleep time per night: _____

15) Do you take daytime naps? _____

If yes: Number of naps per week? _____; Typical duration? _____

16) Do you have difficulty *falling* asleep at night?_____

If yes: How many minutes on average does it take you to fall asleep at night?
[>30]_____

17) Do you *wake up* often during the night? _____

If yes: How many times do you think you awake during night? _____,
and for how long each time?_____?

18) Do you *wake up in the early morning* (e.g., 4am) and then are unable to get back to sleep? _____

If yes: For how many minutes are you awake throughout the night?
[>30]_____

19) (For poor sleepers only):

a) How many nights per week do you have difficulties sleeping [3 or more nights in a week] ? _____

b) For how many months have you had difficulties sleeping? [>3] _____

c) What is the main reason you have difficulty sleeping? _____

d) Do you feel as though your sleeping difficulties negatively impact your daytime functioning or quality of life? [yes] _____

20) Have you ever been to a sleep clinic and diagnosed with a sleep disorder such as *sleep apnea, periodic limb movement disorder*, or *restless leg syndrome*?
[no]_____

21) Have you ever noticed or been told by a bed partner that you kick your legs, snore loudly or stop breathing periodically throughout the night? [no] _____

22) Do you experience restless legs or a "creepy crawling" sensation before bed each night? [no] _____

23) Do you experience frequent coughing, breathing difficulties, or feelings of choking or suffocation during sleep, [no] _____
Morning headaches or extremely dry mouth and throat? [no] _____

24) Do you experience excessive sleepiness throughout the day? [no] _____

# Health

25) Do you consider yourself to be presently in good health [yes]: _____

26) Do you take any prescription medications? _____

If yes: Get name, dose, and frequency and purpose for use:
_____

27) What about over-the-counter (OTC) or Natural Health Products (NHP) – do you use any regularly? _____

If yes: Get name, dose, and frequency and purpose for use:
_____

28) Do you regularly take sleeping aids? _____

If yes: Get name, dose, and frequency:
_____

If yes, would you be willing and able to stop sleeping pills and aids (OTC/NHP) for a two week period prior to the study? _____

29) Are you currently engaged in any other type of therapy/treatment for sleep [no] _____?

30) (Women only):

a. Do you currently take any hormones (such as birth control pills, patches, shots): Y or N -- If yes, what _____?

b. Have you experienced symptoms of menopause or been told by a healthcare worker that you might be entering menopause? [no] _____

31) Any history of depression, anxiety or schizophrenia? [no] _____

32) Any history of head injury (e.g., car accident, stroke, loss of consciousness)? [no]_____

33) Do you experience chronic pain? _____
[If yes]: Where:
_____

How often:_____

**34)** I will now read a list of medical conditions. Please indicate Yes or No, if you have any history of the following conditions:

| **Condition** | **Yes** | **No** | **Condition** | **Yes** | **No** |
|---|---|---|---|---|---|
| Diabetes | | | Restless Leg Syndrome | | |
| Thyroid disorders | | | Periodic Limb movement disorder | | |
| Sleep Apnea | | | Narcolepsy | | |
| Attention Deficit Disorder | | | Kidney disease | | |
| Epilepsy | | | Intestinal disease | | |
| Psychiatric treatment | | | Liver disease | | |
| Neurological disease or condition | | | Heart disease | | |
| Frequent Headaches | | | High blood pressure | | |
| Back pain | | | Arthritis | | |
| Asthma | | | Obesity | | |
| Repeated throat infections | | | Pneumonia | | |
| Deviated nasal septum | | | Chronic sinusitis | | |
| Chronic Fatigue Syndrome or Fibromyalgia | | | Mouth or nose surgery | | |

Note: if Yes to any, obtain information on timeframe (e.g., currently problematic, under treatment):

**III. CONTACT INFORMATION:**

| | |
|---|---|
| **Name:** | |
| **Home phone:** | |
| **Cell phone:** | |
| **E-mail address:** | |
| **Preferred Method / Times of contact:** | |
| **In-lab Orientation Appointment:** | |
| **Task Day Appointment:**<br><br>**(2-4 days later)** | |

**ID Code:**

Appendix E

# Brock University Sleep Research Laboratory

## Demographic Questionnaire

**Instructions**:

- Please complete the following questionnaire to provide demographics.

**Part I. Demographics Questions**

1. Date of birth (day/mth/year)_____
2. Sex, M or F
3. Height
4. Weight
5. Marital status:

- ❑ Single
- ❑ Married
- ❑ With Partner/Not Married
- ❑ Separated
- ❑ Divorced
- ❑ Widowed
- ❑ With Partner/Separated
- ❑ Divorced/With Partner/Remarried

6. Highest level of education:

- ❑ Some high school
- ❑ Completed High school
- ❑ Some College
- ❑ Completed College
- ❑ Some University
- ❑ BA or BSc
- ❑ MA or MSc
- ❑ PhD
- ❑ Professional Degree (MD, LLB, DDS)

7. Current employment status:

- ❑ Employed Full Time
- ❑ Self-Employment
- ❑ Employed Part Time by Choice
- ❑ Employed Part Time Want More
- ❑ Homemaker
- ❑ Unemployed
- ❑ School Full Time
- ❑ School Part Time
- ❑ School Full Time Employed Part Time
- ❑ Employed Full Time School Part Time
- ❑ Retired

8. Your occupation:

- ❑ Professional/Managerial
- ❑ Proprietor/Owner
- ❑ Clerical/Sales
- ❑ Skilled/Technical
- ❑ Unemployed
- ❑ Housewife
- ❑ Student

Other, Specify_____

# Appendix F

## SLEEP - WAKE QUESTIONNAIRE

| ID: | Date: | Height: | Weight: | Sex: |
|---|---|---|---|---|
| | | | | |

INSTRUCTIONS

Read each of the questions carefully indicate the answer that best describes HOW OFTEN YOU HAVE HAD THESE DURING THE PAST 2 MONTHS. Fill in the circle or check it off. Do not skip any item and print your numbers clearly. Make sure that you have answered all the questions.

1.) Before going to sleep how often do you engage in the following activities:

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) Read | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) Smoke | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) Eat a Snack | ○ | ○ | ○ | ○ | ○ | ○ |
| d.) Watch T.V. | ○ | ○ | ○ | ○ | ○ | ○ |
| e.) Drink tea, coffee, cola | ○ | ○ | ○ | ○ | ○ | ○ |
| f.) Drink water, soft drinks | ○ | ○ | ○ | ○ | ○ | ○ |
| g.) Listen to music or radio | ○ | ○ | ○ | ○ | ○ | ○ |
| h.) Take sleeping pills or tranquillizers | ○ | ○ | ○ | ○ | ○ | ○ |
| i.) Shower or bath | ○ | ○ | ○ | ○ | ○ | ○ |
| j.) Exercise or take short walks | ○ | ○ | ○ | ○ | ○ | ○ |
| k.) Relaxation exercises (Meditation, Prayer) | ○ | ○ | ○ | ○ | ○ | ○ |
| l.) Engage in other activities | ○ | ○ | ○ | ○ | ○ | ○ |

2.) How often does it take you more than 30 minutes to fall asleep?

| Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ |

3.) How often are you unable to sleep at all?

| Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ |

4.) Before falling asleep, how often do you experience any of the following:

| | | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|---|
| a.) Coughing, breathing difficulties, suffocation | | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) Feeling hot and sweaty | | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) Headaches | | ○ | ○ | ○ | ○ | ○ | ○ |
| d.) Confusion/disorientation (do not know where you are) | | ○ | ○ | ○ | ○ | ○ | ○ |
| e.) Tension and worry | | ○ | ○ | ○ | ○ | ○ | ○ |
| f.) Unpleasant thoughts | | ○ | ○ | ○ | ○ | ○ | ○ |
| g.) Aches or pains in: | limbs | ○ | ○ | ○ | ○ | ○ | ○ |
| | neck | ○ | ○ | ○ | ○ | ○ | ○ |
| | back | ○ | ○ | ○ | ○ | ○ | ○ |
| | chest | ○ | ○ | ○ | ○ | ○ | ○ |
| | abdomen | ○ | ○ | ○ | ○ | ○ | ○ |
| h.) A need to move your legs because of unpleasant sensations in them | | ○ | ○ | ○ | ○ | ○ | ○ |
| i.) Sudden jerking movements of your arms and legs | | ○ | ○ | ○ | ○ | ○ | ○ |

10.) How often is your sleep?

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) Light | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) Deep | ○ | ○ | ○ | ○ | ○ | ○ |

11.) How often do you have disturbing (bad) dreams during sleep?

| Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ |

12.) When you wake up from these bad dreams, how often do you experience the following?

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) Feel relieved | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) Feel frightened | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) Have no emotion at all | ○ | ○ | ○ | ○ | ○ | ○ |
| d.) Feel heart pounding. | ○ | ○ | ○ | ○ | ○ | ○ |
| e.) Breathe heavily | ○ | ○ | ○ | ○ | ○ | ○ |
| f.) Choke | ○ | ○ | ○ | ○ | ○ | ○ |
| g.) Feel pressure on your chest | ○ | ○ | ○ | ○ | ○ | ○ |
| h.) Not able to move | ○ | ○ | ○ | ○ | ○ | ○ |
| i.) Feel Restless | ○ | ○ | ○ | ○ | ○ | ○ |
| j.) Perspire | ○ | ○ | ○ | ○ | ○ | ○ |
| k.) Scream | ○ | ○ | ○ | ○ | ○ | ○ |
| l.) Wet your bed | ○ | ○ | ○ | ○ | ○ | ○ |
| m.) Immediately fall asleep | ○ | ○ | ○ | ○ | ○ | ○ |

13.) How often do you awaken in the morning feeling:

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) Good mood | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) Bad mood | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) Refreshed | ○ | ○ | ○ | ○ | ○ | ○ |
| d.) Physically tired | ○ | ○ | ○ | ○ | ○ | ○ |
| e.) Headache | ○ | ○ | ○ | ○ | ○ | ○ |
| f.) Muscle stiffness or pain in: limbs | ○ | ○ | ○ | ○ | ○ | ○ |
| neck | ○ | ○ | ○ | ○ | ○ | ○ |
| back | ○ | ○ | ○ | ○ | ○ | ○ |
| chest | ○ | ○ | ○ | ○ | ○ | ○ |
| abdomen | ○ | ○ | ○ | ○ | ○ | ○ |

14.) How often do you nap during the day:

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) On work/school days? | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) On weekends and holidays? | ○ | ○ | ○ | ○ | ○ | ○ |

15.) How often do you feel refreshed after a daytime nap?

| Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ |

16.) How often do you fall asleep during the following situations?

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) While travelling (car, train, etc.) | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) In the movies or theatre | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) During talks or lectures | ○ | ○ | ○ | ○ | ○ | ○ |
| d.) While watching TV | ○ | ○ | ○ | ○ | ○ | ○ |

| | | | | | | |
|---|---|---|---|---|---|---|
| e.) During social situations | ○ | ○ | ○ | ○ | ○ | ○ |
| f.) While reading | ○ | ○ | ○ | ○ | ○ | ○ |
| g.) During work | ○ | ○ | ○ | ○ | ○ | ○ |
| h.) While driving a car | ○ | ○ | ○ | ○ | ○ | ○ |
| i.) While eating | ○ | ○ | ○ | ○ | ○ | ○ |
| j.) During other activities (specify) _____ | ○ | ○ | ○ | ○ | ○ | ○ |

17.) How often do you stop an activity because of an irresistible need to sleep?

| Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ |

18.) During the day, how often do you:

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) Feel refreshed and energetic | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) Feel physically exhausted and listless | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) Yawn | ○ | ○ | ○ | ○ | ○ | ○ |
| d.) Have problems at work/school due to sleepiness or naps | ○ | ○ | ○ | ○ | ○ | ○ |
| e.) Have attacks of sudden muscle weakness or falling | ○ | ○ | ○ | ○ | ○ | ○ |
| f.) Have automatic activity (i.e., driving or walking without recalling where you are) | ○ | ○ | ○ | ○ | ○ | ○ |
| g) Feel faint or lose consciousness | ○ | ○ | ○ | ○ | ○ | ○ |
| h.) Feel dizzy or unsteady | ○ | ○ | ○ | ○ | ○ | ○ |
| i.) Have unusual sensation (numbness, tingling) in arms and legs | ○ | ○ | ○ | ○ | ○ | ○ |
| j.) Have headaches | ○ | ○ | ○ | ○ | ○ | ○ |
| f.) Have pain or discomfort in: limbs | ○ | ○ | ○ | ○ | ○ | ○ |
| neck | ○ | ○ | ○ | ○ | ○ | ○ |
| back | ○ | ○ | ○ | ○ | ○ | ○ |
| chest | ○ | ○ | ○ | ○ | ○ | ○ |
| abdomen | ○ | ○ | ○ | ○ | ○ | ○ |

19.) How often do you have to work on shifts?

| Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ |

20.) How often do you work on the:

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) Day shift | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) Evening shift | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) Night shift | ○ | ○ | ○ | ○ | ○ | ○ |

21.) How often does your work require you:

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) To stay awake most of the night? | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) To travel from one time zone to another? | ○ | ○ | ○ | ○ | ○ | ○ |

22.) How often during your work are you exposed to:

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) Continuous noises? | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) Monotonous activity? | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) Social isolation? | ○ | ○ | ○ | ○ | ○ | ○ |

| | | | | | | |
|---|---|---|---|---|---|---|
| d.) Pressures to increase your work output? | ○ | ○ | ○ | ○ | ○ | ○ |

23.) How often have you used medications for the following purposes?

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) To relieve pain (e.g. aspirin) Specify type: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) To relieve heartburn or indigestion (e.g. Antacids). Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) To diminish nervousness (e.g. Tranquillizer) Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| d.) To relieve depression (e.g. antidepressant) Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| e.) To help you sleep better. Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| f.) To keep you awake during the day. Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| g.) Caffeine tablets | ○ | ○ | ○ | ○ | ○ | ○ |
| h.) Against allergy (e.g. antihistamines). Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| i.) Against asthma (e.g. aminophylline). Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| j.) To prevent convulsions (e.g. dilantin). Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| k.) To treat heart problems. Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| l.) To treat respiratory problems. Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| m.) To treat high blood pressure. Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| n.) Hormones. Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| o.) To treat Parkinsonism. Specify: | ○ | ○ | ○ | ○ | ○ | ○ |
| p.) To reduce weight. Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |
| q.) Other types of medicines. Specify: _____ _____ _____ | ○ | ○ | ○ | ○ | ○ | ○ |

24.) How often have you used:

| | Never | Rarely | Sometimes | Often | Always | N/A |
|---|---|---|---|---|---|---|
| a.) Marijuana/hash? | ○ | ○ | ○ | ○ | ○ | ○ |
| b.) Cocaine/crack? | ○ | ○ | ○ | ○ | ○ | ○ |
| c.) L.S.D., mescaline, ecstasy? | ○ | ○ | ○ | ○ | ○ | ○ |
| d.) Stimulants (speed drugs, uppers, mood elevators, ephedrine) | ○ | ○ | ○ | ○ | ○ | ○ |
| e.) Narcotics (morphine, heroin, opium) | ○ | ○ | ○ | ○ | ○ | ○ |
| f.) Other. Specify: _____ | ○ | ○ | ○ | ○ | ○ | ○ |

## SLEEP - WAKE QUESTIONNAIRE – Part II

INSTRUCTIONS

The following are statements that describe some measurable aspects of your experience. Read each statement carefully and put in the appropriate box the nearest number that describes your experience. If the statement does not apply to you, put "N/A" on the appropriate line.

1.) During work/school days, I usually sleep _____ hours.

2.) During weekends and holidays, I usually sleep _____ hours.

3.) If I nap, they usually last _____ minutes each.

4. During the past 6 months, I have had _____ nightmares each week.

5. During the past 3 years because of sleepiness:

(a) I had _____ work accidents during day time.
(b) I had _____ work accidents during night time.
(c) I had _____ car accidents during day time.
(d) I had _____ car accidents during night time.

6.) During the past month, I had to change:

(a) from morning shift to night shift _____ times.
(b) from night shift to morning shift _____ times.
(c) from evening shift to night shift _____ times.
(d) from night shift to evening shift _____ times.
(e) from morning shift to evening shift _____ times.
(f) from evening shift to morning shift _____ times.

7.) Each day I usually drink:

a) cups of caffeinated coffee. _____
b) cups of regular tea _____
c) cups of herbal tea, _____
Specify types: _____

8.) Each day I usually take:

a) vitamins; _____
Specify type _____
b) herbal remedies; _____
Specify type _____

9. Each day I usually smoke:

a) cigarettes. _____
b) other; _____
Specify type _____

10. Each week I usually drink:

a) glasses of cola. _____
b) glasses of wine. _____
c) bottles of beer. _____
d) ounces of liquor; _____
e) ounces of other liquor; _____
Specify type _____
Specify type _____

Appendix G

## FAMILY MEDICAL HISTORY

INSTRUCTIONS

Please check (✔) in the proper space if any of the following items apply to a member of your family

| | Son | Daughter | Brother | Sister | Father | Mother | Other: _____ |
|---|---|---|---|---|---|---|---|
| 1.) Sleep walking | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.) Screaming during sleep | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.) Very loud snoring in sleep | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4.) Daytime sleepiness | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.) Other sleep problems (specify) | | | | | | | |
| a) _____ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| b) _____ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6.) Chronic Fatigue | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7.) Death during sleep | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8.) Mental illness | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9.) Psychiatric treatment | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10.) Chronic diseases: | | | | | | | |
| a) Cancer | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| b) Heart diseases | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| c) Rheumatoid arthritis | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| d) Diabetes mellitus | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| e) Other chronic disease | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Other chronic disease | | | | | | | |
| 11.) Neurological Diseases: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| a) Epilepsy | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| b) Other | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

## HEALTH QUESTIONNAIRE

INSTRUCTIONS

Please check (✔) in the proper space only the items in the following list that apply to you.

| | During the Past Year | More than a Year Ago |
|---|---|---|
| 1.) Diabetes | ☐ | ☐ |
| 2.) Thyroid disorders | ☐ | ☐ |

| | | |
|---|---|---|
| 3.) Epilepsy | ☐ | ☐ |
| 4.) Psychiatric illness | ☐ | ☐ |
| 5.) Psychiatric treatment | ☐ | ☐ |
| 6.) Neurologic disease | ☐ | ☐ |
| 7.) Kidney disease | ☐ | ☐ |
| 8.) Peptic ulcer, gastritis | ☐ | ☐ |
| 9.) Intestinal disease (colitis) | ☐ | ☐ |
| 10.) Liver disease | ☐ | ☐ |
| 11.) High Blood Pressure | ☐ | ☐ |
| 12.) Heart disease | ☐ | ☐ |
| 13.) Headache | ☐ | ☐ |
| 14.) Arthritis | ☐ | ☐ |
| 15.) Back pain | ☐ | ☐ |
| 16.) Obesity | ☐ | ☐ |
| 17. Asthma | ☐ | ☐ |
| 18.) Pneumonia | ☐ | ☐ |
| 19.) Enlarged tonsils, adenoids | ☐ | ☐ |
| 20.) Repeated throat infections | ☐ | ☐ |
| 21.) Chronic sinusitis | ☐ | ☐ |
| 22.) Deviated Nasal Septum | ☐ | ☐ |
| 23.) Other health problems Specify: _____ | ☐ | ☐ |
| 24.) Hospitalization: | | |
| a) 1 or 2 times | ☐ | ☐ |
| b) 3 or 4 times | ☐ | ☐ |
| c) More than 4 times | ☐ | ☐ |
| 25.) Surgery on mouth and/or nose. Specify: _____ | ☐ | ☐ |
| For Women Only | | |
| 26.) Irregular menstrual periods | ☐ | ☐ |
| 27.) Use of birth control pills | ☐ | ☐ |
| 28.) Problems associated with menopause | ☐ | ☐ |

Appendix H

# Brock University Sleep Research Laboratory

# Sleep & Activity Diary

**Instructions**:

- Please complete this diary each MORNING within 30 minutes after getting out of bed. It is important that you complete the diary first thing in the morning, and at approximately the same time each day.
- If you are unable to enter the data by computer in the morning, you may log your responses on paper and then enter them by computer later in the day (but, be sure to indicate the exact time you logged your responses on paper).

**Questions: Contact the Sleep Lab at: 905-685-5550 ext. 3795**
**or *email:*** *sin@brocku.ca*

## Part 1. Answer the following questions about how you felt **Going to Bed** last night:

1. At what time did you go to bed last night (lights out)? _____

2. How long do you think it took you to fall asleep (minutes)? _____

3. Did you experience any intrusive thoughts or worries when you were lying down to fall asleep?
   Select: Y or N
   **If YES-answer 3a and 3b below**

   a. How frequently did these thoughts, worries, and concerns come to mind as you were trying to fall asleep? Select a # from 1 to 7_____
      1- my mind was **free** of thoughts, worries and concerns

      4- my mind had **some** thoughts, worries, and concerns

      7- my mind was **filled** with thoughts, worries and concerns

   b. How distressing were these thoughts? Select a # from 1 to 7_____

      1-**not at all** distressing

      4-**somewhat** distressing

7-**very** distressing

4. Were there any unusual circumstances that made it difficult for you to fall asleep? (e.g., noise, température, physical symptoms, etc) Select: Y or N

If yes, Explain: _____

5. a. How much sleep did you get last night (hours and minutes)? _____

b. Was this a typical night for you (i.e., a typically good, or typically bad night): Select: Y or N

c. If the quality of your sleep was atypical, please explain:

_____

_____

## Part 2. Answer the following questions about how you felt **During the Night**:

5. Please rate the quality of your sleep last night, from your ***worst*** possible sleep (1) to your ***best*** possible sleep (7). Select a # from 1 to 7_____

6. a. How many times did you wake up in the middle of the night? _____
b. How much time did you spend awake in the middle of the night? (in minutes): _____

7. Were there any unusual circumstances that kept you awake during the night? (e.g., noise, temperature, physical symptoms, etc) Select: Y or N

If yes, Explain: _____

## Part 3. Answer the following questions about how you felt **Upon Awakening** this morning:

8. At what time did you wake up in the morning (time of last awakening)? _____

9. At what time did you get out of bed in the morning? _____

10. Select the number that best describes how you felt when you got out of bed this morning

**a. Fatigue Scale** Select one choice below _____

| | |
|---|---|
| Full of energy: enough to tackle my usual physical activities | 1 |
| Energy level is quite high but not at its peak: most physical activities would pose no problem. | 2 |
| Energy level is such that one would prefer to be doing very light or sedentary tasks at this point. | 3 |
| Energy level is adequate for only routine activities at a leisurely pace. | 4 |
| Energy level is such that it would be preferable to rest before doing any routine activity. | 5 |
| Energy level is quite low: would strongly prefer to rest rather than do anything else. | 6 |
| Totally physically exhausted: unable to undertake the least activity. | 7 |

**b. Sleepiness Scale** Select one choice below _____

| | |
|---|---|
| Feeling active, vital, alert, or wide awake | 1 |
| Functioning at high levels, but not at peak; able to concentrate | 2 |
| Awake, but relaxed; responsive but not fully alert | 3 |
| Somewhat foggy, let down | 4 |
| Foggy; losing interest in remaining awake; slowed down | 5 |
| Sleepy, woozy, fighting sleep; prefer to lie down | 6 |
| No longer fighting sleep, sleep onset soon; having dream-like thoughts | 7 |

## Part 4. Answer the following questions about how you felt **During the Previous Day**:

11. Did you experience any difficulty with daytime functioning yesterday (e.g., trouble paying attention or staying awake, working, studying, getting things done)?

Select a # from 1 to 7_____

1- I had no trouble functioning properly

4- I had some trouble functioning properly

7- I had a lot of trouble functioning properly

12. How sleepy did you feel yesterday during the daytime?

Select a # from 1 to 7_____

1- I did not feel sleepy at all

4- I felt somewhat sleepy

7- I felt extremely sleepy

13. Did you nap yesterday? Y or N

If YES, indicate total duration for all naps combined (in minutes) _____

14. Please complete the table below to indicate all of your **caffeine** intake (coffee, tea, cola, chocolate, energy drink), **alcohol** consumption, **medication/substance** use, and **exercise** activity during the previous day. Complete the table in chronological order, from morning to evening intake/activities

Add as many entries as needed

| Select Category | Specify type and amount | Time of day |
|---|---|---|
| ***Example**: Caffeine* | *1 cup coffee* | *08:00 am* |
| *Medication* | *1 500 mg Aspirin tab* | *3:00 pm* |
| *Exercise* | *1 hr Yoga* | *6:00 pm* |
| *Caffeine* | *1 can diet Coke* | *8:00 pm* |
| *Alcohol* | *2 glasses of wine* | *9:00 pm* |
| *Substance* | *1 Marijuana joint* | *11:00pm* |
| Select caffeine, alcohol, medication, or exercise for each line | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

| | | |
|---|---|---|
| | | |

15.Comments_____
_____
_____
_____

**Thank-you!**

**Call us if you have any questions (905-688-5550, ext. 3795).**

**Or if you can't reach us try the investigator (Reuben - 416-986-7651)**

Appendix I

BROCK UNIVERSITY SLEEP RESEARCH LABORATORY

PSYCHOLOGY DEPARTMENT

**Title of Study:** How Sleep Quality Impacts Emotion and Cognition

**Principal Investigator:** Kimberly A. Cote, Ph.D.

**Student Investigator:** Reuben Howlett

Please carefully read this form to understand all aspects of participation in this part of the research study. **If you have questions about the details of this study prior to completing the on-line questionnaires, please contact Reuben Howlett at 905-688-5550 ext.3795 (office), or 416-986-7651 (cell) or by email at sin@brocku.ca.**

**PART A: INFORMATION ABOUT THE STUDY**

I understand that I am being invited to participate in a research study investigating the role of sleep quality in daytime alertness, attention, and emotion. This study will be of benefit to me because I will learn about the impact of sleep quality on waking function. As well, it will inform the scientific community about the impact of poor sleep on waking brain function.

**I understand that there are four parts remaining to this study that will require:**

1. Completing a series of online questionnaires today (1 hour), and then completing an online daily sleep diary for a week (5 minutes a day, total 35 minutes), to further assess eligibility and to collect information on sleep and well-being.

2. Visiting the Brock University Sleep Research Laboratory for a 1-hour orientation session, where I will tour the facilities, have the study protocol explained, practice computerized performance tasks, and receive instruction on how to use equipment for recording sleep in my home.

3. Recording sleep in my home for 2 consecutive nights using equipment provided. Putting on and taking off the equipment takes 15 minutes each time for a total of 1 hour.

4. Spending an afternoon from 1:00pm until 4:00pm in the Brock University Sleep Research Laboratory following the 2 nights of home sleep recording. At this time, my performance will be assessed through computerized tasks while wearing electrodes to measure my brain activity, and I will fill out a few paper questionnaires.

For this online part of this study (part 1), I understand that I will be asked to complete screening questionnaires that ask about demographic information, sleep quality and habits, physical and mental health, substance use, and personality traits. I understand that the data collected from some of these questionnaires will be used to further assess my eligibility for continued participation in this study.

I also understand that I will be asked to report my sleep quality using the online sleep diary provided for a week until the end of the study. I also understand that I am asked to complete this daily sleep diary on-line within 30 minutes of awakening each day. This should take approximately 5 minutes a day.

I understand that there will be no compensation (monetary honorarium) for this online study-screening portion of the study. The honorarium will be given for the subsequent orientation, home recording and laboratory study parts. I will be paid 10$ for completion of the in-lab orientation session, 5$ for each night of at home sleep-recording, and 40$ for the final 3 hours in-lab session (total 60$).

I understand that if I am deemed eligible after the completion of these online surveys and questionnaires and agree to further participation in the study that I will be contacted to arrange an appointment for the orientation session, home-study and laboratory portions of the study (parts 2-4). During the orientation session, I will be asked to give informed consent to the other sections of the study through a separate written consent form.

**PART B: INFORMATION ABOUT STUDY RISKS & YOUR RIGHTS AS A PARTICIPANT**

I understand that my participation is voluntary and I may withdraw from the study at any time, for any reason. I understand that I may be withdrawn from the protocol by experimenters due to technical or compliance problems. Withdrawing or being withdrawn does not incur any penalty and does not affect my standing at Brock University if affiliated.

I understand that some of the content of this study is related to mood, psychological or physical illness, and other potentially sensitive topics. I am under no obligation to answer any question or participate in any aspect of this project that I consider invasive, offensive, distressing, or inappropriate. I understand that I may ask further questions at any time.

I understand that I will receive an honorarium payment for my participation in the parts of the study after the online questionnaire and sleep-diary. If I withdraw, I am withdrawn, or do not

meet study inclusion criteria during the online screening procedures there will be no compensation. The payment schedule is not designed because it will be more difficult to remain in the study over time, but rather that no data will be useable without complete participation of both sleep and in-lab waking performance data.

I understand that all of my study data will be kept strictly confidential and all information will be coded so that my name is not associated with my answers. Only the researchers named above, and research assistants working under supervision of these researchers, will have access to the data.

I understand that if I withdraw, am withdrawn, or I am deemed ineligible for further participation prior to the home-recording study part of the study, that data I have contributed to the study will be destroyed. I understand that only electronic copies of data collected from study tasks and questionnaires will be kept indefinitely, and that all paper data will be shredded upon final completion of the study and the writing of its results.

I understand that files kept indefinitely in electronic format will not be used for purposes outside the scope of the current study and are for the purpose of keeping records of scientific data (e.g., should anyone at some point in the future request these data for the purpose of validation of results). I understand that this information will be electronically and securely stored on electronic storage devices in the Brock Sleep Laboratory, which is secured, by locked doors and 24-7 camera-surveillance.

I understand that any personal information (e.g., name and contact information) is collected for contacting me about the study and will be destroyed upon completion of the study. I understand that data collected from questionnaires and study tasks will be identified with a unique ID code and that my contact information will not be associated with this ID code after I finish my participation in this study. Additionally, I understand that all data is kept in the secured Sleep Research Laboratory during data collection and analysis and that my ID code will never be used in presentation or publication of any data.

**Checking the box below indicates that, you are of the age of legal consent (i.e., 18 years or older), you have read and understood the details of this part of the study, and you agree to participate.**

☐ Checking this box indicates your Electronic Signature for consent to participate in this part of the study (online questionnaires).

**PART C: CONTACT INFORMATION**

This research is funded by two internal grants from Brock University, a Brock University Advancement Fund (BUAF), and the Council for Research in the Social Sciences (CRISS). This study has been reviewed and cleared by the Brock Bioscience Research Ethics Board (REB-17-322). For answers to questions about your rights as a research participant, contact the Research Ethics Officer, at (905) 688-5550 ext. 3035, or reb@brocku.ca.

If you have any questions or concerns about your participation in the study you may contact the Principal Investigator, Dr. Kimberly Cote in the Psychology Department at (905) 688-5550, extension 4806.

No individual feedback from the sleep study or performance data may be provided at any time. Feedback about the outcome of the study will be available for all participants including those deemed ineligible or who have withdrawn. Feedback will be available by request after completion of the research project in the second-half of 2019 (email: kcote@brocku.ca).

Please print a copy of this form for future reference.

IF YOU NEED TO CONTACT THE LABORATORY REGARDING YOUR APPOINTMENT OR STUDY PROCEDURES, PLEASE **CALL Reuben Howlett at 905-688-5550, EXT. 3795, or reach him by cell phone at 289-407-1567. You may also send email requests to sleeplab@brocku.ca.**

Appendix J

BROCK UNIVERSITY SLEEP RESEARCH LABORATORY

PSYCHOLOGY DEPARTMENT

**Title of Study:** How Sleep Quality Impacts Emotion and Cognition

**Principal Investigator:** Kimberly A. Cote, Ph.D.

**Student Investigator:** Reuben Howlett

**Instructions**: Please carefully read this form to understand all aspects of participation in the research study. Ask the research assistant if you have any questions.

**Name of Participant:**

_____

(*Please print your name in the space above*)

**PART A: INFORMATION ABOUT THE STUDY**

I understand that I am being invited to participate in a research study investigating the role of sleep quality in daytime alertness, attention, and emotion. This study will be of benefit to me because I will learn about the impact of sleep on emotion processing. As well, it will inform the scientific community about the impact of sleep on waking brain function. My participation in this study will allow me to learn about the application and measurement of EEG. As well, if I have poor sleep, this study could allow me to learn more about my symptoms and learn how to better track my own sleep habits using a sleep diary. If I have poor sleep I will also be given a booklet that is intended to aid me in overcoming my poor and reduce its severity.

The results will be published in the Brock Library's Student Thesis database (https://brocku.ca/library/help/theses-and-dissertations/) and potentially in a published journal. The study is expected to be completed and accessible to me in the second half of 2019. Results from the study will be available by request after study completion (see Contact Information section).

**I understand that there are three parts remaining to the study that will require:**

1. Visiting the Brock University Sleep Research Laboratory today for a 1-hour orientation session, where I will tour the facilities, have the study protocol fully explained, practice computerized performance tasks, and receive instruction on how to use home sleep recording equipment.

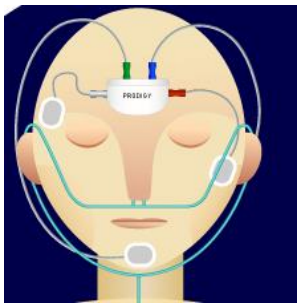
2. Recording sleep in my home for 2 consecutive nights using equipment provided. Putting on or taking off the equipment takes 15 minutes each time for a total of 1 hour.

3. Spending an afternoon from 1:00pm until 4:00pm in the Brock University Sleep Research Laboratory following the 2 nights of home sleep recording. At this time my performance will be assessed through computerized tasks while wearing electrodes to measure my brain activity, and I will fill out a few paper questionnaires.

**During the home data collection phase of study (part 2 above), I understand that I must:**

- Record my sleep for 2 consecutive nights
- Change the batteries before the 2nd night of recording
- Consume no caffeine or alcohol after 6pm each evening
- Follow my regular routine for bedtime and waking up (i.e., no set bed or wakeup times)
- Complete the online sleep diary each morning

I understand that I will be shown how to use the home sleep recording equipment today and be sent home with written instructions. In brief, I will be asked to apply the head monitor and attach sensors to clean skin on my forehead, near my eyes, and on my chin See Figure below.



The Prodigy monitor will take about 10-15 minutes to apply.

I understand that if I have any questions with the home sleep recording procedures, I may **contact the student investigator, Reuben Howlett by cell phone at 416-986-7651**.

I understand that the equipment loaned to me is property of the Brock University Sleep Research Laboratory and should be handled with care and returned after the 2 nights of recording. I understand that if I withdraw or I am withdrawn from the study by investigators, I must return the equipment promptly to the Brock University Sleep Research Laboratory.

**<u>On the day of my afternoon Sleep Lab visit (part 3 above), I understand that I must:</u>**

- Be awake and out of bed by 8am at the latest
- Refrain from alcohol and caffeine use that day
- Take no naps on that day
- Not engage in vigorous exercise on that day
- Eat breakfast soon after awakening, and eat lunch prior to the 1pm appointment

- ***I must arrive to the Brock University Sleep Research Laboratory (MC-B416 – 4$^{th}$ floor) at 1:00 pm sharp.***

I understand that my brain activity will be monitored by electrodes taped on my face (near eyes, under chin, and under collar bone) and forehead, and attached to my scalp using gauze and water-soluble paste. These electrodes monitor eye movements, muscle activity, heart rate, and electric brain and scalp activity. Electrode sites will first be quickly cleaned using an alcohol swab and a mildly abrasive conductive gel. All electrodes will be removed by the investigators at the end of each session. The remaining gel can be washed off easily in the laboratory with soap and warm water.

I understand that I will perform a variety of computerized tasks designed to measure processing of cognitive and emotional information. I will also complete some short computerized questionnaires that measure mood, alertness and perception of performance. Further, I understand that I will complete paper surveys to provide the researcher information on personality, mood, and phase of the menstrual cycle (for women only).

## PART B: INFORMATION ABOUT STUDY RISKS & YOUR RIGHTS AS A PARTICIPANT

I understand that my participation is voluntary and I may withdraw from the study at any time, for any reason. I understand that I may be withdrawn from the protocol by experimenters due to technical or compliance problems. Withdrawing or being withdrawn does not incur any penalty and does not affect my standing at Brock University if affiliated.

I understand that some of the content of this study is related to mood, psychological or physical illness, and other potentially sensitive topics. I am under no obligation to answer any question or participate in any aspect of this project that I consider invasive, offensive, distressing, or inappropriate. I understand that I may ask further questions at any time.

I understand that I may experience some skin irritation (redness and dry skin) as a result of having electrodes attached to my skin during the home sleep-monitoring and in-lab performance assessment portions of this study. This is temporary and may be reduced by applying moisturizing cream to the areas after electrodes are removed.

I understand that the Sleep Laboratory facilities are under 24-hour video surveillance for safety reasons. All activities in the main laboratory, bedrooms, and the kitchen/lounge areas are

recorded and stored in the Sleep Laboratory until completion of the study. The videotaped data will not be used in public presentation or advertising. I understand that I will receive an honorarium payment for my participation. I will be paid a total of $60 for completion of the full study. If I withdraw, I am withdrawn, or do not meet study inclusion criteria after the orientation session I will receive 10$ in compensation. If I withdraw, I am withdrawn or I am deemed ineligible after recording sleep in my home, I will receive partial honorarium (5$ for each night of home-recording, 10$ total). If I complete the final in-lab performance day I will receive 40$. Each stage is cumulative and so I understand I will receive up to 60$ total.

I understand that all of my study data will be kept strictly confidential and all information will be coded so that my name is not associated with my answers. Only the researchers named above, and research assistants working under supervision of these researchers, will have access to the data. I understand that I am not anonymous in this study because the nature of the study requires that research assistants interact with each participant in the laboratory and by correspondence on a one-to-one basis and have contact information to schedule appointments, and that there may be other participants of the current or other studies also in the Sleep Lab at my time of study.

I understand that any personal information (e.g., name and contact information) is collected for contacting me about the study and will be destroyed upon completion of the study. I understand that data collected from questionnaires and study tasks will be identified with a unique ID code and that my contact information will not be associated with this ID code after I finish my participation in this study. Additionally, I understand that all data is kept in the secured Sleep Research Laboratory during data collection and analysis and that my ID code will never be used in presentation or publication of any data.

I understand that for the purpose of processing honorarium payment through the Finance Office, personal information (including name, address, and social insurance number) will be forwarded to administrative staff in the Psychology Department, Office of Research Services, and Finance office at Brock University.

I understand that if I withdraw, am withdrawn, or I am deemed ineligible by the experimenters before recording my sleep, that data I have contributed to the study will be destroyed. If I complete sleep recordings my data will be destroyed by request. I also understand that if I do not request to have data destroyed, that it may be of benefit to researchers, and I give permission for its use.

I understand that only electronic copies of data collected from study tasks and questionnaires will be kept indefinitely and that all paper data will be shredded upon final publication of the results. I understand that files kept indefinitely in electronic format will not be used for purposes outside the scope of the current study and are for the purpose of keeping records of scientific data (e.g., should anyone at some point in the future request these data for the purpose of validation of results). I understand that this information will be electronically and securely stored on offline electronic storage devices in the Brock Sleep Laboratory which is secured by locked doors and 24-7 camera-surveillance.

**PART C: CONTACT INFORMATION**

This research is funded by two internal grants from Brock University, a Brock University Advancement Fund (BUAF), and the Council for Research in the Social Sciences (CRISS). This study has been reviewed and cleared by the Brock Bioscience Research Ethics Board (REB17-322). For answers to questions about your rights as a research participant, contact the Research Ethics Officer, at (905) 688-5550 ext. 3035, or reb@brocku.ca.

If you have any questions or concerns about your participation in the study you may contact the Principal Investigator, Dr. Kimberly Cote in the Psychology Department at (905) 688-5550, extension 4806.

No individual feedback from the sleep study or performance data may be provided at any time. Feedback about the outcome of the study will be available for all participants including those deemed ineligible or who have withdrawn. They will be available by request after completion of the research project in the second-half of 2019 (email: kcote@brocku.ca).

Please take a copy of this form with you for future reference. IF YOU NEED TO CONTACT THE LABORATORY REGARDING YOUR APPOINTMENT OR STUDY PROCEDURES, PLEASE **CALL Reuben Howlett at 905-688-5550, EXT. 3795, or reach him by cell phone at 289-407-1567. You may also send email requests to sleeplab@brocku.ca**

**PART D: HONORARIUM AND SIGNATURES**

**I am participating in this experiment for $_____; this study is not eligible for course credit for Brock University students.**

**My signature below indicates I am the age of legal consent (18 years or older) and have read and understood the procedures of the study and agree to participate.**

**Participant's Signature_____Date _____**

**For Researcher:**

**I have fully explained the procedures of this study to the above volunteer.**

**Researcher's Signature_____Date _____**

Appendix K

Table 19.

*Bivariate correlations between insomnia severity index (ISI), Pittsburgh sleep quality index (PSQI), and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | ISI | PSQI | ISI | PSQI | ISI | PSQI |
| Response Time | .04 | .20 | .19 | -.01 | .17 | .18 |
| Response Time SD | -.10 | .13 | -.04 | -.20 | -.01 | .04 |
| Fastest 10% Response Time | -.03 | .09 | .18 | .01 | .13 | .13 |
| Slowest 10% Response Time | -.08 | -.15 | -.13 | .20 | -.20 | -.19 |
| Number of Lapses | -.21 | .18 | -.29 | .01 | -.16 | .03 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | .30 | .10 | -.45 | **-.60*** | -.17 | -.24 |
| Angry Congruent Response Time | .27 | .14 | -.20 | -.49 | -.08 | -.20 |
| Neutral Congruent Response Time | -.01 | -.12 | -.28 | **-.82**** | -.12 | -.30 |
| Sad Congruent Response Time | .10 | .02 | -.49 | **-.77**** | -.23 | -.27 |
| Happy Incongruent Response Time | .09 | .00 | -.36 | **-.60*** | -.20 | -.30 |
| Angry Incongruent Response Time | .14 | .07 | -.06 | -.43 | -.05 | -.17 |
| Neutral Incongruent Response Time | .06 | -.09 | -.26 | -.55 | -.12 | -.22 |
| Sad Incongruent Response Time | .16 | .14 | -.27 | **-.65*** | -.16 | -.25 |
| Happy Interference | **-.56*** | -.27 | .19 | .18 | -.11 | -.18 |
| Angry Interference | -.26 | -.15 | .22 | -.09 | .06 | .01 |
| Neutral Interference | .11 | -.02 | .03 | .26 | -.03 | .01 |
| Sad Interference | .09 | .23 | .39 | .20 | .19 | .10 |
| Happy Congruent Accuracy | .16 | .01 | -.31 | **-.61*** | .08 | .04 |
| Angry Congruent Accuracy | .18 | .07 | -.07 | -.15 | -.10 | -.15 |
| Neutral Congruent Accuracy | .03 | -.34 | -.17 | .39 | .03 | .14 |
| Sad Congruent Accuracy | .**56*** | .35 | -.05 | .07 | .15 | .14 |
| Happy Incongruent Accuracy | .06 | .19 | -.23 | -.23 | .18 | .28 |
| Angry Incongruent Accuracy | .33 | .09 | -.30 | -.21 | -.17 | -.19 |
| Neutral Incongruent Accuracy | .37 | .15 | -.18 | .29 | -.07 | .00 |
| Sad Incongruent Accuracy | -.15 | -.07 | -.13 | -.15 | -.13 | -.14 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.13 | -.25 | -.23 | -.21 | -.24 | -.25 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Response Time | -.06 | -.40 | -.05 | .07 | -.15 | -.26 |
| Fear Response Time | -.02 | -.31 | -.28 | -.55 | -.12 | -.23 |
| Sad Response Time | -.09 | -.26 | -.51 | -.30 | -.27 | -.24 |
| Happy Accuracy | .22 | -.16 | .16 | .04 | -.02 | -.17 |
| Angry Accuracy | .00 | -.09 | -.35 | -.16 | -.12 | -.03 |
| Fear Accuracy | -.47 | -.39 | -.29 | .11 | -.36 | -.26 |
| Sad Accuracy | .23 | .03 | .25 | -.16 | .03 | -.20 |
| Happy Intensity Rating | -.41 | .08 | .31 | -.02 | .14 | .01 |
| Angry Intensity Rating | -.13 | -.25 | **.54*** | .33 | .11 | -.04 |
| Fear Intensity Rating | -.33 | -.30 | .27 | .20 | -.06 | -.19 |
| Sad Intensity Rating | -.07 | -.04 | .52 | .25 | .24 | .08 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 20.

*Bivariate correlations between total sleep time (TST), and sleep efficiency (SE) and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | TST | SE | TST | SE | TST | SE |
| Response Time | .10 | .18 | .47 | **.57*** | .26 | **.38*** |
| Response Time SD | -.17 | -.17 | .09 | .40 | -.01 | .19 |
| Fastest 10% Response Time | .27 | .48 | **.56*** | .39 | .36 | .31 |
| Slowest 10% Response Time | .00 | .01 | -.50 | **-.63*** | -.23 | -.35 |
| Number of Lapses | -.11 | .01 | -.23 | .28 | -.13 | .15 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.32 | -.35 | -.29 | -.49 | -.21 | -.33 |
| Angry Congruent Response Time | -.38 | -.26 | **-.54*** | **-.66*** | -.32 | -.36 |
| Neutral Congruent Response Time | -.37 | -.23 | -.24 | -.49 | -.25 | **-.41*** |
| Sad Congruent Response Time | -.28 | -.45 | -.26 | -.42 | -.15 | -.26 |
| Happy Incongruent Response Time | -.40 | -.48 | -.39 | **-.74**** | -.28 | **-.49**** |
| Angry Incongruent Response Time | -.44 | -.48 | -.37 | -.37 | -.28 | -.28 |
| Neutral Incongruent Response Time | -.38 | -.46 | -.40 | **-.59*** | -.32 | **-.45*** |
| Sad Incongruent Response Time | -.39 | -.44 | -.37 | -.49 | -.26 | -.34 |
| Happy Interference | -.30 | -.42 | -.30 | **-.68**** | -.22 | **-.49**** |
| Angry Interference | -.23 | **-.62*** | .17 | .37 | .01 | .09 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Neutral Interference | -.20 | -.46 | -.23 | -.12 | -.16 | -.14 |
| Sad Interference | -.12 | .18 | -.26 | -.21 | -.19 | -.10 |
| Happy Congruent Accuracy | .42 | .23 | -.01 | -.28 | .08 | -.10 |
| Angry Congruent Accuracy | .42 | .28 | .11 | .07 | .22 | .13 |
| Neutral Congruent Accuracy | .21 | -.27 | .14 | .04 | .10 | -.06 |
| Sad Congruent Accuracy | .09 | .27 | .28 | -.07 | .17 | -.06 |
| Happy Incongruent Accuracy | **.53*** | .47 | .46 | -.07 | .24 | -.02 |
| Angry Incongruent Accuracy | .31 | .50 | .29 | -.10 | .31 | .07 |
| Neutral Incongruent Accuracy | -.10 | -.26 | .24 | -.18 | .14 | -.13 |
| Sad Incongruent Accuracy | -.05 | .47 | .24 | .02 | .19 | .09 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | .02 | -.03 | -.36 | -.07 | -.11 | .01 |
| Angry Response Time | -.14 | -.10 | **-.68**** | **-.58*** | -.28 | -.27 |
| Fear Response Time | -.01 | -.04 | -.44 | -.32 | -.21 | -.17 |
| Sad Response Time | -.01 | -.14 | -.30 | -.27 | -.09 | -.13 |
| Happy Accuracy | .23 | .09 | .38 | -.10 | **.38*** | -.03 |
| Angry Accuracy | .49 | .29 | .49 | -.07 | **.41*** | .00 |
| Fear Accuracy | .02 | -.24 | .13 | -.20 | .16 | -.11 |
| Sad Accuracy | -.08 | -.16 | .43 | -.04 | .34 | -.01 |
| Happy Intensity Rating | .13 | -.01 | -.20 | -.28 | -.14 | -.24 |
| Angry Intensity Rating | -.10 | -.06 | .00 | .22 | .00 | .14 |
| Fear Intensity Rating | -.25 | -.19 | -.15 | -.29 | -.10 | -.17 |
| Sad Intensity Rating | -.22 | -.16 | -.22 | -.08 | -.21 | -.10 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 21.

*Bivariate correlations between sleep onset latency (SOL), and wake after sleep onset (WASO) and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | SOL | WASO | SOL | WASO | SOL | WASO |
| Response Time | -.18 | -.17 | -.19 | -.51 | -.15 | -.36 |
| Response Time SD | .02 | .07 | -.39 | -.35 | -.19 | .31 |
| Fastest 10% Response Time | -.39 | -.33 | .16 | -.37 | -.03 | -.29 |
| Slowest 10% Response Time | .02 | .04 | .36 | .52 | .19 | .32 |
| Number of Lapses | -.10 | -.04 | -.35 | -.32 | -.21 | -.18 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | .29 | .12 | -.10 | **.57*** | **.57*** | .35 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Congruent Response Time | .20 | -.01 | .07 | **.69**** | **.69**** | .34 |
| Neutral Congruent Response Time | .20 | .04 | -.08 | **.59*** | **.59*** | **.47**** |
| Sad Congruent Response Time | .09 | .36 | .15 | .42 | .42 | .27 |
| Happy Incongruent Response Time | .49 | .17 | .05 | **.80**** | **.80**** | **.50**** |
| Angry Incongruent Response Time | .46 | .16 | -.18 | .43 | .43 | .26 |
| Neutral Incongruent Response Time | .25 | .31 | .02 | **.64*** | **.64*** | **.47**** |
| Sad Incongruent Response Time | .27 | .23 | .07 | .52 | .52 | .34 |
| Happy Interference | **.66**** | .16 | .37 | **.67**** | **.67**** | **.46*** |
| Angry Interference | **.69**** | .41 | -.48 | -.31 | -.31 | -.10 |
| Neutral Interference | .19 | .43 | .15 | .06 | .06 | .11 |
| Sad Interference | .32 | -.38 | -.14 | .27 | .27 | .08 |
| Happy Congruent Accuracy | .05 | -.16 | .23 | .24 | .24 | .09 |
| Angry Congruent Accuracy | -.24 | -.11 | -.31 | -.01 | -.01 | -.05 |
| Neutral Congruent Accuracy | .28 | .32 | .40 | -.14 | -.14 | .01 |
| Sad Congruent Accuracy | -.10 | -.38 | -.16 | .20 | .20 | .13 |
| Happy Incongruent Accuracy | **-.63*** | -.13 | .40 | .09 | .09 | .06 |
| Angry Incongruent Accuracy | **-.70**** | -.24 | -.13 | .21 | .21 | .07 |
| Neutral Incongruent Accuracy | .06 | .18 | .45 | .12 | .12 | .09 |
| Sad Incongruent Accuracy | -.46 | -.40 | -.26 | .06 | .06 | -.02 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.22 | .17 | -.44 | .10 | -.34 | .06 |
| Angry Response Time | -.23 | .21 | .02 | **.59*** | -.12 | .32 |
| Fear Response Time | -.29 | .20 | -.31 | .40 | -.28 | .26 |
| Sad Response Time | -.26 | .33 | -.27 | .31 | -.26 | .21 |
| Happy Accuracy | -.47 | .21 | .48 | .12 | .27 | .10 |
| Angry Accuracy | **-.60*** | .11 | .24 | .13 | -.05 | .12 |
| Fear Accuracy | -.19 | **.53*** | -.11 | .26 | -.17 | .23 |
| Sad Accuracy | -.06 | .16 | .11 | .19 | .04 | .14 |
| Happy Intensity Rating | -.22 | .09 | -.16 | .30 | -.16 | .26 |
| Angry Intensity Rating | -.39 | .22 | -.13 | -.26 | -.23 | -.13 |
| Fear Intensity Rating | -.18 | .25 | -.05 | .35 | -.12 | .24 |
| Sad Intensity Rating | -.16 | .14 | -.08 | .07 | -.09 | .09 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).

Table 22.

*Bivariate correlations between time in wake, time in stage 1, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | Time in Wake | Time in S1 | Time in Wake | Time in S1 | Time in Wake | Time in S1 |
| Response Time | -.21 | .17 | -.19 | -.51 | -.36 | .10 |
| Response Time SD | .09 | .23 | -.42 | -.24 | -.20 | -.02 |
| Fastest 10% Response Time | -.41 | .15 | .16 | -.37 | -.28 | .25 |
| Slowest 10% Response Time | .02 | -.26 | .36 | .52 | .30 | -.06 |
| Number of Lapses | -.04 | .26 | -.42 | -.55 | -.22 | -.14 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | .15 | .37 | -.10 | **.57*** | .28 | .15 |
| Angry Congruent Response Time | .02 | .38 | .07 | **.69**** | .26 | .04 |
| Neutral Congruent Response Time | .06 | .46 | -.08 | **.59*** | .33 | -.07 |
| Sad Congruent Response Time | .11 | .40 | .15 | .42 | .21 | .12 |
| Happy Incongruent Response Time | .33 | .27 | .05 | **.80**** | **.47*** | .07 |
| Angry Incongruent Response Time | .31 | .22 | -.18 | .43 | .24 | .01 |
| Neutral Incongruent Response Time | .23 | .29 | .02 | **.64*** | **.39*** | -.02 |
| Sad Incongruent Response Time | .22 | .29 | .07 | .52 | .32 | -.09 |
| Happy Interference | **.56*** | -.23 | .37 | **.67**** | **.57**** | -.19 |
| Angry Interference | **.73**** | -.31 | -.48 | -.31 | .03 | -.05 |
| Neutral Interference | .28 | -.03 | .15 | .06 | .15 | .06 |
| Sad Interference | .17 | -.36 | -.14 | .27 | .16 | **-.42*** |
| Happy Congruent Accuracy | -.04 | .15 | .23 | .24 | .13 | -.04 |
| Angry Congruent Accuracy | -.26 | .22 | -.31 | -.01 | -.15 | -.11 |
| Neutral Congruent Accuracy | .39 | .34 | .40 | -.14 | .21 | .36 |
| Sad Congruent Accuracy | -.48 | -.09 | -.16 | .20 | -.03 | .33 |
| Happy Incongruent Accuracy | **-.59*** | .29 | .40 | .09 | -.07 | .14 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Incongruent Accuracy | **-.72**** | .41 | -.13 | .21 | -.20 | .27 |
| Neutral Incongruent Accuracy | .03 | **.57*** | .45 | .12 | .12 | **.64**** |
| Sad Incongruent Accuracy | **-.58*** | .37 | -.26 | .06 | -.20 | .36 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.07 | **.58*** | -.44 | .10 | -.08 | -.06 |
| Angry Response Time | -.07 | **.81**** | .02 | **.59*** | .18 | .09 |
| Fear Response Time | -.16 | **.83**** | -.31 | .40 | .05 | -.08 |
| Sad Response Time | -.04 | **.64**** | -.27 | .31 | .07 | .23 |
| Happy Accuracy | -.31 | .50 | .48 | .12 | .14 | .30 |
| Angry Accuracy | -.43 | **.53*** | .24 | .13 | .01 | .34 |
| Fear Accuracy | .25 | .38 | -.11 | .26 | .17 | .35 |
| Sad Accuracy | .04 | .31 | .11 | .19 | .15 | -.04 |
| Happy Intensity Rating | -.20 | .30 | -.16 | .30 | .10 | -.10 |
| Angry Intensity Rating | -.31 | **.53*** | -.13 | -.26 | -.31 | .03 |
| Fear Intensity Rating | -.04 | **.51*** | -.05 | .35 | .09 | -.19 |
| Sad Intensity Rating | -.20 | .48 | -.08 | .07 | -.08 | -.21 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).

Table 23.

*Bivariate correlations between time in stage 2, time in stage 3 (SWS), and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | Time in S2 | Time in S3 | Time in S2 | Time in S3 | Time in S2 | Time in S3 |
| Response Time | -.05 | .16 | .21 | .21 | .00 | .17 |
| Response Time SD | -.19 | .00 | .21 | -.15 | -.02 | -.06 |
| Fastest 10% Response Time | .06 | .14 | .14 | .36 | .02 | .21 |
| Slowest 10% Response Time | .16 | -.13 | -.33 | -.02 | .02 | -.08 |
| Number of Lapses | .01 | -.09 | -.14 | -.11 | -.03 | .10 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.03 | -.37 | .26 | **-.78**** | .14 | **-.54**** |
| Angry Congruent Response Time | -.14 | -.29 | -.08 | **-.63*** | -.06 | **-.41*** |
| Neutral Congruent Response Time | -.08 | -.42 | .09 | **-.61*** | .03 | **-.48*** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sad Congruent Response Time | -.04 | -.28 | .05 | -.39 | .05 | -.33 |
| Happy Incongruent Response Time | .00 | -.41 | .19 | **-.79**** | .13 | **-.57**** |
| Angry Incongruent Response Time | -.14 | -.27 | .14 | **-.65*** | .01 | **-.41*** |
| Neutral Incongruent Response Time | .07 | -.33 | .04 | **-.62*** | .10 | **-.44*** |
| Sad Incongruent Response Time | .00 | -.41 | -.09 | -.46 | .01 | **-.44*** |
| Happy Interference | .07 | -.19 | -.14 | -.14 | .00 | -.17 |
| Angry Interference | -.04 | -.01 | .43 | -.22 | .14 | -.12 |
| Neutral Interference | .18 | -.08 | -.07 | .01 | .11 | -.03 |
| Sad Interference | .08 | -.14 | -.27 | -.21 | -.08 | -.15 |
| Happy Congruent Accuracy | .03 | .24 | .29 | -.01 | .05 | .16 |
| Angry Congruent Accuracy | .41 | -.15 | .19 | -.02 | .31 | -.12 |
| Neutral Congruent Accuracy | .14 | -.06 | .13 | .37 | .08 | .09 |
| Sad Congruent Accuracy | .11 | .14 | .25 | -.35 | .16 | -.09 |
| Happy Incongruent Accuracy | .29 | -.08 | .34 | .07 | .18 | .01 |
| Angry Incongruent Accuracy | .12 | .01 | .47 | -.25 | .32 | -.12 |
| Neutral Incongruent Accuracy | -.20 | -.10 | .38 | .06 | .09 | -.05 |
| Sad Incongruent Accuracy | .12 | -.34 | .52 | -.22 | .36 | -.27 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | .40 | **-.56*** | .23 | -.45 | .37 | **-.55**** |
| Angry Response Time | -.02 | -.46 | -.32 | -.51 | -.07 | **-.49**** |
| Fear Response Time | .13 | **-.52*** | .02 | -.52 | .11 | **-.51**** |
| Sad Response Time | .24 | -.47 | .49 | **-.71**** | .35 | **-.58**** |
| Happy Accuracy | .03 | -.03 | -.07 | .02 | -.02 | .01 |
| Angry Accuracy | .49 | -.27 | .30 | -.06 | .35 | -.18 |
| Fear Accuracy | .29 | -.47 | .49 | -.48 | **.42*** | **-.50**** |
| Sad Accuracy | .03 | -.19 | .16 | -.13 | .10 | -.15 |
| Happy Intensity Rating | .38 | -.47 | .06 | -.33 | .16 | **-.38*** |
| Angry Intensity Rating | .31 | -.48 | -.23 | .31 | .11 | -.12 |
| Fear Intensity Rating | .19 | **-.61*** | -.19 | -.23 | .07 | **-.45*** |
| Sad Intensity Rating | .17 | **-.57*** | -.34 | .05 | -.06 | -.26 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).

Table 24.

*Bivariate correlations between time in REM, time in NREM, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | REM | NREM | REM | NREM | REM | NREM |
| Response Time | -.23 | .18 | .29 | .25 | .06 | .09 |
| Response Time SD | -.17 | -.12 | .19 | .01 | .04 | -.06 |
| Fastest 10% Response Time | -.15 | .32 | .29 | .37 | .09 | .20 |
| Slowest 10% Response Time | .19 | -.05 | -.44 | -.23 | -.16 | .00 |
| Number of Lapses | -.31 | .00 | -.02 | -.20 | -.12 | -.07 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.24 | -.20 | -.05 | -.23 | -.10 | -.14 |
| Angry Congruent Response Time | -.22 | -.27 | -.42 | **-.56*** | -.27 | -.31 |
| Neutral Congruent Response Time | -.14 | -.27 | .02 | -.37 | -.03 | -.28 |
| Sad Congruent Response Time | -.38 | -.10 | .02 | -.27 | -.12 | -.11 |
| Happy Incongruent Response Time | -.28 | -.26 | -.24 | -.32 | -.21 | -.20 |
| Angry Incongruent Response Time | -.28 | -.30 | -.23 | -.34 | -.21 | -.27 |
| Neutral Incongruent Response Time | -.42 | -.17 | -.14 | -.46 | -.24 | -.20 |
| Sad Incongruent Response Time | -.43 | -.21 | -.07 | -.50 | -.18 | -.29 |
| Happy Interference | -.15 | -.20 | -.48 | -.25 | -.32 | -.19 |
| Angry Interference | -.20 | -.14 | .25 | .28 | .07 | .01 |
| Neutral Interference | -.50 | .01 | -.24 | -.11 | -.31 | .05 |
| Sad Interference | .05 | -.16 | -.19 | -.51 | -.09 | -.33 |
| Happy Congruent Accuracy | .28 | .28 | -.11 | .22 | .06 | .16 |
| Angry Congruent Accuracy | -.16 | .47 | .38 | .15 | .24 | .29 |
| Neutral Congruent Accuracy | -.14 | .24 | -.24 | .51 | -.19 | .27 |
| Sad Congruent Accuracy | .28 | .01 | .47 | .16 | .37 | .19 |
| Happy Incongruent Accuracy | .28 | .40 | .22 | .46 | .14 | .33 |
| Angry Incongruent Accuracy | .04 | .29 | .49 | .35 | .33 | **.40*** |
| Neutral Incongruent Accuracy | -.07 | -.10 | -.11 | **.61*** | -.06 | .29 |
| Sad Incongruent Accuracy | -.17 | .04 | .31 | .44 | .20 | .34 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.50 | .23 | -.05 | -.18 | -.16 | .10 |
| Angry Response Time | -.25 | -.03 | **-.57*** | **-.70**** | -.32 | -.26 |
| Fear Response Time | -.16 | .06 | -.22 | -.49 | -.16 | -.12 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sad Response Time | -.50 | .20 | .03 | .00 | -.15 | .13 |
| Happy Accuracy | .15 | .16 | -.11 | .05 | -.05 | .12 |
| Angry Accuracy | -.22 | **.56*** | .44 | .36 | .18 | **.42*** |
| Fear Accuracy | -.34 | .14 | .31 | .34 | .12 | .30 |
| Sad Accuracy | -.13 | -.05 | -.14 | .01 | -.13 | .03 |
| Happy Intensity Rating | -.24 | .22 | .09 | -.17 | -.01 | -.07 |
| Angry Intensity Rating | -.42 | .11 | .13 | -.07 | -.08 | .14 |
| Fear Intensity Rating | -.29 | -.11 | -.07 | -.41 | -.14 | -.16 |
| Sad Intensity Rating | -.12 | -.13 | -.15 | -.39 | -.17 | -.18 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 25.

*Bivariate correlations between diary reports of total sleep time (TST) and sleep efficiency (SE), and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | Diary TST | Diary SE | Diary TST | Diary SE | Diary TST | Diary SE |
| Response Time | -.13 | -.35 | -.10 | -.17 | -.18 | -.21 |
| Response Time SD | -.23 | .12 | .17 | .28 | .00 | .15 |
| Fastest 10% Response Time | .11 | -.18 | -.17 | -.36 | -.11 | -.29 |
| Slowest 10% Response Time | .19 | .37 | -.13 | -.10 | .12 | .09 |
| Number of Lapses | -.28 | .19 | .09 | .25 | -.01 | .15 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.36 | -.09 | **.67*** | **.76**** | .25 | **.48*** |
| Angry Congruent Response Time | -.42 | -.23 | .49 | **.70**** | .11 | .38 |
| Neutral Congruent Response Time | -.32 | -.17 | **.61*** | **.67*** | .24 | **.44*** |
| Sad Congruent Response Time | -.37 | .07 | **.75**** | **.80**** | .23 | **.47*** |
| Happy Incongruent Response Time | -.36 | -.11 | **.58*** | **.62*** | .20 | **.40*** |
| Angry Incongruent Response Time | -.41 | -.19 | .42 | **.57*** | .05 | .29 |
| Neutral Incongruent Response Time | -.46 | -.19 | **.68*** | **.70**** | .17 | **.40*** |
| Sad Incongruent Response Time | -.54 | -.08 | **.70**** | **.79**** | .20 | **.50**** |
| Happy Interference | -.08 | -.09 | -.12 | -.23 | -.10 | -.18 |
| Angry Interference | -.17 | .05 | .01 | -.06 | -.14 | -.12 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Neutral Interference | -.38 | -.12 | .07 | .02 | -.05 | .04 |
| Sad Interference | -.36 | -.51 | .01 | .12 | -.11 | .01 |
| Happy Congruent Accuracy | .40 | -.12 | .25 | .07 | .14 | -.08 |
| Angry Congruent Accuracy | .22 | .25 | .13 | -.02 | .24 | .11 |
| Neutral Congruent Accuracy | .45 | .47 | -.27 | -.55 | .00 | -.29 |
| Sad Congruent Accuracy | .04 | -.29 | .19 | .06 | .07 | -.03 |
| Happy Incongruent Accuracy | .29 | .13 | .33 | -.02 | .07 | -.13 |
| Angry Incongruent Accuracy | .24 | .24 | .29 | -.06 | .37 | .12 |
| Neutral Incongruent Accuracy | -.21 | -.09 | -.17 | -.52 | -.03 | -.20 |
| Sad Incongruent Accuracy | .00 | .04 | .04 | -.21 | .08 | -.10 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.10 | .17 | .22 | .30 | .20 | .29 |
| Angry Response Time | -.05 | .21 | .16 | .49 | .14 | .35 |
| Fear Response Time | .01 | .26 | .49 | **.65*** | .26 | **.41*** |
| Sad Response Time | -.13 | .26 | .53 | .51 | .24 | .35 |
| Happy Accuracy | .31 | .46 | -.01 | .11 | .10 | .16 |
| Angry Accuracy | .32 | .46 | .21 | -.02 | .21 | .04 |
| Fear Accuracy | -.11 | .27 | .16 | .04 | .17 | .16 |
| Sad Accuracy | -.22 | -.15 | -.05 | -.22 | -.06 | -.12 |
| Happy Intensity Rating | .03 | .32 | -.09 | .04 | -.04 | .06 |
| Angry Intensity Rating | -.11 | .32 | -.42 | -.30 | -.16 | -.09 |
| Fear Intensity Rating | -.21 | .13 | -.16 | .04 | -.09 | .09 |
| Sad Intensity Rating | -.24 | .16 | -.33 | -.09 | -.25 | -.05 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 26.

*Bivariate correlations between diary reports of sleep onset latency (SOL) and wake after sleep onset (WASO), and behavioural performance, split by group and for all participants combined*.

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | Diary SOL | Diary WASO | Diary SOL | Diary WASO | Diary SOL | Diary WASO |
| Response Time | -.06 | -.36 | -.06 | -.09 | .00 | -.11 |
| Response Time SD | -.02 | .43 | -.43 | -.31 | -.26 | -.05 |
| Fastest 10% Response Time | -.23 | -.40 | .27 | .04 | .17 | -.04 |
| Slowest 10% Response Time | .00 | .38 | .37 | .10 | .18 | .09 |
| Number of Lapses | -.12 | .35 | -.30 | -.39 | -.20 | -.11 |
| Emotion Stroop | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Happy Congruent Response Time | .02 | -.20 | -.48 | -.39 | -.34 | -.31 |
| Angry Congruent Response Time | .15 | -.18 | -.40 | -.33 | -.24 | -.27 |
| Neutral Congruent Response Time | .04 | -.26 | -.44 | -.31 | -.33 | -.24 |
| Sad Congruent Response Time | -.12 | -.10 | -.44 | -.42 | -.30 | -.29 |
| Happy Incongruent Response Time | .08 | -.10 | -.32 | -.24 | -.23 | -.20 |
| Angry Incongruent Response Time | .20 | -.13 | -.42 | -.45 | -.22 | -.25 |
| Neutral Incongruent Response Time | -.02 | -.23 | -.40 | -.19 | -.28 | -.19 |
| Sad Incongruent Response Time | -.09 | -.11 | -.41 | -.43 | -.31 | -.32 |
| Happy Interference | .25 | .35 | .32 | .33 | .28 | .29 |
| Angry Interference | .23 | .08 | -.15 | -.33 | -.04 | -.03 |
| Neutral Interference | -.06 | -.09 | .07 | .32 | .01 | .04 |
| Sad Interference | .17 | -.02 | .00 | -.07 | .03 | -.02 |
| Happy Congruent Accuracy | .25 | **-.62*** | -.28 | .39 | -.03 | -.03 |
| Angry Congruent Accuracy | -.28 | -.41 | -.11 | .09 | -.16 | -.10 |
| Neutral Congruent Accuracy | -.19 | **-.74**** | .46 | .54 | .28 | .08 |
| Sad Congruent Accuracy | .40 | .20 | .06 | .06 | .11 | .10 |
| Happy Incongruent Accuracy | -.21 | .14 | .05 | .44 | .07 | .35 |
| Angry Incongruent Accuracy | -.33 | -.42 | .04 | .17 | -.08 | -.09 |
| Neutral Incongruent Accuracy | .05 | -.55 | **.56*** | .28 | .30 | -.09 |
| Sad Incongruent Accuracy | -.23 | -.22 | .04 | -.02 | -.01 | -.06 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.47 | -.14 | -.55 | .19 | **-.43*** | -.04 |
| Angry Response Time | -.28 | -.35 | -.29 | -.05 | -.24 | -.20 |
| Fear Response Time | -.37 | -.33 | **-.72**** | .06 | **-.49*** | -.11 |
| Sad Response Time | **-.58*** | -.32 | **-.57*** | .10 | **-.41*** | -.13 |
| Happy Accuracy | -.52 | -.29 | .32 | **-.65*** | .21 | **-.59**** |
| Angry Accuracy | **-.65*** | -.29 | .11 | .15 | .00 | .01 |
| Fear Accuracy | **-.63*** | .08 | .03 | -.02 | -.12 | -.06 |
| Sad Accuracy | .28 | .18 | -.10 | **.71*** | -.05 | **.43*** |
| Happy Intensity Rating | -.15 | .54 | -.24 | .20 | -.20 | .28 |
| Angry Intensity Rating | -.35 | .16 | .12 | .05 | .01 | .01 |
| Fear Intensity Rating | -.19 | .46 | -.16 | .24 | -.15 | .19 |
| Sad Intensity Rating | -.04 | .45 | -.07 | .16 | -.04 | .21 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 27.

*Bivariate correlations between diary reports of sleep quality (SQ) and number of awakenings (NA), and behavioural performance, split by group and for all participants combined*.

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | Diary SQ | Diary NA | Diary SQ | Diary NA | Diary SQ | Diary NA |
| Response Time | -.06 | .23 | -.16 | .19 | -.13 | .21 |
| Response Time SD | -.05 | .32 | -.18 | -.07 | -.09 | .04 |
| Fastest 10% Response Time | .08 | .10 | -.34 | .36 | -.10 | .27 |
| Slowest 10% Response Time | .05 | -.19 | .16 | -.21 | .13 | -.21 |
| Number of Lapses | -.02 | .39 | .06 | -.42 | .03 | -.10 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | .27 | .05 | -.50 | -.17 | .04 | -.12 |
| Angry Congruent Response Time | .17 | .23 | -.21 | -.38 | .09 | -.16 |
| Neutral Congruent Response Time | .28 | -.03 | **-.58*** | -.18 | -.13 | -.12 |
| Sad Congruent Response Time | .26 | -.01 | -.45 | -.41 | .09 | -.24 |
| Happy Incongruent Response Time | .15 | .17 | -.44 | -.08 | -.02 | -.03 |
| Angry Incongruent Response Time | .05 | .21 | -.33 | -.19 | -.05 | -.05 |
| Neutral Incongruent Response Time | .25 | .10 | -.33 | -.18 | .04 | -.10 |
| Sad Incongruent Response Time | .27 | .01 | -.52 | -.36 | .04 | -.25 |
| Happy Interference | -.42 | **.64*** | .08 | .19 | -.17 | .29 |
| Angry Interference | -.34 | .04 | -.30 | .27 | -.33 | .22 |
| Neutral Interference | .10 | .20 | .37 | .02 | .22 | .01 |
| Sad Interference | -.11 | .08 | -.21 | .05 | -.15 | .02 |
| Happy Congruent Accuracy | -.18 | -.13 | .15 | .20 | -.14 | .08 |
| Angry Congruent Accuracy | .37 | -.50 | -.48 | .41 | .04 | .12 |
| Neutral Congruent Accuracy | .21 | -.38 | **.65*** | .22 | .33 | .04 |
| Sad Congruent Accuracy | -.21 | .54 | -.27 | .32 | -.23 | .36 |
| Happy Incongruent Accuracy | .23 | -.35 | .23 | .33 | .15 | .13 |
| Angry Incongruent Accuracy | .52 | -.49 | -.22 | .35 | .22 | .08 |
| Neutral Incongruent Accuracy | .13 | -.10 | .46 | .24 | .28 | .08 |
| Sad Incongruent Accuracy | .39 | .16 | -.50 | .50 | -.05 | **.41*** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | **.77**** | -.20 | -.13 | .19 | **.53**** | -.03 |
| Angry Response Time | **.76**** | -.33 | .11 | -.33 | **.58**** | -.31 |
| Fear Response Time | **.75**** | -.38 | -.09 | -.14 | **.48*** | -.22 |
| Sad Response Time | **.76**** | -.40 | -.21 | .22 | **.53**** | -.09 |
| Happy Accuracy | .45 | -.56 | -.35 | -.28 | .01 | -.31 |
| Angry Accuracy | **.64*** | -.50 | -.30 | .30 | .23 | .08 |
| Fear Accuracy | **.62*** | -.44 | -.34 | .41 | .29 | .08 |
| Sad Accuracy | .31 | .27 | -.10 | **.64*** | .16 | **.50*** |
| Happy Intensity Rating | .11 | .18 | .14 | .22 | .11 | .21 |
| Angry Intensity Rating | **.67*** | .04 | .34 | -.03 | **.54**** | -.04 |
| Fear Intensity Rating | **.58*** | .14 | .26 | .02 | **.47*** | .02 |
| Sad Intensity Rating | .42 | .08 | .44 | -.10 | **.40*** | -.04 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 28.

*Bivariate correlations between objective-subjective discrepancy of total sleep time (TST) and sleep onset latency (SOL), wake after sleep onset (WASO), and behavioural performance, split by group and for all participants combined*.

| | GS | | | INS | | | All (GS & INS) | | |
|---|---|---|---|---|---|---|---|---|---|
| Psychomotor Vigilance | SOD TST | SOD SOL | SOD WASO | SOD TST | SOD SOL | SOD WASO | SOD TST | SOD SOL | SOD WASO |
| Response Time | -.26 | -.08 | -.04 | -.36 | .08 | .45 | -.33 | .08 | .29 |
| Response Time SD | -.04 | -.19 | .17 | .00 | .32 | .22 | .00 | -.23 | .17 |
| Fastest 10% Response Time | -.14 | .11 | .06 | -.49 | .28 | .40 | -.36 | .22 | .26 |
| Slowest 10% Response Time | .23 | .17 | .14 | .25 | .22 | -.46 | .26 | .12 | -.27 |
| Number of Lapses | -.21 | .12 | .20 | .08 | -.21 | .09 | .02 | -.15 | .10 |
| Emotion Stroop | | | | | | | | | |
| Happy Congruent Response Time | -.05 | **-.59*** | -.31 | **.67*** | **-.55*** | **-.59*** | **.43*** | **-.45*** | **-.42*** |
| Angry Congruent Response Time | .01 | -.46 | -.16 | **.88**** | -.54 | **-.70**** | **.49*** | -.38 | **-.40*** |
| Neutral Congruent Response Time | .02 | -.41 | -.16 | **.69**** | -.49 | **-.58*** | **.52**** | **-.42*** | **-.49*** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sad Congruent Response Time | -.05 | **-.78**** | -.41 | **.73**** | **-.63*** | -.51 | **.40*** | **-.47*** | -.35 |
| Happy Incongruent Response Time | -.04 | **-.60*** | -.21 | **.74**** | -.44 | **-.75**** | **.46*** | -.37 | **-.50**** |
| Angry Incongruent Response Time | -.07 | -.53 | -.18 | **.61*** | -.43 | -.46 | .32 | -.32 | -.29 |
| Neutral Incongruent Response Time | -.20 | **-.58*** | -.35 | **.83**** | -.52 | **-.62*** | **.49*** | **-.42*** | **-.48*** |
| Sad Incongruent Response Time | -.22 | **-.72**** | -.38 | **.85**** | -.54 | **-.60*** | **.49*** | **-.45*** | **-.43*** |
| Happy Interference | .00 | -.18 | .32 | .27 | .20 | -.48 | .19 | .15 | -.33 |
| Angry Interference | -.26 | -.44 | -.15 | -.27 | .05 | .27 | -.28 | .03 | .16 |
| Neutral Interference | -.33 | -.46 | -.36 | .18 | -.02 | -.02 | .06 | -.08 | -.08 |
| Sad Interference | -.53 | **.59*** | .34 | .37 | .09 | -.28 | .16 | .13 | -.16 |
| Happy Congruent Accuracy | -.04 | .38 | -.15 | .11 | -.47 | -.05 | -.01 | -.11 | -.06 |
| Angry Congruent Accuracy | -.19 | .01 | -.31 | -.15 | .01 | .02 | -.09 | -.03 | -.02 |
| Neutral Congruent Accuracy | .25 | -.28 | **-.74**** | -.41 | .34 | .29 | -.21 | .20 | .03 |
| Sad Congruent Accuracy | .14 | .24 | .42 | -.12 | .15 | -.15 | -.10 | .17 | -.08 |
| Happy Incongruent Accuracy | -.14 | .27 | .07 | -.11 | -.14 | .05 | -.16 | .02 | .03 |
| Angry Incongruent Accuracy | .22 | .12 | -.23 | -.14 | .11 | -.15 | .01 | .03 | -.14 |
| Neutral Incongruent Accuracy | .04 | -.51 | **-.60*** | -.41 | .44 | -.02 | -.19 | .19 | -.12 |
| Sad Incongruent Accuracy | .27 | .01 | .18 | -.33 | .17 | -.02 | -.20 | .13 | .01 |
| Face Categorization & Intensity | | | | | | | | | |
| Happy Response Time | -.15 | -.31 | -.31 | .26 | -.47 | .02 | .17 | -.34 | -.04 |
| Angry Response Time | .22 | -.31 | -.42 | **.75**** | -.37 | -.53 | **.48*** | -.27 | -.36 |
| Fear Response Time | .19 | -.37 | -.48 | **.73**** | **-.74**** | -.32 | **.48*** | **-.49*** | -.28 |
| Sad Response Time | -.11 | **-.59*** | **-.56*** | .38 | **-.59*** | -.24 | .20 | **-.40*** | -.23 |
| Happy Accuracy | .40 | -.39 | **-.57*** | .03 | .14 | -.40 | .10 | .08 | **-.41*** |
| Angry Accuracy | -.04 | -.20 | -.48 | -.20 | .03 | -.09 | -.14 | .00 | -.15 |
| Fear Accuracy | -.26 | -.36 | -.43 | -.19 | .07 | -.23 | -.11 | -.04 | -.22 |
| Sad Accuracy | -.13 | .22 | -.05 | -.01 | -.10 | .04 | -.02 | -.06 | .02 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Happy Intensity Rating | .03 | -.17 | .12 | .03 | -.23 | -.15 | .03 | -.20 | -.11 |
| Angry Intensity Rating | .21 | -.41 | -.17 | -.30 | .22 | .20 | -.12 | .08 | .11 |
| Fear Intensity Rating | .10 | -.20 | .06 | .18 | -.14 | -.27 | .15 | -.13 | -.15 |
| Sad Intensity Rating | .18 | -.31 | .03 | .06 | -.03 | -.03 | .07 | -.05 | -.02 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 29.

*Bivariate correlations between ORP for stages 1-3 of sleep, and behavioural performance, split by group and for all participants combined*.

| | GS | | | INS | | | All (GS & INS) | | |
|---|---|---|---|---|---|---|---|---|---|
| Psychomotor Vigilance | ORP S1 | ORP S2 | ORP S3 | ORP S1 | ORP S2 | ORP S3 | ORP S1 | ORP S2 | ORP S3 |
| Response Time | .22 | .15 | .22 | -.04 | -.42 | -.48 | .07 | -.09 | -.16 |
| Response Time SD | -.21 | -.15 | .49 | .24 | -.06 | -.14 | .00 | -.11 | .18 |
| Fastest 10% Response Time | .35 | .29 | .39 | -.27 | -.43 | -.45 | .03 | .02 | -.14 |
| Slowest 10% Response Time | -.11 | -.06 | -.08 | -.19 | .22 | .31 | -.14 | .06 | .06 |
| Number of Lapses | .04 | .13 | **.67**** | .19 | -.16 | -.14 | .09 | .02 | .31 |
| Emotion Stroop | | | | | | | | | |
| Happy Congruent Response Time | -.34 | -.40 | -.43 | .30 | **.56*** | .52 | -.10 | .00 | .13 |
| Angry Congruent Response Time | -.28 | -.40 | -.34 | .35 | **.54*** | .46 | -.13 | -.02 | .10 |
| Neutral Congruent Response Time | -.36 | -.38 | -.43 | -.03 | .41 | .52 | -.17 | .05 | .16 |
| Sad Congruent Response Time | -.29 | -.40 | -.38 | -.01 | .28 | .40 | -.26 | -.14 | .07 |
| Happy Incongruent Response Time | -.27 | -.26 | -.38 | .26 | **.62*** | **.60*** | -.04 | .05 | .22 |
| Angry Incongruent Response Time | -.32 | -.30 | -.41 | .26 | .40 | .41 | -.09 | -.09 | .08 |
| Neutral Incongruent Response Time | -.09 | -.09 | -.16 | .41 | **.57*** | **.59*** | .14 | .18 | .22 |
| Sad Incongruent Response Time | -.34 | -.41 | -.47 | .23 | .38 | .49 | -.15 | -.11 | .16 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Happy Interference | .15 | .35 | .08 | -.06 | .22 | .27 | .14 | .14 | .27 |
| Angry Interference | -.18 | .16 | -.24 | -.08 | -.11 | .05 | .06 | -.18 | -.03 |
| Neutral Interference | .22 | .24 | .18 | **.62*** | .22 | .10 | **.41*** | .19 | .12 |
| Sad Interference | .00 | .11 | -.03 | .50 | .24 | .25 | .27 | .08 | .16 |
| Happy Congruent Accuracy | .22 | .35 | .30 | -.40 | .01 | .23 | .13 | .21 | -.04 |
| Angry Congruent Accuracy | -.15 | -.14 | -.16 | -.04 | -.05 | .33 | -.09 | -.10 | -.01 |
| Neutral Congruent Accuracy | .25 | .34 | .25 | -.10 | -.22 | -.32 | .16 | .06 | -.14 |
| Sad Congruent Accuracy | .00 | -.13 | .08 | .17 | .36 | .33 | .06 | .24 | .17 |
| Happy Incongruent Accuracy | .01 | -.18 | .01 | .05 | .05 | .03 | -.06 | .03 | -.05 |
| Angry Incongruent Accuracy | -.17 | -.40 | -.10 | -.30 | .08 | .24 | -.36 | -.02 | -.09 |
| Neutral Incongruent Accuracy | -.18 | -.35 | -.23 | -.39 | -.12 | -.22 | **-.38*** | -.18 | -.14 |
| Sad Incongruent Accuracy | .27 | .01 | .28 | -.40 | -.12 | .17 | -.24 | .04 | .13 |
| Face Categorization & Intensity | | | | | | | | | |
| Happy Response Time | .12 | -.03 | .02 | .43 | .39 | .37 | .15 | .16 | .19 |
| Angry Response Time | -.13 | -.30 | -.18 | **.74**** | **.68**** | .39 | .08 | .13 | .00 |
| Fear Response Time | -.02 | -.25 | -.09 | .50 | .47 | .44 | .04 | .13 | .11 |
| Sad Response Time | -.03 | -.16 | -.12 | .53 | .57* | .50 | .09 | .13 | .13 |
| Happy Accuracy | -.02 | -.24 | .01 | -.15 | -.21 | -.39 | -.17 | -.13 | -.31 |
| Angry Accuracy | .27 | .05 | .24 | -.18 | .04 | -.05 | -.06 | .14 | -.02 |
| Fear Accuracy | .24 | .18 | .11 | .24 | .39 | .34 | .18 | .23 | .32 |
| Sad Accuracy | .05 | -.11 | .02 | -.01 | -.02 | -.18 | -.07 | -.01 | -.07 |
| Happy Intensity Rating | .24 | -.08 | .11 | .14 | **.57*** | **.59*** | .06 | .36 | **.58**** |
| Angry Intensity Rating | .14 | -.17 | .08 | -.12 | -.12 | .00 | -.15 | -.01 | .02 |
| Fear Intensity Rating | .10 | -.18 | -.02 | .30 | .44 | .22 | .02 | .17 | .28 |
| Sad Intensity Rating | -.19 | -.50 | -.29 | .16 | .22 | .15 | -.18 | -.05 | .09 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).

Table 30.

*Bivariate correlations between ORP for REM and NREM sleep, and behavioural performance, split by group and for all participants combined*.

| | GS | INS | All (GS & INS) |
|---|---|---|---|

| Psychomotor Vigilance | ORP REM | ORP NREM | ORP REM | ORP NREM | ORP REM | ORP NREM |
|---|---|---|---|---|---|---|
| Response Time | .25 | .22 | .04 | -.40 | .14 | -.09 |
| Response Time SD | -.10 | -.06 | .31 | -.03 | .11 | -.05 |
| Fastest 10% Response Time | .37 | .17 | -.24 | -.42 | .05 | -.02 |
| Slowest 10% Response Time | -.16 | -.21 | -.26 | .19 | -.23 | .04 |
| Number of Lapses | .19 | .22 | .31 | -.15 | .23 | .07 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.38 | -.27 | .40 | **.62*** | .02 | .10 |
| Angry Congruent Response Time | -.35 | -.16 | .27 | **.54*** | -.07 | .05 |
| Neutral Congruent Response Time | -.42 | -.50 | .05 | .44 | -.11 | .12 |
| Sad Congruent Response Time | -.39 | -.16 | .04 | .30 | -.20 | -.06 |
| Happy Incongruent Response Time | -.25 | -.15 | .26 | **.66**** | .00 | .16 |
| Angry Incongruent Response Time | -.32 | -.19 | .22 | .45 | -.07 | .00 |
| Neutral Incongruent Response Time | -.14 | -.19 | .30 | **.59*** | .10 | .24 |
| Sad Incongruent Response Time | -.36 | -.14 | .17 | .39 | -.10 | -.01 |
| Happy Interference | .30 | .28 | -.28 | .19 | -.04 | .17 |
| Angry Interference | -.01 | -.11 | -.03 | -.01 | -.01 | -.10 |
| Neutral Interference | .21 | .15 | .36 | .20 | .28 | .20 |
| Sad Interference | .20 | .09 | .27 | .23 | .23 | .10 |
| Happy Congruent Accuracy | .33 | -.21 | -.50 | .00 | .02 | .14 |
| Angry Congruent Accuracy | -.15 | -.52 | -.05 | .03 | -.10 | -.06 |
| Neutral Congruent Accuracy | .41 | .01 | -.14 | -.23 | .14 | .04 |
| Sad Congruent Accuracy | -.16 | -.13 | .35 | .42 | .20 | .26 |
| Happy Incongruent Accuracy | -.19 | -.14 | .04 | .07 | -.05 | .04 |
| Angry Incongruent Accuracy | -.35 | -.48 | -.03 | .16 | -.18 | -.01 |
| Neutral Incongruent Accuracy | -.22 | -.07 | -.23 | -.08 | -.23 | -.13 |
| Sad Incongruent Accuracy | .12 | .08 | -.23 | .00 | -.12 | .09 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | .02 | .00 | .30 | .39 | .14 | .23 |
| Angry Response Time | -.28 | -.39 | .53 | **.62*** | .07 | .16 |
| Fear Response Time | -.19 | -.28 | .36 | .45 | .07 | .17 |
| Sad Response Time | -.13 | -.17 | .49 | **.61*** | .14 | .22 |
| Happy Accuracy | -.16 | -.15 | .01 | -.19 | -.04 | -.13 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Accuracy | .14 | .02 | .06 | .07 | .10 | .17 |
| Fear Accuracy | .19 | .31 | .40 | .49 | .28 | .35 |
| Sad Accuracy | -.11 | .12 | -.09 | -.04 | -.11 | -.01 |
| Happy Intensity Rating | .07 | **.59*** | -.04 | .52 | .00 | **.41*** |
| Angry Intensity Rating | -.14 | .05 | -.23 | -.17 | -.19 | -.01 |
| Fear Intensity Rating | -.15 | .35 | .20 | .36 | .02 | .21 |
| Sad Intensity Rating | -.46 | .00 | -.05 | .13 | -.22 | -.03 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 31.

*Bivariate correlations between ORP for the correlation between left-frontal and right-frontal (right and left electrodes), the maximum ORP during arousal, and behavioural performance, split by group and for all participants combined*.

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | R/L ORP Correlation | ORPmax during Arousal | R/L ORP Correlation | ORPmax during Arousal | R/L ORP Correlation | ORPmax during Arousal |
| Response Time | .06 | -.17 | .42 | .48 | .21 | .12 |
| Response Time SD | .22 | .27 | .10 | **.64*** | .18 | **.41*** |
| Fastest 10% Response Time | -.16 | -.08 | .46 | .24 | .08 | .05 |
| Slowest 10% Response Time | -.15 | .23 | -.46 | -.51 | -.28 | -.10 |
| Number of Lapses | .20 | .22 | -.05 | .32 | .12 | .25 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | .29 | -.09 | -.35 | -.02 | .05 | -.06 |
| Angry Congruent Response Time | .17 | -.08 | -.38 | -.12 | .00 | -.10 |
| Neutral Congruent Response Time | .30 | -.06 | -.29 | -.28 | .01 | -.17 |
| Sad Congruent Response Time | .36 | .14 | -.15 | -.37 | .19 | -.03 |
| Happy Incongruent Response Time | .39 | -.14 | -.45 | -.12 | .08 | -.14 |
| Angry Incongruent Response Time | .34 | -.20 | -.44 | .20 | .09 | -.06 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Neutral Incongruent Response Time | .35 | -.15 | -.28 | -.19 | .10 | -.17 |
| Sad Incongruent Response Time | .49 | -.09 | -.21 | -.35 | .23 | -.19 |
| Happy Interference | .35 | -.17 | -.32 | -.27 | .07 | -.21 |
| Angry Interference | .47 | -.31 | -.23 | **.60*** | .22 | .06 |
| Neutral Interference | .23 | -.16 | .01 | .13 | .13 | -.03 |
| Sad Interference | .12 | -.48 | -.14 | -.01 | .04 | -.31 |
| Happy Congruent Accuracy | -.28 | -.50 | -.11 | -.28 | -.22 | **-.42*** |
| Angry Congruent Accuracy | .06 | -.16 | -.12 | -.25 | -.04 | -.20 |
| Neutral Congruent Accuracy | -.09 | **-.54*** | .19 | -.05 | .01 | -.35 |
| Sad Congruent Accuracy | -.39 | .25 | .03 | -.19 | -.14 | .00 |
| Happy Incongruent Accuracy | -.10 | **.58*** | .46 | -.45 | .09 | .23 |
| Angry Incongruent Accuracy | -.31 | .23 | -.04 | -.24 | -.21 | .02 |
| Neutral Incongruent Accuracy | .11 | -.18 | .00 | .00 | .06 | -.11 |
| Sad Incongruent Accuracy | -.33 | .22 | -.26 | .11 | -.27 | .14 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | .18 | .12 | -.37 | **.58*** | -.03 | .29 |
| Angry Response Time | -.02 | .09 | -.35 | .15 | -.14 | .11 |
| Fear Response Time | .00 | .20 | -.24 | .07 | -.08 | .15 |
| Sad Response Time | .27 | .13 | -.36 | .44 | .07 | .23 |
| Happy Accuracy | -.19 | .35 | .40 | -.22 | .12 | -.03 |
| Angry Accuracy | -.08 | .28 | .36 | -.23 | .10 | .05 |
| Fear Accuracy | .39 | .28 | -.20 | .21 | .13 | .24 |
| Sad Accuracy | -.15 | .04 | .41 | -.05 | .09 | -.01 |
| Happy Intensity Rating | .15 | **.59*** | -.42 | .13 | -.11 | .32 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Intensity Rating | -.07 | .51 | -.07 | -.06 | -.07 | .28 |
| Fear Intensity Rating | .09 | **.58*** | -.07 | .04 | .03 | .36 |
| Sad Intensity Rating | .12 | **.60*** | -.13 | .00 | .03 | .35 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 32.

*Bivariate correlations between baseline ORP before arousal, and average ORP for 9 seconds following an arousal/awakening, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | Baseline ORP before Arousal | ORP-9 | Baseline ORP before Arousal | ORP-9 | Baseline ORP before Arousal | ORP-9 |
| Response Time | .02 | .21 | -.32 | -.18 | -.15 | .00 |
| Response Time SD | .12 | -.03 | .16 | .19 | .14 | .08 |
| Fastest 10% Response Time | .11 | .27 | -.41 | -.42 | -.14 | -.08 |
| Slowest 10% Response Time | .05 | -.12 | .07 | -.10 | -.14 | -.08 |
| Number of Lapses | .31 | .19 | .00 | .10 | .19 | .15 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.41 | -.35 | **.64*** | .46 | .07 | .05 |
| Angry Congruent Response Time | -.33 | -.24 | **.54*** | .38 | .01 | .03 |
| Neutral Congruent Response Time | -.44 | -.30 | .29 | .13 | -.02 | -.04 |
| Sad Congruent Response Time | -.33 | -.23 | .33 | .04 | -.07 | -.10 |
| Happy Incongruent Response Time | -.26 | -.27 | **.55*** | .37 | .10 | .05 |
| Angry Incongruent Response Time | -.30 | -.24 | .45 | .31 | .00 | .01 |
| Neutral Incongruent Response Time | -.23 | -.03 | .48 | .31 | .11 | .15 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sad Incongruent Response Time | -.36 | -.36 | .32 | .13 | -.06 | -.12 |
| Happy Interference | .36 | .20 | -.14 | -.17 | .12 | .01 |
| Angry Interference | -.01 | -.06 | -.01 | -.02 | -.01 | -.04 |
| Neutral Interference | .09 | .26 | .26 | .27 | .18 | .26 |
| Sad Interference | .05 | -.17 | .04 | .17 | .04 | -.02 |
| Happy Congruent Accuracy | -.03 | .21 | -.05 | -.24 | -.04 | .04 |
| Angry Congruent Accuracy | -.38 | -.32 | -.20 | -.10 | -.27 | -.18 |
| Neutral Congruent Accuracy | .12 | .12 | -.14 | -.16 | .01 | -.01 |
| Sad Congruent Accuracy | -.12 | .01 | .23 | .34 | .08 | .22 |
| Happy Incongruent Accuracy | -.17 | -.06 | .01 | .03 | -.11 | -.03 |
| Angry Incongruent Accuracy | -.41 | -.24 | -.20 | -.10 | -.30 | -.16 |
| Neutral Incongruent Accuracy | -.33 | -.19 | -.17 | -.21 | -.25 | -.19 |
| Sad Incongruent Accuracy | .13 | .19 | -.24 | -.21 | -.09 | -.07 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.05 | .01 | .47 | .38 | .18 | .18 |
| Angry Response Time | -.25 | -.10 | **.73**** | **.65*** | .13 | .21 |
| Fear Response Time | -.22 | -.09 | .47 | .44 | .07 | .15 |
| Sad Response Time | -.22 | -.11 | **.69**** | **.55*** | .13 | .17 |
| Happy Accuracy | -.20 | -.14 | -.15 | -.09 | -.14 | -.09 |
| Angry Accuracy | -.01 | .06 | -.05 | -.03 | -.03 | .01 |
| Fear Accuracy | .19 | .16 | .40 | .42 | .30 | .30 |
| Sad Accuracy | .04 | .17 | -.18 | -.03 | -.08 | .05 |
| Happy Intensity Rating | .35 | .16 | .38 | .37 | .35 | .29 |
| Angry Intensity Rating | .05 | .14 | -.27 | -.09 | -.09 | .03 |
| Fear Intensity Rating | .18 | .14 | .20 | .40 | .20 | .27 |
| Sad Intensity Rating | -.12 | -.17 | .05 | .20 | -.04 | .02 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 33.

*Bivariate correlations between number of arousals that had a >.05 difference between ORP max and Baseline ORP, and behavioural performance, split by group and for all participants combined.*

| | GS | INS | All (GS & INS) |
|---|---|---|---|
| Psychomotor Vigilance | Number of Arousals with ORPMax - Baseline ORP >0.5 | | |
| Response Time | .19 | .19 | .19 |
| Response Time SD | .08 | -.01 | .03 |
| Fastest 10% Response Time | .06 | .35 | .23 |
| Slowest 10% Response Time | -.21 | -.22 | -.22 |
| Number of Lapses | -.02 | -.41 | -.20 |
| Emotion Stroop | | | |
| Happy Congruent Response Time | .35 | -.12 | .07 |
| Angry Congruent Response Time | .28 | -.33 | -.03 |
| Neutral Congruent Response Time | .07 | -.40 | -.25 |
| Sad Congruent Response Time | **.56*** | -.36 | .08 |
| Happy Incongruent Response Time | .18 | -.15 | -.02 |
| Angry Incongruent Response Time | .31 | -.15 | .06 |
| Neutral Incongruent Response Time | .24 | -.33 | -.10 |
| Sad Incongruent Response Time | .46 | -.41 | -.03 |
| Happy Interference | -.45 | -.09 | -.23 |
| Angry Interference | .14 | .27 | .21 |
| Neutral Interference | .30 | .11 | .17 |
| Sad Interference | -.38 | -.15 | -.24 |
| Happy Congruent Accuracy | .00 | -.04 | .00 |
| Angry Congruent Accuracy | .25 | .04 | .10 |
| Neutral Congruent Accuracy | .21 | .37 | .28 |
| Sad Congruent Accuracy | -.18 | .28 | .16 |
| Happy Incongruent Accuracy | .05 | .45 | .23 |
| Angry Incongruent Accuracy | .24 | -.03 | .07 |
| Neutral Incongruent Accuracy | .51 | .45 | **.44*** |
| Sad Incongruent Accuracy | -.10 | .22 | .13 |
| Face Categorization & Intensity | | | |
| Happy Response Time | .11 | -.22 | -.08 |
| Angry Response Time | .24 | -.30 | -.04 |

| | | | |
|---|---|---|---|
| Fear Response Time | .18 | -.50 | -.17 |
| Sad Response Time | .41 | -.02 | .16 |
| Happy Accuracy | .25 | .41 | .35 |
| Angry Accuracy | .25 | .24 | .24 |
| Fear Accuracy | .05 | .46 | .27 |
| Sad Accuracy | .13 | .22 | .18 |
| Happy Intensity Rating | .01 | .08 | .06 |
| Angry Intensity Rating | .12 | -.01 | .04 |
| Fear Intensity Rating | -.14 | -.16 | -.15 |
| Sad Intensity Rating | .01 | -.16 | -.08 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 34.

*Bivariate correlations between left-frontal (LF) and right-frontal (RF) Delta power, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | LF Delta | RF Delta | LF Delta | RF Delta | LF Delta | RF Delta |
| Response Time | .03 | -.20 | .34 | .14 | .13 | -.09 |
| Response Time SD | -.24 | -.36 | .00 | -.09 | -.16 | -.26 |
| Fastest 10% Response Time | .25 | .08 | .50 | .34 | .32 | .14 |
| Slowest 10% Response Time | .18 | .41 | -.13 | -.05 | .08 | .24 |
| Number of Lapses | -.22 | -.28 | -.08 | -.35 | -.18 | -.29 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.32 | -.36 | -.53 | .06 | **-.38*** | -.20 |
| Angry Congruent Response Time | -.20 | -.35 | **-.69**** | -.22 | -.32 | -.29 |
| Neutral Congruent Response Time | -.12 | -.27 | -.43 | .01 | -.24 | -.13 |
| Sad Congruent Response Time | -.17 | -.34 | **-.56*** | .02 | -.26 | -.22 |
| Happy Incongruent Response Time | -.36 | -.39 | -.54 | -.03 | **-.40*** | -.24 |
| Angry Incongruent Response Time | -.16 | -.29 | -.43 | .03 | -.23 | -.17 |
| Neutral Incongruent Response Time | -.35 | -.51 | -.54 | -.19 | **-.41*** | -.37 |
| Sad Incongruent Response Time | -.31 | -.32 | **-.58*** | -.04 | **-.38*** | -.19 |
| Happy Interference | -.17 | -.13 | -.10 | -.20 | -.13 | -.14 |
| Angry Interference | .07 | .08 | .29 | .44 | .13 | .20 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Neutral Interference | -.42 | -.49 | -.18 | -.31 | -.31 | **-.39*** |
| Sad Interference | -.21 | .27 | -.11 | -.12 | -.18 | .11 |
| Happy Congruent Accuracy | .16 | .11 | -.20 | .06 | .07 | .08 |
| Angry Congruent Accuracy | .06 | .28 | .12 | .38 | .09 | .32 |
| Neutral Congruent Accuracy | -.44 | -.30 | .27 | .12 | -.22 | -.15 |
| Sad Congruent Accuracy | -.04 | -.09 | -.09 | .02 | -.07 | -.05 |
| Happy Incongruent Accuracy | .20 | .21 | -.27 | .06 | .05 | .12 |
| Angry Incongruent Accuracy | .18 | .13 | .06 | -.01 | .14 | .09 |
| Neutral Incongruent Accuracy | -.39 | -.51 | .09 | .03 | -.22 | -.31 |
| Sad Incongruent Accuracy | .34 | .20 | .37 | **.60*** | .32 | .36 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.41 | -.39 | .11 | -.23 | -.22 | -.30 |
| Angry Response Time | -.16 | -.36 | -.50 | -.57 | -.23 | **-.39*** |
| Fear Response Time | -.33 | -.41 | -.39 | -.31 | -.34 | -.37 |
| Sad Response Time | -.29 | -.34 | -.18 | -.24 | -.25 | -.29 |
| Happy Accuracy | -.30 | -.29 | -.41 | .20 | -.27 | -.01 |
| Angry Accuracy | -.21 | -.10 | .01 | -.05 | -.14 | -.09 |
| Fear Accuracy | -.46 | -.39 | -.12 | .04 | -.33 | -.22 |
| Sad Accuracy | -.28 | -.41 | .11 | .11 | -.08 | -.20 |
| Happy Intensity Rating | -.11 | -.03 | -.32 | -.53 | -.19 | -.26 |
| Angry Intensity Rating | -.21 | -.35 | -.07 | -.31 | -.15 | -.32 |
| Fear Intensity Rating | -.37 | -.49 | -.38 | **-.85**** | -.35 | **-.60**** |
| Sad Intensity Rating | -.25 | -.29 | -.30 | **-.68*** | -.26 | **-.43*** |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 35.

*Bivariate correlations between left-frontal (LF )and right-frontal (RF) Theta power, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | LF Theta | RF Theta | LF Theta | RF Theta | LF Theta | RF Theta |
| Response Time | .08 | -.08 | .01 | .01 | .05 | -.05 |
| Response Time SD | -.16 | -.36 | -.14 | -.24 | -.15 | -.23 |
| Fastest 10% Response Time | .09 | -.10 | .02 | .09 | .06 | -.04 |
| Slowest 10% Response Time | .01 | .16 | .23 | .24 | .10 | .19 |
| Number of Lapses | -.26 | -.30 | .29 | .07 | -.09 | -.19 |
| Emotion Stroop | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Happy Congruent Response Time | -.09 | -.10 | -.50 | -.43 | -.25 | -.22 |
| Angry Congruent Response Time | .06 | -.02 | -.53 | -.49 | -.13 | -.16 |
| Neutral Congruent Response Time | -.07 | -.19 | -.45 | -.38 | -.25 | -.27 |
| Sad Congruent Response Time | -.09 | -.19 | -.43 | -.41 | -.19 | -.25 |
| Happy Incongruent Response Time | -.13 | -.11 | -.52 | -.44 | -.27 | -.22 |
| Angry Incongruent Response Time | .14 | .10 | -.44 | -.40 | -.06 | -.06 |
| Neutral Incongruent Response Time | -.12 | -.18 | **-.69**** | **-.71**** | -.35 | -.39 |
| Sad Incongruent Response Time | -.19 | -.15 | **-.57*** | -.54 | -.33 | -.28 |
| Happy Interference | -.11 | -.03 | -.11 | -.12 | -.11 | -.06 |
| Angry Interference | .20 | .30 | .00 | .02 | .12 | .19 |
| Neutral Interference | -.12 | -.08 | -.38 | -.50 | -.22 | -.24 |
| Sad Interference | -.16 | .20 | -.35 | -.33 | -.22 | -.03 |
| Happy Congruent Accuracy | .27 | .20 | -.08 | -.13 | .17 | .11 |
| Angry Congruent Accuracy | -.20 | -.10 | .15 | .18 | -.04 | .03 |
| Neutral Congruent Accuracy | -.33 | -.25 | .20 | .20 | -.14 | -.08 |
| Sad Congruent Accuracy | .33 | .29 | -.19 | -.07 | .05 | .08 |
| Happy Incongruent Accuracy | -.21 | -.32 | -.37 | -.27 | -.25 | -.30 |
| Angry Incongruent Accuracy | -.04 | -.15 | .06 | .04 | -.01 | -.08 |
| Neutral Incongruent Accuracy | -.14 | -.22 | .25 | .27 | .01 | -.04 |
| Sad Incongruent Accuracy | .03 | -.18 | .35 | .44 | .18 | .12 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | **-.61*** | **-.67**** | -.26 | -.52 | **-.48*** | **-.59**** |
| Angry Response Time | -.28 | -.50 | -.53 | **-.60*** | -.35 | **-.59**** |
| Fear Response Time | -.51 | **-.67**** | -.53 | **-.62*** | **-.52**** | **-.65**** |
| Sad Response Time | **-.54*** | **-.64*** | -.41 | **-.65*** | **-.49**** | **-.62**** |
| Happy Accuracy | -.44 | -.53 | -.04 | .32 | -.15 | -.03 |
| Angry Accuracy | **-.62*** | **-.66*** | -.05 | .03 | -.39* | **-.40*** |
| Fear Accuracy | **-.85**** | **-.87**** | -.04 | .00 | **-.54**** | **-.54**** |
| Sad Accuracy | .01 | -.05 | -.39 | -.30 | -.18 | -.15 |
| Happy Intensity Rating | -.49 | -.50 | -.14 | -.30 | -.29 | -.38 |
| Angry Intensity Rating | -.37 | -.52 | .36 | .23 | -.09 | -.23 |
| Fear Intensity Rating | -.51 | **-.65*** | -.12 | -.26 | -.36 | **-.50**** |
| Sad Intensity Rating | -.37 | -.44 | .01 | -.13 | -.22 | -.33 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).

Table 36.

*Bivariate correlations between left-frontal (LF) and right-frontal (RF) Alpha power, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | LF Alpha | RF Alpha | LF Alpha | RF Alpha | LF Alpha | RF Alpha |
| Response Time | .20 | .19 | -.46 | -.49 | -.02 | -.05 |
| Response Time SD | .15 | .19 | -.33 | -.30 | .02 | .05 |
| Fastest 10% Response Time | .05 | -.01 | -.46 | -.52 | -.10 | -.17 |
| Slowest 10% Response Time | -.22 | -.20 | .45 | .41 | .01 | .03 |
| Number of Lapses | -.01 | .04 | -.01 | -.06 | .00 | .03 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | .28 | .27 | .43 | .52 | .31 | .34 |
| Angry Congruent Response Time | .43 | .39 | .21 | .24 | **.39*** | .37 |
| Neutral Congruent Response Time | .04 | -.01 | .16 | .16 | .07 | .04 |
| Sad Congruent Response Time | .24 | .29 | .04 | .11 | .21 | .26 |
| Happy Incongruent Response Time | .25 | .26 | .38 | .41 | .28 | .31 |
| Angry Incongruent Response Time | .49 | .51 | .06 | .09 | **.39*** | **.41*** |
| Neutral Incongruent Response Time | .08 | .10 | -.06 | -.01 | .04 | .07 |
| Sad Incongruent Response Time | .24 | .29 | .00 | .04 | .18 | .24 |
| Happy Interference | -.06 | .02 | -.06 | -.19 | -.04 | -.03 |
| Angry Interference | .27 | .42 | -.24 | -.22 | .12 | .21 |
| Neutral Interference | .07 | .17 | -.33 | -.25 | -.02 | .06 |
| Sad Interference | -.09 | -.15 | -.09 | -.12 | -.09 | -.11 |
| Happy Congruent Accuracy | .14 | .06 | -.11 | -.14 | .07 | .00 |
| Angry Congruent Accuracy | -.30 | -.29 | .39 | .35 | -.04 | -.03 |
| Neutral Congruent Accuracy | .03 | -.03 | .03 | .10 | .02 | .00 |
| Sad Congruent Accuracy | .17 | .13 | .36 | .41 | .16 | .15 |
| Happy Incongruent Accuracy | **-.57*** | **-.59*** | -.09 | .04 | **-.48**** | **-.48*** |
| Angry Incongruent Accuracy | -.20 | -.28 | .11 | .02 | -.11 | -.19 |
| Neutral Incongruent Accuracy | .31 | .25 | -.03 | -.04 | .23 | .18 |
| Sad Incongruent Accuracy | .04 | -.08 | .42 | .32 | .14 | .05 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.44 | -.47 | -.11 | -.14 | -.31 | -.32 |
| Angry Response Time | -.08 | -.21 | .21 | .23 | .01 | -.07 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Fear Response Time | -.34 | -.46 | .08 | .10 | -.22 | -.30 |
| Sad Response Time | -.32 | -.35 | .14 | .23 | -.20 | -.19 |
| Happy Accuracy | -.38 | -.49 | .23 | .34 | -.02 | -.08 |
| Angry Accuracy | **-.61*** | **-.65*** | .20 | .20 | **-.38*** | **-.42*** |
| Fear Accuracy | **-.79**** | **-.76**** | **.60*** | **.63*** | **-.39*** | -.34 |
| Sad Accuracy | .15 | .13 | -.11 | -.17 | .07 | .05 |
| Happy Intensity Rating | -.31 | -.25 | -.22 | -.34 | -.24 | -.24 |
| Angry Intensity Rating | -.28 | -.31 | -.29 | -.41 | -.25 | -.30 |
| Fear Intensity Rating | -.38 | -.41 | -.10 | -.26 | -.27 | -.33 |
| Sad Intensity Rating | -.26 | -.27 | -.34 | -.46 | -.26 | -.31 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).

Table 37.

*Bivariate correlations between left-frontal (LF) and right-frontal (RF) Sigma power, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | LF Sigma | RF Sigma | LF Sigma | RF Sigma | LF Sigma | RF Sigma |
| Response Time | .16 | -.01 | -.20 | -.28 | -.04 | -.11 |
| Response Time SD | -.05 | -.24 | -.09 | -.27 | -.15 | -.14 |
| Fastest 10% Response Time | .16 | .00 | -.39 | -.51 | -.15 | -.22 |
| Slowest 10% Response Time | .01 | .16 | .16 | .20 | .04 | .11 |
| Number of Lapses | -.19 | -.15 | .09 | .09 | -.04 | -.06 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.17 | -.16 | -.22 | -.11 | -.21 | -.16 |
| Angry Congruent Response Time | -.07 | -.16 | .19 | .28 | .03 | .02 |
| Neutral Congruent Response Time | -.25 | -.43 | -.27 | -.20 | -.24 | -.25 |
| Sad Congruent Response Time | -.01 | -.12 | -.08 | .00 | -.08 | -.09 |
| Happy Incongruent Response Time | -.16 | -.15 | -.17 | -.07 | -.18 | -.14 |
| Angry Incongruent Response Time | .11 | .00 | .02 | .09 | .02 | .01 |
| Neutral Incongruent Response Time | .06 | -.04 | -.13 | -.06 | -.07 | -.06 |
| Sad Incongruent Response Time | -.14 | -.07 | -.08 | -.01 | -.13 | -.08 |
| Happy Interference | .00 | -.02 | .10 | .08 | .03 | .02 |
| Angry Interference | .41 | .36 | -.28 | -.30 | -.01 | -.01 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Neutral Interference | .33 | .36 | .20 | .22 | .20 | .23 |
| Sad Interference | -.24 | .20 | .00 | -.02 | -.07 | .04 |
| Happy Congruent Accuracy | .27 | .12 | .28 | .31 | .25 | .21 |
| Angry Congruent Accuracy | -.04 | .19 | -.22 | -.23 | -.20 | -.14 |
| Neutral Congruent Accuracy | -.07 | .15 | .13 | .13 | .07 | .13 |
| Sad Congruent Accuracy | .14 | .09 | -.48 | -.45 | -.28 | -.25 |
| Happy Incongruent Accuracy | -.34 | -.42 | .04 | .07 | -.02 | -.04 |
| Angry Incongruent Accuracy | -.13 | -.12 | **-.57*** | **-.57*** | **-.42*** | **-.41*** |
| Neutral Incongruent Accuracy | -.26 | -.31 | -.09 | -.08 | -.17 | -.20 |
| Sad Incongruent Accuracy | -.02 | -.19 | -.48 | -.48 | -.37 | **-.40*** |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.36 | -.25 | -.18 | -.19 | -.27 | -.26 |
| Angry Response Time | -.29 | -.44 | .26 | .33 | -.03 | -.08 |
| Fear Response Time | **-.55*** | **-.59*** | .13 | .18 | -.14 | -.17 |
| Sad Response Time | -.32 | -.29 | -.27 | -.23 | -.28 | -.27 |
| Happy Accuracy | **-.55*** | -.49 | .18 | .29 | .01 | .08 |
| Angry Accuracy | -.39 | -.22 | -.49 | -.49 | **-.41*** | -.35 |
| Fear Accuracy | **-.58*** | -.48 | -.44 | -.39 | **-.50**** | **-.45*** |
| Sad Accuracy | .12 | .09 | -.06 | -.13 | -.06 | -.05 |
| Happy Intensity Rating | -.38 | -.27 | .26 | .27 | .12 | .11 |
| Angry Intensity Rating | -.16 | -.20 | .46 | .39 | .18 | .13 |
| Fear Intensity Rating | -.47 | -.51 | .31 | .29 | -.03 | -.07 |
| Sad Intensity Rating | -.48 | -.48 | **.57*** | .52 | .19 | .14 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 38.

*Bivariate correlations between left-frontal (LF) and right-frontal (RF) Beta1 power, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | LF Beta1 | RF Beta1 | LF Beta 1 | RF Beta 1 | LF Beta 1 | RF Beta 1 |
| Response Time | -.04 | -.24 | **-.57*** | **-.59*** | -.31 | -.37 |
| Response Time SD | -.05 | .02 | -.32 | -.33 | -.17 | .16 |
| Fastest 10% Response Time | .06 | -.28 | **-.58*** | **-.60*** | -.27 | **-.38*** |
| Slowest 10% Response Time | .10 | .22 | .50 | .48 | .27 | .29 |
| Number of Lapses | -.13 | -.05 | -.19 | -.33 | -.15 | -.19 |
| Emotion Stroop | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Happy Congruent Response Time | -.23 | -.20 | .28 | .38 | .02 | .09 |
| Angry Congruent Response Time | -.12 | -.25 | **.59*** | **.64*** | .16 | .15 |
| Neutral Congruent Response Time | -.27 | -.32 | .19 | .29 | .05 | .11 |
| Sad Congruent Response Time | -.18 | -.20 | .11 | .19 | -.07 | -.03 |
| Happy Incongruent Response Time | -.21 | .02 | .46 | **.55*** | .11 | .25 |
| Angry Incongruent Response Time | -.05 | .08 | .30 | .37 | .10 | .19 |
| Neutral Incongruent Response Time | -.26 | -.19 | .39 | .45 | .10 | .17 |
| Sad Incongruent Response Time | -.33 | -.12 | .27 | .35 | -.04 | .09 |
| Happy Interference | .03 | **.59*** | .48 | .48 | .26 | **.47*** |
| Angry Interference | .16 | **.78**** | -.35 | -.35 | -.10 | .12 |
| Neutral Interference | -.12 | .03 | .27 | .21 | .09 | .11 |
| Sad Interference | -.22 | .33 | .35 | .35 | .08 | .31 |
| Happy Congruent Accuracy | .15 | -.02 | .10 | .13 | .15 | .08 |
| Angry Congruent Accuracy | -.37 | -.35 | -.06 | -.07 | -.20 | -.20 |
| Neutral Congruent Accuracy | -.04 | .09 | -.08 | -.12 | -.03 | -.02 |
| Sad Congruent Accuracy | .11 | -.30 | .02 | .08 | .08 | .01 |
| Happy Incongruent Accuracy | -.26 | **-.57*** | -.04 | .06 | -.06 | -.12 |
| Angry Incongruent Accuracy | -.22 | **-.79**** | -.26 | -.26 | -.27 | **-.47*** |
| Neutral Incongruent Accuracy | -.21 | -.41 | -.14 | -.14 | -.19 | -.27 |
| Sad Incongruent Accuracy | .07 | -.46 | -.29 | -.27 | -.19 | -.33 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.46 | -.53 | .13 | .03 | -.18 | -.27 |
| Angry Response Time | -.18 | **-.59*** | **.75**** | **.74**** | .19 | .04 |
| Fear Response Time | -.36 | **-.71**** | .39 | .40 | .01 | -.11 |
| Sad Response Time | -.42 | -.52 | .19 | .17 | -.14 | -.21 |
| Happy Accuracy | -.23 | **-.64*** | -.03 | .22 | -.11 | .00 |
| Angry Accuracy | -.42 | **-.67**** | -.27 | -.21 | -.31 | -.35 |
| Fear Accuracy | -.45 | -.24 | .06 | .07 | -.20 | -.11 |
| Sad Accuracy | -.01 | -.26 | .00 | .21 | -.04 | .02 |
| Happy Intensity Rating | -.26 | -.15 | .52 | .48 | .28 | .29 |
| Angry Intensity Rating | -.22 | **-.60*** | .14 | .06 | -.04 | -.20 |
| Fear Intensity Rating | -.25 | -.41 | .51 | .49 | .12 | .08 |
| Sad Intensity Rating | -.32 | -.47 | .48 | .42 | .14 | .08 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).

Table 39.

*Bivariate correlations between left-frontal (LF) and right-frontal (RF) Beta-2 power, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | LF Beta2 | RF Beta2 | LF Beta2 | RF Beta | LF Beta2 | RF Beta2 |
| Response Time | -.05 | -.24 | -.51 | -.52 | -.22 | -.34 |
| Response Time SD | -.13 | -.16 | -.32 | -.27 | -.20 | -.20 |
| Fastest 10% Response Time | .10 | -.22 | -.47 | -.51 | -.11 | -.32 |
| Slowest 10% Response Time | .07 | .20 | .48 | .46 | .21 | .28 |
| Number of Lapses | -.15 | -.15 | -.18 | -.23 | -.16 | -.19 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.23 | -.26 | .40 | .55 | .00 | .13 |
| Angry Congruent Response Time | -.15 | -.33 | **.60*** | **.69**** | .08 | .11 |
| Neutral Congruent Response Time | -.23 | -.29 | .38 | .51 | .08 | .24 |
| Sad Congruent Response Time | -.30 | -.34 | .19 | .29 | -.16 | -.07 |
| Happy Incongruent Response Time | -.23 | -.03 | **.62*** | **.74**** | .07 | .32 |
| Angry Incongruent Response Time | -.18 | -.05 | .32 | .45 | -.02 | .16 |
| Neutral Incongruent Response Time | -.24 | -.15 | .52 | **.56*** | .06 | .23 |
| Sad Incongruent Response Time | -.38 | -.25 | .39 | .46 | -.11 | .09 |
| Happy Interference | -.04 | **.61*** | **.60*** | .55 | .21 | **.54**** |
| Angry Interference | -.11 | **.63*** | -.39 | -.26 | -.21 | .15 |
| Neutral Interference | -.14 | .07 | .19 | .04 | -.01 | .04 |
| Sad Interference | -.04 | .44 | .45 | .40 | .13 | **.40*** |
| Happy Congruent Accuracy | .23 | .15 | .07 | .10 | .19 | .14 |
| Angry Congruent Accuracy | -.30 | -.28 | .10 | .11 | -.12 | -.07 |
| Neutral Congruent Accuracy | .17 | .33 | -.19 | -.30 | .05 | .01 |
| Sad Congruent Accuracy | .10 | -.29 | .16 | .20 | .13 | .07 |
| Happy Incongruent Accuracy | -.22 | -.53 | -.04 | -.07 | -.13 | -.22 |
| Angry Incongruent Accuracy | -.10 | **-.73**** | -.01 | .04 | -.08 | -.31 |
| Neutral Incongruent Accuracy | -.12 | -.40 | -.17 | -.16 | -.15 | -.28 |
| Sad Incongruent Accuracy | .16 | -.41 | -.09 | .03 | .02 | -.11 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.26 | -.37 | .19 | .16 | -.12 | -.15 |
| Angry Response Time | -.03 | -.47 | **.74**** | **.68*** | .19 | .03 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Fear Response Time | -.11 | -.51 | .49 | .48 | .09 | -.04 |
| Sad Response Time | -.29 | -.42 | .30 | .34 | -.11 | -.12 |
| Happy Accuracy | .01 | -.46 | -.01 | .18 | -.02 | -.01 |
| Angry Accuracy | -.20 | -.48 | -.03 | -.01 | -.12 | -.20 |
| Fear Accuracy | -.26 | -.06 | .21 | .26 | -.08 | .07 |
| Sad Accuracy | .02 | -.24 | .16 | .28 | .07 | .04 |
| Happy Intensity Rating | -.31 | -.27 | .40 | .40 | .05 | .18 |
| Angry Intensity Rating | -.15 | **-.53*** | -.06 | -.10 | -.12 | -.29 |
| Fear Intensity Rating | -.15 | -.36 | .53 | .49 | .08 | .06 |
| Sad Intensity Rating | -.30 | -.52 | .29 | .23 | -.05 | -.08 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 40.

*Bivariate correlations between Stanford Sleepiness Scale (SSS), Visual Analog Scale – Mood: Energetic-Sluggish, and behavioural performance, split by group and for all participants combined*.

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | SSS | VAS-M Energetic-Sluggish | SSS | VAS-M Energetic-Sluggish | SSS | VAS-M Energetic-Sluggish |
| Response Time | -.06 | .27 | .09 | .15 | .08 | .22 |
| Response Time SD | .03 | .12 | .23 | .41 | .13 | .26 |
| Fastest 10% Response Time | -.02 | .33 | -.24 | -.30 | -.08 | -.01 |
| Slowest 10% Response Time | .07 | -.24 | -.26 | -.40 | -.18 | -.36 |
| Number of Lapses | -.03 | .16 | .33 | .43 | .09 | .23 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.11 | -.19 | .04 | .27 | -.07 | .03 |
| Angry Congruent Response Time | .00 | .00 | .04 | .31 | -.03 | .09 |
| Neutral Congruent Response Time | -.24 | -.31 | -.27 | .04 | -.22 | -.05 |
| Sad Congruent Response Time | -.33 | -.35 | -.22 | .18 | -.30 | -.12 |
| Happy Incongruent Response Time | -.09 | -.23 | -.08 | .17 | -.13 | -.05 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Incongruent Response Time | .02 | -.16 | .07 | .41 | .00 | .09 |
| Neutral Incongruent Response Time | -.43 | -.40 | .14 | .36 | -.12 | .04 |
| Sad Incongruent Response Time | -.18 | -.30 | .02 | .32 | -.12 | .00 |
| Happy Interference | .04 | -.15 | -.29 | -.21 | -.17 | -.20 |
| Angry Interference | .04 | -.40 | .08 | .29 | .07 | .02 |
| Neutral Interference | -.42 | -.30 | **.59*** | .46 | .09 | .13 |
| Sad Interference | .39 | .23 | .47 | .33 | **.39*** | .26 |
| Happy Congruent Accuracy | .17 | .28 | **-.66*** | -.04 | -.05 | .17 |
| Angry Congruent Accuracy | -.25 | -.23 | .04 | .18 | -.12 | -.01 |
| Neutral Congruent Accuracy | -.02 | .16 | .02 | -.15 | .05 | .03 |
| Sad Congruent Accuracy | .08 | .22 | .20 | -.07 | .20 | .06 |
| Happy Incongruent Accuracy | -.36 | -.24 | -.01 | .15 | -.02 | .08 |
| Angry Incongruent Accuracy | -.25 | .02 | -.23 | -.10 | -.27 | -.10 |
| Neutral Incongruent Accuracy | -.05 | .14 | -.31 | -.29 | -.21 | -.13 |
| Sad Incongruent Accuracy | .04 | .25 | -.36 | -.11 | -.23 | -.04 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | **-.60*** | -.40 | .19 | .26 | -.26 | -.09 |
| Angry Response Time | -.40 | -.26 | .39 | .21 | -.11 | -.08 |
| Fear Response Time | -.49 | -.27 | .20 | .47 | -.16 | .10 |
| Sad Response Time | **-.65**** | -.46 | .22 | .33 | -.27 | -.09 |
| Happy Accuracy | -.39 | -.04 | -.20 | -.09 | -.27 | -.13 |
| Angry Accuracy | **-.57*** | -.19 | -.32 | -.39 | -.36 | -.28 |
| Fear Accuracy | **-.78**** | **-.61*** | .10 | -.01 | -.32 | -.29 |
| Sad Accuracy | -.12 | -.10 | -.23 | -.17 | -.24 | -.19 |
| Happy Intensity Rating | -.18 | -.12 | -.18 | -.03 | -.12 | -.03 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Intensity Rating | **-.58*** | -.35 | .03 | .06 | -.26 | -.13 |
| Fear Intensity Rating | -.49 | -.40 | .00 | -.06 | -.26 | -.22 |
| Sad Intensity Rating | -.35 | -.38 | .05 | .05 | -.08 | -.08 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 41.

*Bivariate correlations between Visual Analog Scale – Mood: Calm-Irritable, Visual Analog Scale – Mood: Happy-Sad, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | VAS-M Calm-Irritable | VAS-M Happy-Sad | VAS-M Calm-Irritable | VAS-M Happy-Sad | VAS-M Calm-Irritable | VAS-M Happy-Sad |
| Response Time | -.06 | .27 | .25 | -.04 | .32 | -.02 |
| Response Time SD | .03 | .12 | .49 | .13 | .27 | .00 |
| Fastest 10% Response Time | -.02 | .33 | -.18 | -.39 | .04 | -.21 |
| Slowest 10% Response Time | .07 | -.24 | -.43 | -.14 | **-.41*** | -.09 |
| Number of Lapses | -.03 | .16 | .35 | .47 | .11 | .04 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | **.63*** | .22 | -.18 | -.11 | .26 | .04 |
| Angry Congruent Response Time | **.62*** | .35 | .17 | -.09 | **.42*** | .14 |
| Neutral Congruent Response Time | .46 | .15 | -.32 | -.28 | .02 | -.12 |
| Sad Congruent Response Time | .48 | .10 | -.13 | -.21 | .22 | -.05 |
| Happy Incongruent Response Time | **.62*** | .11 | -.19 | -.16 | .24 | -.04 |
| Angry Incongruent Response Time | **.71**** | .29 | .26 | -.12 | **.51**** | .09 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Neutral Incongruent Response Time | .44 | .06 | .07 | -.03 | .26 | .01 |
| Sad Incongruent Response Time | **.55*** | .09 | -.06 | -.16 | .27 | -.05 |
| Happy Interference | .08 | -.29 | -.05 | -.12 | .01 | -.21 |
| Angry Interference | .37 | -.06 | .24 | -.10 | .31 | -.07 |
| Neutral Interference | .20 | -.06 | **.59*** | .37 | .35 | .16 |
| Sad Interference | -.03 | -.06 | .13 | .08 | .04 | .01 |
| Happy Congruent Accuracy | .11 | .17 | .08 | -.18 | .12 | .05 |
| Angry Congruent Accuracy | .15 | -.04 | -.48 | .08 | -.19 | .02 |
| Neutral Congruent Accuracy | .04 | .09 | -.02 | .05 | .03 | .08 |
| Sad Congruent Accuracy | .27 | .26 | -.40 | .26 | -.11 | .27 |
| Happy Incongruent Accuracy | -.40 | -.39 | .05 | .22 | -.18 | -.08 |
| Angry Incongruent Accuracy | -.04 | .22 | -.41 | .24 | -.23 | .21 |
| Neutral Incongruent Accuracy | .33 | .26 | .04 | .13 | .18 | .17 |
| Sad Incongruent Accuracy | .06 | .20 | -.51 | -.15 | -.27 | -.04 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | .04 | -.23 | .17 | .01 | .06 | -.13 |
| Angry Response Time | .10 | .23 | .28 | .07 | .13 | .13 |
| Fear Response Time | -.09 | -.01 | .18 | .05 | .01 | .01 |
| Sad Response Time | .12 | -.18 | .09 | .16 | .08 | -.04 |
| Happy Accuracy | -.32 | -.09 | .02 | -.12 | -.10 | -.12 |
| Angry Accuracy | -.32 | -.36 | **-.54*** | -.01 | **-.42*** | -.16 |
| Fear Accuracy | **-.57*** | **-.71**** | -.27 | .27 | **-.44*** | -.19 |
| Sad Accuracy | -.07 | .28 | -.15 | -.34 | -.13 | -.13 |
| Happy Intensity Rating | -.35 | -.44 | **.53*** | .35 | .16 | .07 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Intensity Rating | -.11 | -.03 | **.55*** | .46 | .17 | .21 |
| Fear Intensity Rating | -.28 | -.22 | .46 | .48 | .02 | .11 |
| Sad Intensity Rating | -.12 | -.08 | **.68**** | .40 | .25 | .18 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 42.

*Bivariate correlations between Visual Analog Scale – Mood: Relaxed-Tense, Depression Anxiety Scale - Anxiety, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | VAS-M Relaxed-Tense | DAS A | VAS-M Relaxed-Tense | DAS A | VAS-M Relaxed-Tense | DAS A |
| Response Time | **.53*** | -.11 | .38 | .17 | **.44*** | .09 |
| Response Time SD | .27 | -.41 | .47 | .29 | .36 | .01 |
| Fastest 10% Response Time | .35 | -.05 | -.09 | -.23 | .11 | -.14 |
| Slowest 10% Response Time | **-.59*** | .23 | -.46 | -.25 | **-.51**** | -.10 |
| Number of Lapses | .24 | -.15 | **.59*** | **.62*** | **.38*** | .23 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | **.54*** | -.22 | -.37 | -.06 | .05 | -.13 |
| Angry Congruent Response Time | **.56*** | -.23 | -.05 | -.02 | .25 | -.12 |
| Neutral Congruent Response Time | .48 | -.43 | -.34 | -.09 | -.06 | -.18 |
| Sad Congruent Response Time | .51 | -.31 | -.21 | -.18 | .16 | -.23 |
| Happy Incongruent Response Time | **.61*** | -.22 | -.37 | -.13 | .08 | -.17 |
| Angry Incongruent Response Time | **.71**** | -.22 | .05 | -.07 | .36 | -.13 |
| Neutral Incongruent Response Time | **.64*** | -.10 | -.09 | -.17 | .22 | -.14 |
| Sad Incongruent Response Time | .50 | -.12 | -.11 | -.15 | .17 | -.15 |
| Happy Interference | .31 | -.06 | -.05 | -.17 | .10 | -.14 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Interference | .49 | -.04 | .18 | -.10 | .32 | -.06 |
| Neutral Interference | .49 | .27 | .36 | -.10 | **.41*** | .01 |
| Sad Interference | -.19 | .47 | .17 | .03 | -.01 | .21 |
| Happy Congruent Accuracy | .15 | .17 | .03 | -.20 | .09 | .02 |
| Angry Congruent Accuracy | -.15 | .23 | -.13 | .13 | -.14 | .14 |
| Neutral Congruent Accuracy | .03 | .34 | -.12 | -.29 | -.04 | -.01 |
| Sad Congruent Accuracy | .00 | .06 | -.40 | .07 | -.27 | .08 |
| Happy Incongruent Accuracy | -.40 | -.25 | -.06 | -.18 | -.20 | -.13 |
| Angry Incongruent Accuracy | -.38 | .00 | -.15 | .18 | -.25 | .08 |
| Neutral Incongruent Accuracy | .26 | -.14 | -.08 | -.14 | .07 | -.15 |
| Sad Incongruent Accuracy | .11 | -.05 | -.27 | .05 | -.15 | .02 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | .35 | -.18 | .06 | .00 | .18 | -.09 |
| Angry Response Time | .34 | -.45 | -.04 | .02 | .14 | -.19 |
| Fear Response Time | .10 | -.35 | .12 | .14 | .10 | -.07 |
| Sad Response Time | .35 | -.27 | -.10 | .02 | .12 | -.12 |
| Happy Accuracy | -.48 | -.15 | .00 | .18 | -.11 | .09 |
| Angry Accuracy | -.28 | .08 | -.42 | .09 | -.36 | .08 |
| Fear Accuracy | .02 | -.25 | -.33 | .17 | -.19 | -.02 |
| Sad Accuracy | .29 | -.04 | -.16 | -.10 | -.02 | -.10 |
| Happy Intensity Rating | -.20 | -.08 | .29 | .15 | .13 | .10 |
| Angry Intensity Rating | .10 | -.17 | **.64*** | .35 | **.37*** | .13 |
| Fear Intensity Rating | .19 | -.47 | .42 | **.55*** | .29 | .11 |
| Sad Intensity Rating | -.07 | -.35 | **.58*** | .32 | .29 | .08 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).

Table 43.

*Bivariate correlations between Depression Anxiety Scale - Depression, Depression Anxiety Scale – Stress, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | DAS D | DAS S | DAS D | DAS S | DAS D | DAS S |

| | | | | | | |
|---|---|---|---|---|---|---|
| Response Time | -.08 | **.64*** | .40 | .38 | .25 | **.49**** |
| Response Time SD | **.59*** | .33 | .33 | .51 | **.40*** | **.41*** |
| Fastest 10% Response Time | -.21 | **.55*** | .15 | .04 | .03 | .27 |
| Slowest 10% Response Time | -.01 | **-.53*** | -.37 | -.38 | -.26 | **-.47*** |
| Number of Lapses | .37 | **.53*** | .39 | .31 | .32 | **.38*** |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | -.06 | -.01 | -.41 | .07 | -.27 | .01 |
| Angry Congruent Response Time | .08 | .14 | -.28 | .31 | -.13 | .17 |
| Neutral Congruent Response Time | -.10 | -.24 | -.39 | .06 | -.30 | -.04 |
| Sad Congruent Response Time | -.03 | .02 | -.40 | -.10 | -.23 | -.07 |
| Happy Incongruent Response Time | .02 | .04 | -.38 | .20 | -.23 | .08 |
| Angry Incongruent Response Time | .16 | .13 | -.12 | .50 | -.02 | .26 |
| Neutral Incongruent Response Time | -.35 | .01 | -.38 | .22 | -.35 | .11 |
| Sad Incongruent Response Time | .03 | .06 | -.39 | .10 | -.23 | .04 |
| Happy Interference | .22 | .14 | .04 | .32 | .07 | .20 |
| Angry Interference | .20 | .00 | .23 | .47 | .21 | .25 |
| Neutral Interference | -.43 | .25 | .03 | .24 | -.14 | .21 |
| Sad Interference | .12 | .07 | -.03 | .40 | .05 | .23 |
| Happy Congruent Accuracy | -.40 | .13 | .08 | .00 | -.10 | .11 |
| Angry Congruent Accuracy | **-.56*** | -.31 | .07 | -.12 | -.14 | -.22 |
| Neutral Congruent Accuracy | -.48 | -.06 | -.04 | -.34 | -.17 | -.16 |
| Sad Congruent Accuracy | -.19 | .17 | -.24 | -.31 | -.19 | -.12 |
| Happy Incongruent Accuracy | -.32 | -.25 | -.08 | -.33 | -.08 | -.17 |
| Angry Incongruent Accuracy | -.42 | -.31 | .04 | -.08 | -.15 | -.21 |
| Neutral Incongruent Accuracy | -.09 | .13 | .16 | -.02 | .03 | .02 |
| Sad Incongruent Accuracy | -.14 | .21 | .17 | .12 | .08 | .13 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.49 | -.22 | -.04 | .36 | -.24 | .02 |
| Angry Response Time | -.26 | -.46 | -.31 | .25 | -.28 | -.16 |
| Fear Response Time | -.45 | -.44 | -.17 | .30 | -.26 | -.08 |
| Sad Response Time | -.49 | -.24 | -.14 | .24 | -.28 | -.05 |
| Happy Accuracy | -.46 | -.36 | .19 | .11 | .04 | -.03 |
| Angry Accuracy | **-.73**** | -.17 | -.09 | -.36 | -.28 | -.26 |
| Fear Accuracy | -.36 | -.34 | .01 | .01 | -.16 | -.18 |
| Sad Accuracy | -.02 | -.14 | .01 | .13 | -.04 | .00 |
| Happy Intensity Rating | .17 | .16 | .29 | .37 | .27 | .31 |
| Angry Intensity Rating | -.38 | -.22 | **.54*** | .24 | .15 | .00 |
| Fear Intensity Rating | .02 | -.30 | .38 | .41 | .18 | .04 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sad Intensity Rating | .03 | -.36 | .38 | .36 | .25 | .06 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).

Table 44.

*Bivariate correlations between State-Trait Anxiety Index – State, State-Trait Anxiety Index – Trait, and behavioural performance, split by group and for all participants combined*.

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | STAI-State | STAI-Trait | STAI-State | STAI-Trait | STAI-State | STAI-Trait |
| Response Time | .17 | -.02 | .31 | -.14 | .23 | -.07 |
| Response Time SD | -.14 | .29 | .40 | -.29 | .08 | -.02 |
| Fastest 10% Response Time | .17 | -.05 | -.08 | -.26 | .06 | -.15 |
| Slowest 10% Response Time | -.12 | .01 | -.34 | .15 | -.20 | .07 |
| Number of Lapses | -.13 | .20 | .40 | .09 | .06 | .13 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | .00 | -.10 | -.30 | -.52 | -.12 | -.33 |
| Angry Congruent Response Time | -.08 | -.17 | .17 | -.47 | .02 | -.30 |
| Neutral Congruent Response Time | -.06 | -.43 | -.23 | **-.58*** | -.15 | **-.52**** |
| Sad Congruent Response Time | -.13 | -.06 | -.21 | **-.59*** | -.15 | -.30 |
| Happy Incongruent Response Time | .14 | .00 | -.25 | **-.55*** | -.01 | -.30 |
| Angry Incongruent Response Time | .20 | .07 | .17 | -.53 | .19 | -.23 |
| Neutral Incongruent Response Time | .07 | -.26 | -.07 | **-.73**** | .01 | **-.52**** |
| Sad Incongruent Response Time | -.03 | .01 | -.07 | **-.70**** | -.04 | **-.37*** |
| Happy Interference | .43 | .29 | .10 | -.14 | .28 | .02 |
| Angry Interference | **.66**** | **.56*** | .04 | -.27 | **.40*** | .10 |
| Neutral Interference | .17 | .03 | .24 | -.20 | .20 | -.11 |
| Sad Interference | .22 | .15 | .26 | -.30 | .23 | -.07 |
| Happy Congruent Accuracy | .38 | -.09 | -.17 | -.03 | .21 | -.04 |
| Angry Congruent Accuracy | .20 | -.19 | -.48 | .11 | -.13 | -.01 |
| Neutral Congruent Accuracy | .27 | .26 | -.30 | .33 | .05 | .29 |
| Sad Congruent Accuracy | -.12 | -.42 | -.43 | .09 | -.29 | -.04 |
| Happy Incongruent Accuracy | -.47 | -.50 | -.29 | .12 | **-.40*** | -.14 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Angry Incongruent Accuracy | -.42 | **-.60*** | -.40 | .00 | **-.40*** | -.26 |
| Neutral Incongruent Accuracy | -.32 | -.19 | -.11 | .27 | -.23 | .04 |
| Sad Incongruent Accuracy | -.25 | -.33 | -.47 | .00 | -.35 | -.10 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | -.05 | -.25 | -.09 | -.50 | -.05 | **-.38*** |
| Angry Response Time | -.25 | -.37 | .26 | -.33 | -.06 | -.34 |
| Fear Response Time | -.46 | -.51 | .07 | -.43 | -.26 | **-.44*** |
| Sad Response Time | -.15 | -.22 | -.28 | -.49 | -.19 | -.34 |
| Happy Accuracy | **-.70**** | -.42 | .37 | .22 | .03 | .06 |
| Angry Accuracy | -.35 | -.35 | -.44 | .02 | **-.39*** | -.12 |
| Fear Accuracy | -.31 | -.08 | -.40 | .03 | -.33 | -.04 |
| Sad Accuracy | -.10 | -.13 | .01 | -.08 | -.03 | -.11 |
| Happy Intensity Rating | -.41 | .01 | .41 | .14 | .04 | .11 |
| Angry Intensity Rating | -.42 | -.44 | **.66*** | **.58*** | .03 | .11 |
| Fear Intensity Rating | -.45 | -.30 | **.69**** | .30 | .02 | .01 |
| Sad Intensity Rating | **-.60*** | -.46 | **.79**** | .39 | .00 | .04 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

Table 45.

*Bivariate correlations between Positive and Negative Affect Schedule - Positive, Positive and Negative Affect Schedule - Negative, and behavioural performance, split by group and for all participants combined.*

| | GS | | INS | | All (GS & INS) | |
|---|---|---|---|---|---|---|
| Psychomotor Vigilance | PANAS POS | PANAS NEG | PANAS POS | PANAS NEG | PANAS POS | PANAS NEG |
| Response Time | -.13 | .07 | -.30 | .23 | -.20 | .15 |
| Response Time SD | -.21 | -.03 | -.26 | .46 | -.22 | .19 |
| Fastest 10% Response Time | -.10 | .16 | -.07 | -.09 | -.09 | .04 |
| Slowest 10% Response Time | .14 | -.04 | .46 | -.22 | .26 | -.13 |
| Number of Lapses | -.22 | -.03 | -.22 | .28 | -.22 | .09 |
| Emotion Stroop | | | | | | |
| Happy Congruent Response Time | .29 | -.20 | .09 | .30 | .22 | .04 |
| Angry Congruent Response Time | .15 | -.31 | .30 | **.64*** | .20 | .08 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Neutral Congruent Response Time | .47 | -.24 | .39 | .42 | **.39*** | .16 |
| Sad Congruent Response Time | .32 | -.26 | .39 | .25 | .34 | -.05 |
| Happy Incongruent Response Time | .23 | -.05 | .19 | .44 | .22 | .18 |
| Angry Incongruent Response Time | .06 | -.06 | .16 | **.70**** | .09 | .26 |
| Neutral Incongruent Response Time | .32 | -.20 | .06 | .50 | .22 | .15 |
| Sad Incongruent Response Time | .20 | -.19 | .27 | .44 | .22 | .10 |
| Happy Interference | -.12 | .40 | .27 | .39 | .03 | **.39*** |
| Angry Interference | -.20 | **.54*** | -.19 | .32 | -.20 | **.43*** |
| Neutral Interference | .01 | -.06 | -.48 | .09 | -.17 | .02 |
| Sad Interference | -.34 | .23 | -.20 | .42 | -.30 | .31 |
| Happy Congruent Accuracy | -.10 | .30 | .33 | .06 | .00 | .20 |
| Angry Congruent Accuracy | .38 | .21 | -.24 | -.30 | .11 | -.08 |
| Neutral Congruent Accuracy | -.20 | .37 | -.32 | **-.56*** | -.24 | -.05 |
| Sad Congruent Accuracy | .37 | -.39 | -.28 | -.41 | .03 | **-.39*** |
| Happy Incongruent Accuracy | **.69**** | -.31 | -.32 | -.50 | **.38*** | -.36 |
| Angry Incongruent Accuracy | .47 | -.41 | -.14 | -.13 | .24 | -.26 |
| Neutral Incongruent Accuracy | .11 | -.38 | -.02 | -.19 | .07 | -.29 |
| Sad Incongruent Accuracy | .13 | -.28 | -.04 | -.03 | .04 | -.12 |
| Face Categorization & Intensity | | | | | | |
| Happy Response Time | .41 | -.01 | -.30 | .36 | .18 | .16 |
| Angry Response Time | .31 | -.24 | .02 | .48 | .23 | .06 |
| Fear Response Time | **.54*** | -.38 | -.12 | .52 | .34 | .01 |
| Sad Response Time | .45 | -.10 | -.38 | .21 | .21 | .03 |
| Happy Accuracy | **.52*** | -.50 | .33 | .13 | .32 | -.03 |
| Angry Accuracy | **.54*** | -.15 | -.05 | -.41 | .29 | -.29 |
| Fear Accuracy | .33 | -.03 | -.31 | -.22 | .09 | -.12 |
| Sad Accuracy | -.11 | -.22 | -.08 | .14 | -.08 | .00 |
| Happy Intensity Rating | .26 | -.20 | .27 | .32 | .24 | .12 |
| Angry Intensity Rating | .51 | -.45 | .18 | .09 | **.39*** | -.19 |
| Fear Intensity Rating | .38 | -.37 | .15 | .44 | .30 | .01 |
| Sad Intensity Rating | **.61*** | **-.59*** | .24 | .36 | **.46*** | -.11 |

*Note.* ** = Correlation is significant at the 0.01 level (2-tailed).

* = Correlation is significant at the 0.05 level (2-tailed).