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Effects of Partial Sleep Deprivation on the Neural Mechanisms of Face Perception

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Introduction

Lack of sleep is associated with a number of physiological and mental changes, including impaired immune system (Bryant et al., 2004) and attention as well as effects on both cognitive and emotional processing (Walker, 2009). Yet, despite the great impact sleep has on daily functioning, much is still unknown about the impact of sleepiness on the biological mechanisms behind the behavioural changes. Most measures of sleepiness used clinically and in research settings focus primarily on symptoms rather than on the underlying biology. Therefore, sleep researchers are increasingly attempting to map the neural characteristics of the sleepy brain using fMRI (Sämann et al., 2010; Bell-McGinty et al., 2004; Yoo et al., 2007).

Furthermore, many basic neural processes have not been studied from a sleep perspective. One such function is face perception, which involves several functions known to be vulnerable to sleep deprivation such as basic attention and higher cognitive and emotional processes (Vuilleumier & Pourtois, 2007). Although some groups have studied subjective face recognition (Huck et al., 2006; Van der Helm et al., 2010), the neural effects of sleep deprivation on brain regions important for face perception have not been studied.

Face perception is an essential social process which allows individuals to interact with others. Understanding the role of sleep in face perception could thus have important social implications.
The human face contains a vast amount of information and subtle cues which enable us to draw conclusions about the gender, age, emotions and personality of others. On a brain level this process is complex and activates both frontal and occipito-temporal regions. Two key areas in the network are the fusiform gyrus and the amygdala. (Vuilleumier & Pourtois, 2007).

Objectives

This study aimed to investigate the neural effects of partial sleep deprivation (PSD) and sleepiness on face perception and to examine how two classic sleepiness measures – The Karolinska sleepiness Scale (KSS) and a psychomotor vigilance task (PVT) (Kaida et al., 2006) – reflected changes in BOLD activity in two regions of interest (the amygdala and the fusiform gyrus).

Methods

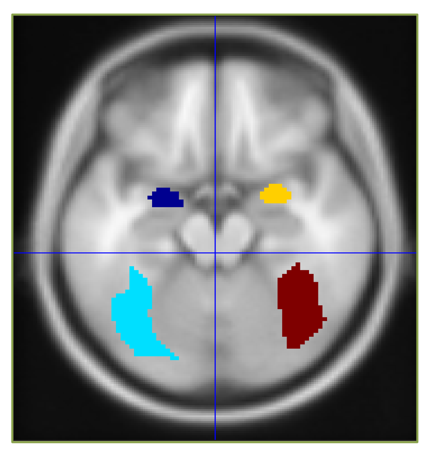
27 healthy young adults (mean age = 23.9, sd = 2.4, females= 14) participated in a within-subject partial sleep deprivation (PSD) experiment.

All participants were monitored using polysomnography during the sleep intervention nights, and underwent an fMRI paradigm on the following evenings.

During the fMRI session, subjects were instructed to view pictures of neutral, angry and happy faces in a block design, and rate their subjective sleepiness on 9 occasions using the KSS. Sleepiness was also assessed using a 5-minute PVT. The fusiform gyri and amygdalae, known to be involved in face perception, were chosen as regions of interest (ROI) (Figure 1).

fMRI data were preprocessed using the SPM12b software package and analysed in the SPM8 software package (Wellcome Department of Imaging, Neuroscience, University College London, London, UK; *http://www.fil.ion.ucl.ac.uk/spm*) using MarsBaR toolbox (Brett et al., 2002) to extract region of interest BOLD activity data. The sleepiness data (KSS and PVT) were analysed using the programming software R (R Core Team, 2013, *http://www.R-project.org/*)

Figure 1) ROI definition of Amygdalae and Fusiform Gyri



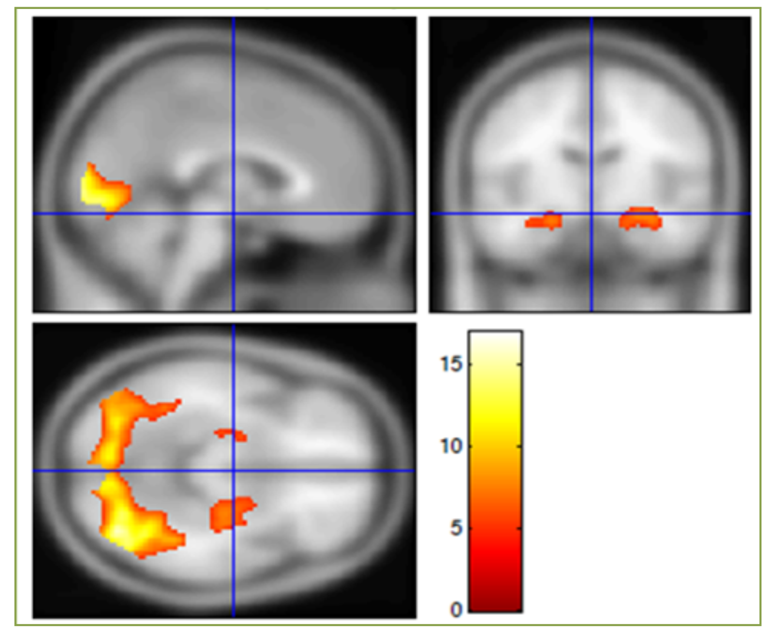
Definition of amygdalae and fusiform gyri ROIs used in the present analysis

Results

Across sleep conditions, viewing faces caused a significant increase in fusiform gyrus and amygdala activation ($p<0.05$, FWE corrected). This was also the case when only neutral faces were compared to baseline (Figure 2).

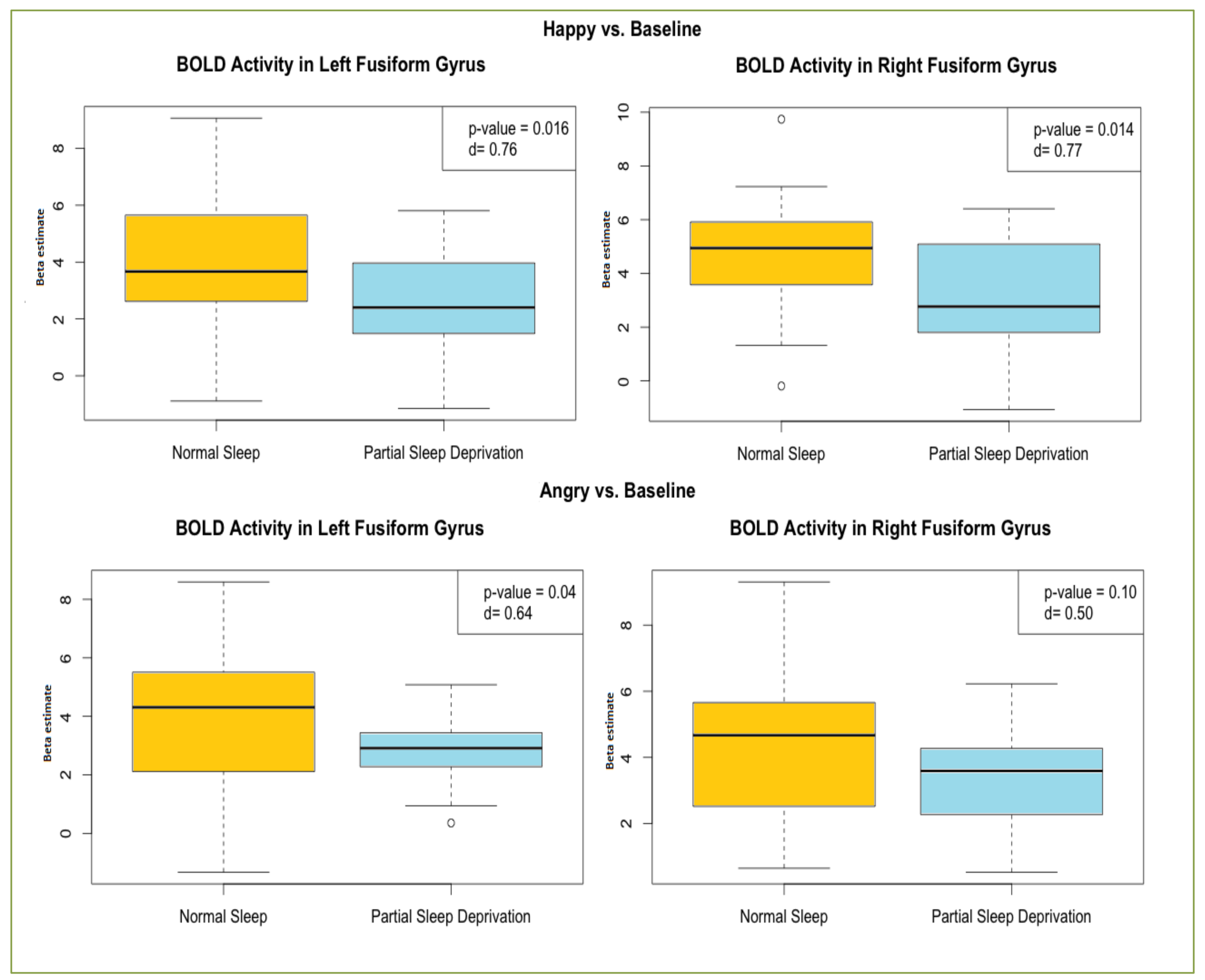
Region of interest analyses on the amygdalae and fusiform gyri revealed no effect of PSD on the BOLD activity during neutral face perception. Similarly, the analysis of emotional faces showed no effect in the amygdalae. However, the sleep intervention was associated with a significant reduction in activity in the fusiform gyrus during perception of faces with emotional expressions (Figure 3)

Figure 2) Whole-Brain analysis of BOLD Activity During Neutral Face Perception Compared to Baseline Fixation Cross



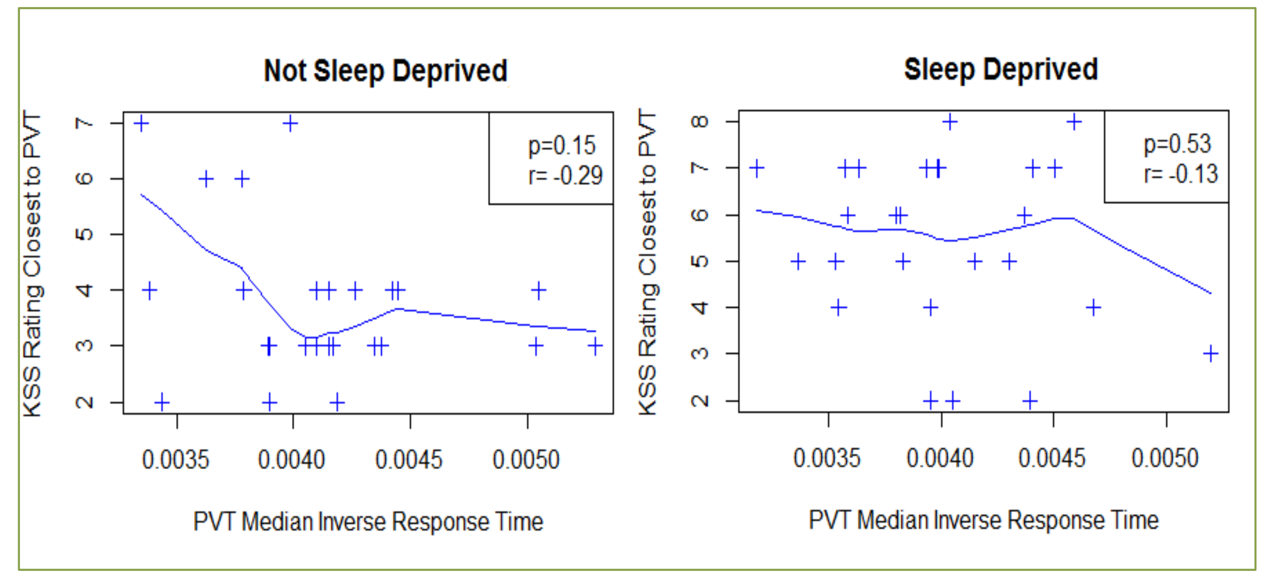
Whole-brain analyses showed that perception of neutral faces significantly increased BOLD activity in primarily the predefined regions of interest, as well as other occipito-temporal regions (p> 0.05,FWE corrected)

Figure 3) Effects of PSD on FUsiform Gyrus Activity during Perception of Emotional Faces



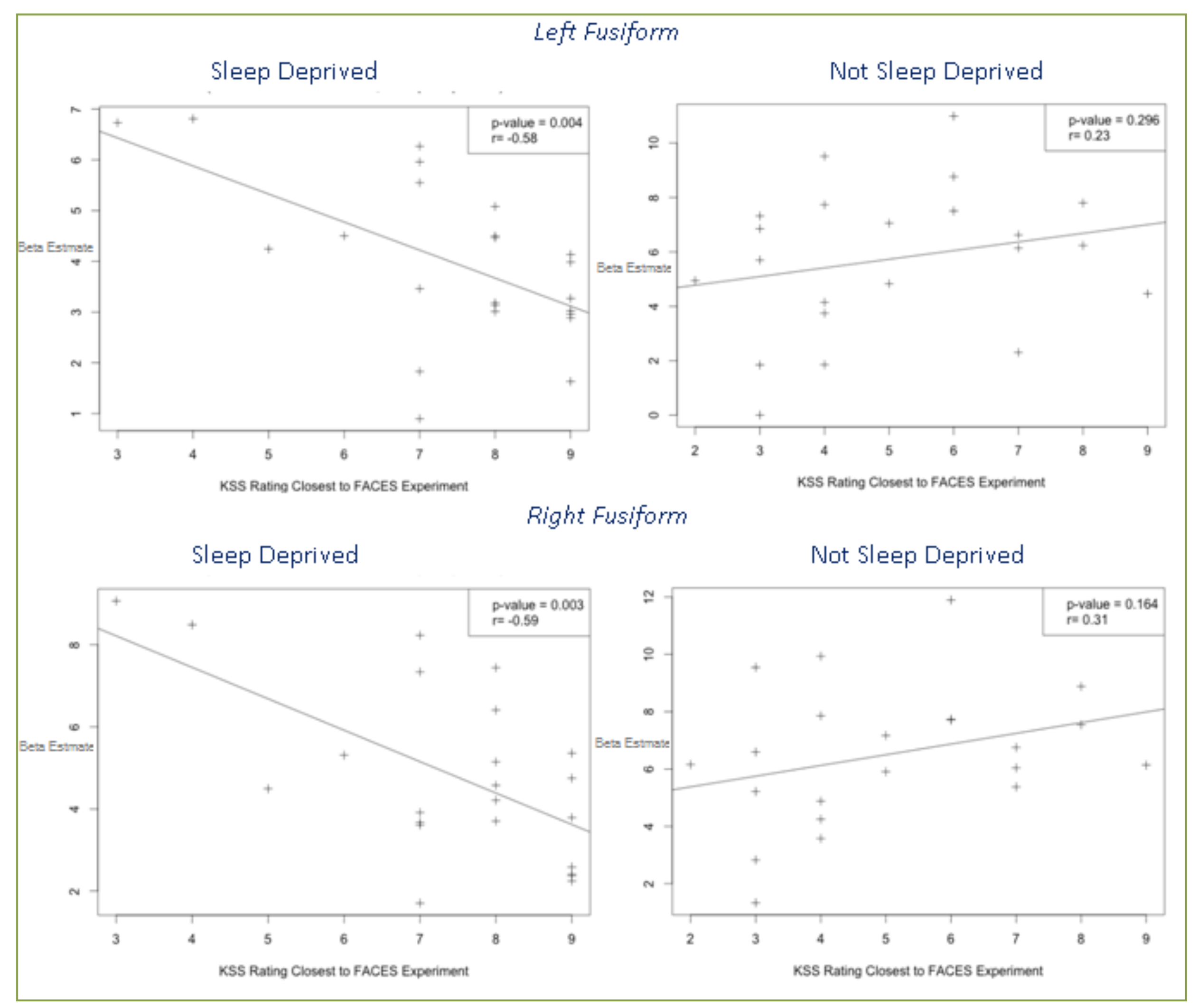
There was a significant association between PSD and reduced activation in fusiform gyrus bilaterally when seeing happy faces and in the left fusiform gyrus when viewing angry faces compared to baseline (Happy: R-fusiform, p=0.01 d=0.77, L-fusiform, p=0.02 d=0.76; Angry: L-fusiform, p = 0.04 d= 0.64).

Figure 4



Plots illustrating the relationship between PVT reaction times and the KSS rating made closest to the PVT. Pearson's correlation analyses showed that the two measures were not significantly correlated in any sleep condition.

Figure 5



The fusiform gyrus activation in response to all faces and the KSS rating made immediately after the fMRI experiment were negatively correlated bilaterally (R-fusiform: p= 0.003, r= -0.59, L-fusiform: p=0.004, r=-0.58) in the PSD condition (mean score= 7.19, sd =1.66) but not in the full sleep condition (mean score= 5.12, sd = 1.95).

Discussion

These data indicate that fusiform gyrus activity during emotional face perception is reduced in conditions of PSD. This suggests that sleep might play an important role in social interactions by modulating the ability to perceive emotional expressions in human faces. To investigate this assumption, future studies should combine imaging data with behavioural measures.

The data showed no effects of PSD on neutral face perception, suggesting that the impact of sleepiness on face perception is driven by the effects on emotional processing. However, the MRI data only revealed changes in the fusiform gyrus and not in the amygdala, which is an important region for emotional processing (Santos et al., 2011). Based on these findings we suggest that the PSD intervention reduced the connectivity between the amygdala and the fusiform gyrus and thus weakened the feedback signal from the amygdala. This hypothesis is in line with recent fMRI studies which have demonstrated that lack of sleep is associated with reduced network connectivity in several brain regions (Sämann et al., 2010; Bell-McGinty et al., 2004; Yoo et al., 2007). To verify this theory, follow-up studies using connectivity analyses are necessary.

Furthermore, the present data indicate that subjective sleepiness ratings (here measured with the KSS) reflect sleep-related changes in BOLD activity when the sleep pressure is high. In contrast, PVT reaction times did not predict changes in activity. The outcome from the sleepiness measures could be affected by the study design; a short version of the reaction time test was used and participants did the test early during the session, while subjective ratings were collected throughout the evening. However, the findings may suggest that the KSS is more stable predictor of the biological changes occurring in the sleepy brain.

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