Comparison of driving performance in treated and untreated Obstructive Sleep Apnoea Syndrome (OSAS) patients and healthy controls

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Abstract

Background
Obstructive Sleep Apnoea Syndrome (OSAS) has been shown to be an increased risk factor for traffic accidents. Studies performed in driving simulators have reported improvements in driving performance with the application of Continuous Positive Airway Pressure (CPAP) treatment.

Aims
This study aims to investigate the effect of OSAS to driving behaviour and the comparison to driving under the influence of alcohol.

Methods
In the present study, 18 OSAS patients were treated with CPAP treatment for 7 consecutive days. A second group of healthy participants (N=18) was included in the study with a baseline and an alcohol consumption condition (BAC=0.50 g/l). All participants drove two scenarios in a simulated environment; a lane tracking and a car following scenario.

Results
No improvement due to CPAP treatment was found ($p>.05$) in weaving control (SDLP) for the lane tracking scenario. On the contrary, statistically significant impairment was found in SDLP due to alcohol ($p=.027$). Percentage (%) of time spent driven with low Time-to-Collision (TTC) values was calculated. Treated OSAS patients spent significantly more time with safe keeping distance than untreated patients ($p<.001$). Likewise, intoxicated participants spent significantly less time driving with safe distance from lead vehicle in car following scenario ($p=.008$). Equivalence in impairment level was found for Brake Reaction Time (BRT) (sec) for the car following scenario between OSAS and alcohol.

Discussion and conclusion
In conclusion, the effect of sleep apnoea appears to be detrimental compared to the alcohol effect at the legal limit. The application of intermediate alcohol BAC levels (i.e. 0.02, 0.08., 0.1) could provide insight in finding comparable levels of impairment. The difference in mean SDLP values in OSAS patients seems to be almost double the difference induced by alcohol consumption at BAC=1.2 (5.3 cm; Verster & Raemekers, 2009). Probably higher levels of alcohol levels are necessary to be included in a future research effort for the chosen types of driving parameters in order to perform comparisons of effects in driving fitness due to Obstructive Sleep Apnoea Syndrome.

Introduction
A large number of subjective (i.e. self-report) and objective (e.g., insurance or police records) studies have looked at the prevalence of Motor Vehicle Accidents (MVAs) for patients suffering from Obstructive Sleep Apnoea Syndrome (OSAS) as compared to the general population (e.g., George, 1996; Maycock, 1996; Wu & Yan-Go, 1996). The majority of these studies have suggested that OSAS presents an increased risk factor for MVAs.
Results from these studies have shown that patients with OSAS have an increased accident rate in driving simulation tests (e.g. Findley et al., 1995; George, Boudreau, & Smiley, 1996; Juniper et al., 2000), estimated to be around two to seven-times higher compared to healthy participants (e.g. George, 2004). It has also been reported that OSAS patients exhibit slower reaction times than controls in road obstacle avoidance, resulting in four times more object collisions than normals (Findley et al., 1989). In addition, it has been demonstrated that OSAS patients perform poorer than controls in steering ability (referred to as “tracking error”; George et al., 1996; Juniper et al., 2000), with half of the patients being worse than any one control participant, and with some patients showing worse performance than healthy controls under the influence of alcohol (George et al., 1996). Finally, research conducted to-date have concluded that the OSAS patients face an increased difficulty in sustaining attention while driving, thus exhibiting poorer performance and lower vigilance during experimental testing when driving on a monotonous highway route (e.g. George, Boudreau, & Smiley, 1996; Juniper et al., 2000; Turkington et al., 2001).

Given that driving is an essential part of everyday life for the majority of people, a series of treatments have been developed, in order to assist OSAS patients in driving and other daily activities. Continuous Positive Airway Pressure (CPAP) represents the most commonly used treatment and it is considered to be the most effective one (Cassel et al., 1996; Yamamoto et al., 2000). Studies have shown that CPAP treatment can reduce the number of accidents in patients with OSAS, both in simulated driving (Findley et al., 1989) and in real-life situations (e.g. Cassel et al., 1996; Findley et al., 2000; George, Boudreau, & Smiley, 1997; Yamamoto et al., 2000). Specifically, studies have shown that regular use of CPAP improves self-reported (Cassel et al., 1996; Yamamoto et al., 2000) and objective MVA rates (Findley et al. 2000; George, 2001). Relevant studies have shown that CPAP treatment may effectively reduce the MVA risk of OSAS patients in experimental tests conducted in a simulated driving setting (e.g. Engleman et al., 1994; Note, however, that the task utilised in some of these studies was actually a choice reaction task that required sustained vigilance rather than a simulated driving task).

Alcohol remains the greatest documented risk factor in driving performance and the literature is vast on alcohol effects on fitness to drive. Alcohol is the only substance affecting driving behaviour that legal limits apply. Alcohol-impaired driving is a major cause of serious and fatal car accidents. The relative crash rate for a driver with a BAC of 1.5 g/l is about 22, but drivers’ relative crash rate for fatal crashes with that amount of alcohol in their blood is about 200 (Simpson & Mayhew, 1991). Individual differences play a sizeable role in the elimination of alcohol from the human organism. Difference in accident risks is, also, an outcome of causation. Alcohol is classified as a depressant, due to its effects to the central nervous system (CNS). Existing diversity in findings across studies leads to no consensus on the effects on driving impairment in performance by a given amount of alcohol (34% of studies report impairment by .05%). Current research techniques have revealed deterioration in driving performance at lower BAC levels. However, Moskowitz and Robinson (1987) reported in their review that impairment was recorded in psychomotor tasks at a level of 0.07%. In addition, simple reaction time score (RT) was found to be an unreliable and insensitive measure. On the contrary, tracking and divided attention tasks were shown to be impaired at much lower levels (0.01-0.02%). In most studies deterioration is present above 0.08%.
Methods

Participants
Eighteen OSAS patients (17 male/1 female; 51.9±11.54 years old) and 18 healthy controls (14 male/4 female; 45.5±16.4 years old) with Body Mass Index (BMI) 33.4±7.13 kg/m², 26.26±3.25 kg/m², respectively matched for driving experience volunteered in this study. Participants received reimbursement for their participation. Inclusion criteria for sleep apnoea patients OSAS was based on a diagnosis of an Apnoea-Hypopnoea Index (AHI) ≥10 (after a polysomnographic study). Participants in both groups were active and experienced drivers. Written informed consent was obtained from all participants before enrolment and after briefing.

Procedure
Untreated OSAS patients were tested and then re-tested after having used the CPAP treatment continuously for at least 7 days. The healthy group was tested in two conditions, with zero BAC level and with BAC 0.5g/l, which is the legal limit for driving in Greece. The level of alcohol had to be sustained throughout the experiment; hence breathanalysis was performed prior and post driving scenarios and in-between neuropsychological tasks. Participants had to complete a lane tracking scenario on a highway environment maintaining a constant speed of 90 km/h (20 minutes) and a car following scenario maintaining a safe distance from the lead vehicle that was moving with a steady speed of 90 km/h. The vehicle ahead would brake abruptly suddenly and unexpectedly during the scenario.

Statistical analysis
Within and between participants comparisons were carried out with repeated measures ANOVAs and one-way ANOVAs. In case of violation of homogeneity and homoscedacity assumptions, non-parametric equivalents were administered (Friedman and Wilcoxon rank test, respectively). Within comparisons were carried out in order to investigate the effect of CPAP treatment and alcohol. Between comparisons were carried out in order to investigate the relationship between OSAS and alcohol in driving impairment. The α level was set at .05. Statistical analyses were carried out with SPSS 18.0 for Windows (SPSS 18.0, Chicago, IL.).

Results
OSAS patients showed more deteriorated performance in lane keeping (SDLP) than any other condition. CPAP treatment did not seem to significantly improve lane keeping behaviour, although decreased swerving was recorded. Figure 1 depicts mean SDLP (m) values per condition. As shown below, OSAS patients showed lower lateral control before CPAP treatment. After treatment, lateral control increases but not significantly (p>.05). However, the tracking control is still impaired compared to suggested thresholds (Brookhuis et al., 2003) and when compared to the control group before (F (1,34) = 10.57, p<.001)** and after alcohol consumption (F (1,34) = 8.23, p<.001)**. In addition, intoxicated control group weaving was greater compared to the no alcohol condition (F (1,17) = 5.9, p=.027)*. Alcohol had an effect on participants’ lateral control but the magnitude was not as great as the sleep apnoea’s effect on OSAS patients****. Untreated OSAS patients spent significantly more time (6.81±0.57% of time) driving with low TTC values (between 0 and 1 sec) which is extremely risky (F (1,17) = 5.46, p = .032) compared to the CPAP treated condition (6.37±0.54% of time). Similarly, participants from the control group (6.35±0.44% of time) spent significantly more time with low TTC values (between 0 and 1 sec) when compared to
the alcohol consumption condition (5.7±0.36% of time) \( F(1,17) = 4.27, p = .054 \). Between groups’ comparisons were not significant \( p>.05 \).

**Figure 1: Mean SDLP (m) values per condition in lane tracking scenario**

Almost all comparisons were statistically significant (Figure 1) except the comparison between the treated OSAS group and the alcohol group \( p>.05 \). Treated OSAS patients spent significantly more time driving with TTC values between 2 and 4 seconds (i.e. safe car following driving style) before treatment (3% more time, \( F(1,17) = 18.05, p = .001 \)). Likewise, participants in the control group spent more time (approx. 2.5%) with safe car following style than the intoxicated group \( F(1,17) = 8.93, p = .008 \). Untreated OSAS patients spent more time than the control group with safe car following distance \( F(1,34) = 11.42, p = .002 \). This TTC category is strongly connected to safety distance keeping; hence the significant difference among groups could reflect risk taking behaviour. The control group spent significantly more time (3%) than the treated OSAS patients in car following \( F(1,34) = 4.49, p =.041 \). On the other hand, no statistically significant differences between the OSAS treated group and the alcohol group \( p>.05 \) were found. Similarly, no significant difference were found between the alcohol and the untreated OSAS patients groups \( p =.066 \); trend). Greater braking reaction times (sec) were recorded for the untreated OSAS patients and the lowest reaction times (sec) were recorded for the CPAP treated patients \( F (1,17)=12.37, p =.003 \). Moreover, it seems that alcohol did not have an impact in braking reaction time for the alcohol group \( p>.05 \) at the legal limit. On the contrary, participants from the control group reacted much faster when they were sober compared to the untreated OSAS patients \( F (1,17)=6.55, p=.015 \).
**Discussion and conclusions**

The main findings demonstrated that sleep apnoea affects driving performance. Continuous Positive Airway Pressure (CPAP) treatment did not seem to improve significantly driving performance. Furthermore, the present experiment suggests that alcohol consumption at legal BAC might impair driving performance; however deterioration is less when compared to sleep apnoea. The difference in mean SDLP in OSAS patients seems to be almost double the difference induced by alcohol consumption at BAC=1.2 (5.3 cm; Verster & Raemekers, 2009). Equivalence might be present for brake reaction time (sec) between sleep apnoea and alcohol effect. The present study showed that sleepiness and hypo-vigilance induced by sleep apnoea may be an increasingly contributing factor in road accidents which are sometimes overlooked in driving research focusing mainly on alcohol and illicit drugs. In the present experiment, OSAS patients showed almost one third more weaving than the control group participants (31.5%). Other studies have shown significant improvement in driving behaviour as a result of using the nasal CPAP for different periods of time. For instance, Loredo and colleagues (1999) found improvement in CPAP treatment after 7 days. The same treatment period was used in this study based on Loredo et al.’s (1999) findings. The differences were not found in the quality of sleep (sleep architecture) and, thus, changes in this type of sleep may be influential in order to find improvement in driving variables such as the ones measured in this experiment (SDLP, %TTC, and BRT). In other words, the period of treatment time may not suffice in order to reveal improvement in driving behaviour when the driving task is performed in a monotonous simulated environment with these specific vehicle parameters. In addition, the monotonous environment may be the most “dangerous” choice or the most “accident-evoking” but it is far from realistic and induces sleepiness beyond control which reflects probably the worse-case scenario and not necessarily the most frequent situation. The percentage (%) of time spent driving within certain categories of TTC values has not been investigated in the literature before, thus, it is difficult to examine the TTC results under the prism of research-to-date and to step forward towards any generalisable inferences. Decrease in number of crashes, as mentioned above, might be associated with the significant decrease in driving time with TTC values lower than 2 seconds (p=.032). Therefore, the accident risk might be reduced. Driving impairment due to alcohol consumption, even for the legal national limit (0.5g/l), is evident in both lane and car following scenarios. One of the main objectives was to investigate the relation of sleep apnoea effect and alcohol in specific driving variables. Inferences should be conservative and differences were not found for brake reaction time (sec). This finding suggests that braking delay might be similar for sleep apnoea patients and intoxicated participants (alcohol consumption at legal limit). Brake reaction time (BRT) is the time to respond to sudden changes in the driving environment by fully depressing a brake pedal. Previous research has identified possible risk factors associated with delayed brake reaction time, such as alcohol use (Kuypers et al., 2006) and medications causing sedation such as antihistamines or psychotropic agents (Vuurman et al., 2004). brake Brake reaction time could be influenced by factors like gender and age. Therefore, by controlling these factors, it might be possible to reveal effects. Overall, it seems that the effect of sleep apnoea is detrimental compared to the alcohol effect at legal limit. Probably higher levels of alcohol are required in order to reveal any equivalence to OSAS for the chosen types of driving parameters.

**References**

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