

THE EFFECTS OF SLEEP RESTRICTION AND ALCOHOL ON SIMULATED DRIVING AND CORTICAL FUNCTION IN OBSTRUCTIVE SLEEP APNOEA

by

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ABSTRACT

Obstructive sleep apnoea (OSA) is a common sleep disorder associated with neurobehavioural daytime abnormalities including poor driving simulator performance and an increased risk of motor-vehicle accidents. Treating OSA with continuous positive airway pressure (CPAP) significantly improves many of the daytime consequences of OSA. Until recently it was believed that CPAP treatment can completely resolve excessive daytime sleepiness and neurobehavioural abnormalities associated with OSA. However, recent evidence suggests that compared to results in well-matched healthy subjects, levels of daytime vigilance and cortical activation and some domains of cognitive function in OSA patients may not return to normal, even after effective OSA treatment with good treatment compliance.

Sleep restriction and low-dose alcohol consumption are common “life style” factors that have a negative impact on the central nervous system and driving performance in healthy subjects. However, their impact on driving simulator performance and cortical information processing in patients with OSA has not been examined.

The hypotheses tested in the work presented in this thesis were that:

- a) Sleep restriction and alcohol have a greater deleterious effect on driving simulator performance and cortical information processing in untreated OSA patients than in healthy subjects.
- b) Treatment of severe OSA with CPAP improves, but does not normalise driving simulator performance and cortical information processing.

Consequently, the broad aims were:

- a) To compare the effects of sleep restriction and alcohol on driving simulator performance and auditory cortical event-related potentials in OSA patients and healthy age and gender-matched controls.
- b) To compare driving simulator performance and auditory cortical event-related potentials in severe OSA patients before and after 3-months of CPAP therapy and to compare these results with those of healthy, untreated subjects also studied 3-months apart.

Study 1 (CHAPTER 2) compared performance during a 90-minute simulated drive in 38 patients with OSA and 20 healthy age and gender-matched control subjects under 3 conditions studied in random order: 1) normal sleep, 2) sleep restriction (4 hours in bed on the night prior to study) and 3) low-dose alcohol (blood alcohol concentration 0.05 g/dL). Compared to control subjects, OSA patients exhibited a higher crash rate, increased overall steering deviation and more steering deterioration with time-on-task. Following sleep restriction and alcohol there was a ~40% greater increase in steering deviation in OSA patients than in control subjects. Crashes were more likely to occur in patients with OSA compared with control subjects. OSA patients were more likely to crash under sleep restriction and alcohol conditions compared to the normal sleep condition. Simulator crashes were associated with behavioural and physiological evidence of increased sleepiness. The results of this study showed that compared with healthy subjects, OSA patients have worse driving simulator performance and are more vulnerable to the effects of prior alcohol and sleep restriction on various driving performance parameters. To the extent that these simulator findings may be indicative of real on-road driving

performance, it may be advisable for untreated OSA patients to avoid sleep restriction and even legal doses of alcohol prior to extended driving.

Study 2 (CHAPTER 3) assessed the effectiveness of ~3 months CPAP treatment in improving driving simulator performance. Eleven severe OSA patients and nine age- and gender-matched controls were studied on two occasions 3 months apart using the same protocol as in Study 1. In the intervening period OSA patients were treated with CPAP during which they showed a high level of compliance with therapy (mean \pm SD, 6.0 \pm 1.4 hours/night). At baseline, OSA patients demonstrated worse driving simulator performance compared to controls under all conditions, and showed greater steering decrements following sleep restriction and alcohol than control subjects. After CPAP treatment, OSA patients showed significant improvements in steering deviation under all conditions, but steering deviation did not reach the level of control subjects and crash frequency remained significantly elevated. Braking reaction time was not significantly different between groups, conditions, or treatments and there were no significant interaction effects. Taken together, these findings suggest that CPAP treatment is only partially effective in improving driving performance during simulated long and monotonous driving. To the extent that driving simulator findings may be indicative of real on-road driving performance it may be appropriate to advise patients, even after apparent optimal CPAP treatment, to be cautious when undertaking long distance driving, as they could remain at higher than normal accident risk.

Given the behavioural finding of residual driving simulator impairment in CPAP-treated, severe OSA patients in studies 1 and 2, the final study (CHAPTER 4)

explored whether cortical information processing during a simple attention task demonstrated similar treatment resistant abnormalities. The effects of CPAP treatment on cortical information processing in OSA patients were examined by comparing early and late components of auditory target (odd-ball) event-related potential responses in 9 patients with severe OSA and 9 healthy age- and gender-matched controls. The results showed that compared to controls, early and late auditory event related potentials were abnormal in severe OSA patients at baseline. Specifically, N2 and P3 peaks were smaller and delayed in latency, and P2 amplitude was larger. At follow-up, P3 latency was the only measure to show improvement following CPAP treatment, but remained prolonged in patients compared to control subjects despite high CPAP treatment compliance in OSA patients (mean \pm SD, 6.0 \pm 1.6 hours/night). None of the abnormalities in earlier components (N2 and P2) observed at baseline changed in CPAP-treated OSA patients.

In summary, driving simulator performance is impaired in patients with OSA compared to healthy controls, and patients demonstrate a greater susceptibility to the detrimental effects of sleep restriction and alcohol. Driving simulator performance is only partially improved in CPAP-treated OSA patients. Thus, it may be prudent to advise patients with OSA to be cautious and avoid sleep loss or alcohol prior to long distance driving, even when optimally treated. Residual abnormalities were also evident in auditory cortical evoked responses in optimally treated OSA patients, suggesting the possibility of a permanent reduction in information processing capacity. The mechanisms underlying the observed vulnerability to additional stressors (sleep loss and alcohol) and the residual driving

performance and electrophysiological abnormalities observed in CPAP-treated patients warrants further investigation. In addition, examining how these driving simulator and electrophysiological findings relate to on-road motor vehicle accident risk in patients with OSA is another important question worthy of further investigation.

PUBLICATIONS

The following are publications that have arisen from work conducted towards this thesis:

Journal articles:

Vakulin A, Baulk SD, Catchside PG, Antic NA, van den Heuvel CJ, Dorrian J & McEvoy RD. Effects of Alcohol and Sleep Restriction on Simulated Driving Performance in Untreated Patients with Obstructive Sleep Apnea and Health. *Annals of Internal Medicine* 2009; **151**:447-455.

Vakulin A, Baulk SD, Catchside PG, Antic NA, van den Heuvel CJ, Dorrian J & McEvoy RD. Driving Simulator Performance Remains Impaired in Patients with Severe OSA After CPAP Treatment. *Journal of Clinical Sleep Medicine* (Accepted for Publication 02/01/2011).

Book Chapters:

Vakulin A, Baulk SD, Antic NA, Catchside PG, McEvoy RD. Sleep, Sleepiness and Traffic Safety: Chapter 14: Sleepiness, Alcohol and Traffic Safety. Nova Science Publishers, USA, 2010 ISBN:978-1-61728-943-9.

Published abstracts:

Vakulin A, Baulk SD, Anderson R, Catcheside PG, Banks S, van den Heuvel CJ & McEvoy D. The Effects of Sleep Deprivation and Legal Alcohol Intoxication on Simulated Driving Performance. *Sleep & Biological Rhythms*, 2006; **4**(S1): A52.

Vakulin, A, Baulk, S.D, Catcheside, P. G, Banks, S, Antic, N, van den Heuvel, C. & McEvoy. R.D. Alcohol Effects on Driving Performance and Neurocognition in Obstructive Sleep Apnoea. *Sleep and Biological Rhythms* 2007; **5**(Suppl): PO409, A121.

Baulk, S.D, **Vakulin, A**, Catcheside, P.G, Dorrian, J, Antic, N, van den Heuvel, C.J. & McEvoy, R.D. Are OSA Patients Vulnerable to Sleep Restriction? Effects on Sleepiness and Perception During Simulated Driving. *Sleep and Biological Rhythms* 2007; **5**(Suppl): PO333, A98.

Baulk, S.D, **Vakulin, A**, Catcheside, P.G, Dorrian, J, Antic, N, van den Heuvel, C.J. & McEvoy, R.D. Are OSA Patients Vulnerable to Sleep Restriction? Effects on Sleepiness and Awareness During Simulated Driving. *Journal of Sleep Research* 2008; (Suppl 1), p151.

Vakulin, A, Baulk, S.D, Catcheside, P. G, Antic, N, van den Heuvel, C, Dorrian, J & McEvoy, R.D. Simulated Driving Performance in Obstructive Sleep Apnoea: Evidence for OSA-Dependent Vulnerability to Sleep Restriction and Alcohol. *Sleep and Biological Rhythms* 2008; **6**: A1-A8.

Vakulin, A., Baulk, S.D., Catcheside, P. G., Antic, N., van den Heuvel, C, Dorrian, J & McEvoy. R.D. The Effects of Sleep Restriction & Alcohol on Simulated Driving Performance in OSA Patients and Controls. *Am. J. Respir. Crit. Care Med*, Apr 2009; **179**: A5319.

Vakulin, A, Baulk, S.D, Catcheside, P. G, Antic, N, van den Heuvel, C, Dorrian, J & McEvoy. R.D. CPAP Treatment Partially Improves Driving Simulator Performance in Severe OSA Patients and Reduces OSA-Dependent Vulnerability to Sleep Restriction and Alcohol. *Sleep and Biological Rhythms* 2009; **7**(Suppl s1): O004.

Vakulin, A, Baulk, S.D, Catcheside, P. G, Antic, N, van den Heuvel, C, Banks, S & McEvoy. R.D. The Effects of Sleep Restriction and Alcohol on Cognitive Function and P300 in Obstructive Sleep Apnoea Patients Before and After CPAP Treatment. *Sleep and Biological Rhythms* 2010; **8**(Suppl s1): OP04.

Unpublished Conference Proceedings:

Vakulin, A, Baulk, S.D, Antic, N, van den Heuvel, C.J & McEvoy, R.D. Driving and Neurocognitive Performance in OSA: Vulnerability to Sleep Restriction and Alcohol (*Proceedings of Australasian Chronobiology Society 2006*).

Vakulin, A, Baulk, S.D, Catcheside, P. G, Banks, S, Antic, N, van den Heuvel, C. & McEvoy. R.D. Alcohol Effects on Driving Performance and Neurocognition in

Obstructive Sleep Apnoea. (*Proceedings of the 10th International Sleep & Breathing Meeting 2007*)

Baulk, S.D, **Vakulin, A**, Catcheside, P.G, Dorrian, J, Antic, N, van den Heuvel, C.J & McEvoy, R.D. Are OSA Patients Vulnerable to Sleep Restriction? Effects on Sleepiness and Perception During Simulated Driving. (*Proceedings of the 10th International Sleep and Breathing Meeting 2007*)

Vakulin, A, Baulk, S.D, Catcheside, P.G, van den Heuvel, C.J, Antic, N & McEvoy, R.D. OSA Dependant Vulnerability to Sleep Restriction and Low-Dose Alcohol: Study of Simulated Driving Performance. (*Proceedings of the Australian Society for Medical Research Annual Conference 2008*).

Vakulin, A, Baulk, S.D, Catcheside, P.G, van den Heuvel, C.J, Antic, N & McEvoy, R.D. Mid-Afternoon Simulated Driving Performance in Severe Obstructive Sleep Apnoea: Evidence for OSA-Dependent Vulnerability to Sleep Restriction and Alcohol. (*Proceedings of the Australasian Chronobiology Society 2008 Conference Sydney July 2008*).

Vakulin, A, Baulk, S.D, Catcheside, P. G, Antic, N, van den Heuvel, C, Dorrian, J & McEvoy, R.D. Investigations of Driving Performance in Sleep Apnoea Patients. (*Proceedings of the South Australia Defence and Veteran Health Research Paper Day, Repatriation General Hospital, 2009*).

Vakulin, A, Baulk, S.D, Catcheside, P. G, Banks, S, Antic, N, van den Heuvel, C. & McEvoy. R.D. Neurocognitive Function in Sleep Restricted Patients with Obstructive Sleep Apnoea. (*Proceedings of the Adelaide Sleep Retreat Conference, Adelaide, 2009*).

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any university or tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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GLOSSARY OF ABBREVIATIONS

AERP(s)	Auditory event related potential(s)
AHI	Apnoea hypopnoea index
BAC	Blood alcohol concentration
BMI	Body mass index
COPD	Chronic obstructive pulmonary disease
CPAP	Continuous positive airway pressure
EDS	Excessive day-time sleepiness
EEG	Electroencephalogram
ERP(s)	Event related potential(s)
ESS	Epworth sleepiness scale
FA	Fractional anisotropy
fMRI	Functional magnetic resonance imaging
GABA	γ -Aminobutyric acid
IH	Intermittent hypoxia
MRI	Magnetic resonance imaging
MSLT	Multiple sleep latency test
MVA(s)	Motor vehicle accident(s)
MWT	Maintenance of wakefulness test
NMDA	N-methyl D-aspartate
NREM	Non-rapid eye movement
N1 & N2	First and second negative peak of the ERP respectively
OSA	Obstructive sleep apnoea
P2 & P3	First and second positive peak of the ERP respectively

PFC	Pre-frontal cortex
PVT	Psychomotor vigilance test
REM	Rapid eye movement