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 sleep on brain function behind the behavioral 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 sleep-deprived brain using fMRI (Simmons et al., 2010, Bell-McGuire et al., 2004, Yoo et al., 2007).

Furthermore, 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 (Vuillesquin & Prouzet, 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 activating both frontal and occipito-temporal regions. Two key areas in the network are the fusiform gyrus and the amygdala (Vuillesquin & Prouzet, 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 basic sleepiness measures – The Karolinska sleepiness scale (KSS) and a psychomotor vigilance task (PVT) (Kaida et al., 2016) – reflected changes in BOLD activity in two regions of interest (the amygdala and the fusiform).

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 paradigm under the following evenings.

During the MRI 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 gyrus and amygdala, known to be involved in face perception, were chosen as regions of interest (ROI) (Figure 1).

fMRI data were preprocessed using the SPM2 software package and analysed in the SPM2 software package (Welcome 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/).

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 amygdala 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 amygdala. 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).

Discussion

These data indicate that fusiform gyrus activity during emotional face perception is reduced in conditions of PSD. This suggests that sleep may 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 sleep 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. This leaves open the question regarding the involvement of the amygdala in emotional face processing (Santos et al., 2010). Based on these findings we suggest that the PSD intervention reduced the connectivity between the amygdala and the fusiform gyrus and thus weakened the basal signal from the amygdala. This hypothesis is in line with recent fMRI studies which have demonstrated that lack of sleep affects brain connectivity in several brain regions (Simmons et al., 2010, Bell-McGuire et al., 2004, Yoo et al., 2007). To verify this theory, follow-up studies using connectivity analysis 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 shorter version of the reaction time task was used and participants did the test early during the session, while subjective ratings were collected throughout the evening. The finding that subjective sleepiness is a more reliable predictor of the biological changes occurring in the sleeping brain.

References

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

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