ELSEVIER

Sleep Medicine 1 (2000) 245–246

SLEEP MEDICINE

www.elsevier.com/locate/sleep

Journal search and commentary

Articles reviewed: 1. Sleep deprivation-induced reduction in cortical functional response to serial subtraction. 2. Altered brain response to verbal learning following sleep deprivation ☆

Richard P. Allen

Johns Hopkins University, School of Medicine, Baltimore, MD, USA

Category

Imaging, fMRI, sleep deprivation, cognitive performance

Objective(s)

Determine changes after moderate sleep deprivation in activation of cortical areas of the brain on functional magnetic resonance imaging (fMRI) during a short duration verbal learning task and a short serial subtraction task (the results were presented from the verbal learning task in *Nature* and from the serial subtraction task in *NeuroReport*, both obtained from the same study as described here).

Study design

Within subject crossover between rested and 35-h sleep deprived (SD) conditions, order counterbalanced.

Study population

Thirteen healthy, normal young adults (average age 27.2 years, range 21–35 years; average education 16.5 years, range 14–18 years).

Methods

The blood oxygen level-dependent (BOLD) fMRI provided relative quantitative measures of regional cerebral activation during a verbal learning task which was alternated with a serial subtraction task. Verbal and numeric cognitive tasks were each divided into four 40 s blocks with a 40 s neutral task (e.g. determining if the letters presented were in all upper or lower case) occurring first and in between each cognitive task. In each 40 s block the cognitive verbal task involved learning five words and the numeric task involved serial subtraction. fMRI had 90 repetitions of echo planar images with 6 mm slice thickness. Statistical analyses corrected for the large number of fMRI comparisons that were made. The accuracy of the verbal learning was tested about 10 min after completing the fMRI scans. Subjective ratings were obtained for sleepiness on the Stanford Sleepiness Scale and for effort on a 5-point Lickert scale. The scans were obtained on the evening either after normal sleep or after no sleep (35 h SD) the prior night.

Results

Serial subtraction and verbal learning performance significantly decreased after SD. For the serial subtraction the rested state showed bilateral activation

☆ First paper: Drummond SPA, Brown GG, Gillin JC, Stricker JL, Wong EC, Buxton RB. Altered brain response to verbal learning following sleep deprivation. Nature 2000;403:655–657. Second paper: Drummond SPA, Brown GG, Stricker JL, Buxton RB, Wong EC, Gillin JC. Sleep deprivation-induced reduction in cortical functional response to serial subtraction. NeuroReport 1999;10:3745–3748.

1389-9457/00/$ - see front matter
PII: S1389-9457(00)00035-6

in prefrontal cortex (PFC), parietal lobes and premotor areas and the SD state showed much less activation in these areas. For verbal learning, the rested state showed left hemisphere activation in the PFC, premotor area and temporal lobe. The SD state compared to the rested state showed decreased left temporal lobe activity but also *increased* activity for areas of the Left PFC, bilateral parietal lobes, and two frontal lobe areas (left middle frontal gyrus and right inferior frontal gyrus). For the verbal tasks, PFC activation after SD correlated significantly with sleepiness in two bilateral PFC areas: left inferior frontal gyrus at BA47 and right superior/middle frontal gyri at B10. Better recall on the verbal learning task was correlated with greater activation in bilateral parietal lobes, right temporal gyrus and left supplementary motor area. All of these results were statistically significant.

Conclusion

The authors concluded that pattern of brain functioning is altered in the sleep deprived state and that this change is task dependent. For immediate performance on serial subtraction there is a general decrease in critical areas that are activated by this task in the rested state (PFC, premotor areas, and parietal lobes). For the verbal task of memorizing words for later recall there is similarly a decrease in temporal lobe activation that is activated by this task in the rested state. But brain activation during verbal learning also showed compensatory increases in activation that for the PFC related to degree of subjective sleepiness and for parietal lobes to degree of preservation of normal verbal learning.

Comment

The results from this study showing that areas activated by cognitive tasks in the rested state are significantly less activated after SD are consistent with prior studies and the poorer performance after SD. In particular numeric task association with bilateral parietal lobes and verbal learning with left temporal lobe generally corresponds with other neuropsychological studies.

The surprising and somewhat puzzling results from this study come from the verbal learning task where there is increased activation of some areas, mostly left frontal and bilateral parietal areas. The authors suggest this represents attempts to compensate for the deficits produced by SD with the frontal activation responding to the sleepiness while the parietal activation provides some partial correction of the verbal performance loss. The puzzle then becomes why similar compensation did not occur for the numeric task. The numeric task activation of the parietal lobes in the rested state may somewhat explain performance adaptation involving this area occurring only during verbal learning. But the PFC was activated by both tasks in the rested state and it showed areas of increased activation after SD for only the verbal and not the numeric task. If, as suggested, this increased PFC activation related to response to sleepiness and not to task performance then why did it not also occur for the numeric task?

It is also important to remember that these results assume that the relevant cognitive activity occurs mainly during the cognitive and not the neutral task. This seems fairly certain during the serial subtraction task, but, for verbal learning, motivated subjects may have been continuing to rehearse the recently presented words during the neutral tasks. If this occurred more in the rested than the SD state it could have artificially reduced the activation in the rested state compared to the SD state. This problem, however, would not seem related to the parietal lobe activation occurring for SD and not the rested state. Further evaluation of this problem is, however, needed in future studies.

Overall these results strike a blow at what might be called the passive theory of brain functioning in sleep deprivation. The sleepy brain is not simply a less active brain. Sleep deprivation may produce a change in the pattern of brain activation, which includes areas with increased as well as those with decreased activation. These changes depend on the task and presumably will be found to also depend upon subject variables. This mirrors the clinical experience. Some subjects and some tasks are certainly much more sensitive to sleep loss than others. The pattern of changes might also relate to the well-established effects of sleep loss on mood. Determining the changes in brain patterns of activation with SD and the factors affecting them may help us better understand the wide range of clinical effects and variability seen with sleep loss.