Examining Signs of Driver Sleepiness, Usage of Sleepiness Countermeasures and the Associations with Sleepy Driving Behaviours and Individual Factors

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Highlights

- A telephone survey was conducted to examine Australian drivers experiences with sleepiness
- Yawning, changing position frequently, and frequent eye blinks were commonly experienced signs of sleepiness while driving
- Difficulty keeping eyes open had the largest association with having a sleep-related close call
- More experience with signs of sleepiness was associated with using roadside countermeasures
- Age, education, professional driver status were also related with using a roadside countermeasure

Keywords: Driver sleepiness, signs of sleepiness, sleepiness countermeasures, individual factors, Australian drivers

Abstract

The impairing effect from sleepiness is a major contributor to road crashes. The ability of a sleepy driver to perceive their level of sleepiness is an important consideration for road safety as well as the type of sleepiness countermeasure used by drivers as some sleepiness countermeasures are more effective than others. The aims of the current study were to determine the extent that the signs of driver sleepiness were associated with sleepy driving behaviours, as well as determining which individual factors (demographic, work, driving, and sleep-related factors) were associated with using a roadside or in-vehicle sleepiness countermeasure. A sample of 1518 Australian drivers from the Australian State of New South Wales and the neighbouring Australian Capital Territory took part in the study. The participants' experiences with the signs of sleepiness were reasonably extensive. A number of the early signs of sleepiness (e.g., yawning, frequent eye blinks) were related with continuing to drive while sleepy, with the more advanced signs of sleepiness (e.g., difficulty keeping eyes open, dreamlike state of consciousness) associated with having a sleep-related close call. The individual factors associated with using a roadside sleepiness countermeasure included age (being older), education (tertiary level), difficulties getting to sleep, not continuing to drive while sleepy, and having experienced many signs of sleepiness. The results suggest that these participants have a reasonable awareness and experience with the signs of driver sleepiness. Factors related to previous experiences with sleepiness were associated with implementing a roadside countermeasure. Nonetheless, the high proportions of drivers performing sleepy driving behaviours, suggest that concerted efforts are needed with road safety campaigns regarding the dangers of driving while sleepy.

1. Introduction

Driver sleepiness is a substantial contributor to road crashes. Current estimates suggest that the effect from sleepiness accounts for 20% of all fatal and severe crashes (Connor et al., 2002; Kecklund, Anund, Wahlström, Philip, & Akerstedt, 2012; Nabi et al., 2006). However, without an objective measure of a driver's level of sleepiness, such as breath alcohol content level as with drink driving, the exact incident levels are suggested to be greater than current estimates (Cercarelli & Haworth, 2002). Many crashes are multifactorial in nature and it is likely that sleepiness could have contributed to crashes ascribed to other risky driving behaviours (Watling, Armstrong, & Smith, 2013). Reducing the occurrence of driving while sleepy in the general driving population is largely reliant on educational campaigns that publicise the risks associated with driving while sleepy. Therefore, mitigating the risk from sleepiness is largely reliant on drivers' awareness of the signs of sleepiness and their subsequent actions they take to counteract their sleepiness.

1.1 Experiencing Signs of Sleepiness

The ability of a sleepy driver to perceive their level of sleepiness is an important consideration for road safety. Simulated driving studies reveal a good correspondence between a driver's awareness of sleepiness and their likelihood of falling asleep (Horne & Baulk, 2004; Reyner & Horne, 1998b; Williamson, Friswell, Olivier, & Grzebieta, 2014). Moreover, drivers who rate themselves at a high levels of sleepiness and at a high likelihood of falling asleep also have impaired driving performance levels with more centreline crossings and crashes during simulated driving (Williamson et al., 2014). Other driver simulator studies reveal good correspondence between drivers' subjective and physiological sleepiness, as well as greater frequency of line crossings when subjective and physiological sleepiness is high (Horne & Baulk, 2004; Reyner & Horne, 1998b). Considered together, these results suggest that drivers have some level of insight of their level of sleepiness and high levels of subjective sleepiness corresponds with impaired driving performance.

The insight of individuals regarding their ability to recognise particular signs of sleepiness has been explored. For instance, Kaplan, Itoi, and Dement (2007) examined the associations between experiencing certain signs of sleepiness with the ability to predict sleep onset with a computerised task. The results suggest individuals were aware of their sleepiness and could report experiencing particular signs of sleepiness – as sleepiness levels increased the amount of signs of sleepiness experienced also increased. A study by Howard et al. (2014) examined the relationships with particular signs of sleepiness and the corresponding physiological, subjective, and performance indices during a simulated driving task. As physiological and subjective sleepiness increased and driving performance subsequently became more impaired, the frequency with which the signs of sleepiness were reported increased correspondingly. Signs of sleepiness that were specifically associated with severely impaired simulated driving performance were related to visual disturbances (e.g., struggling to keep your eyes open) and overt signs of sleepiness impaired driving performance (e.g., difficulty keeping to middle of road). These studies of *specific* signs of sleepiness similarly suggest that drivers have some level of insight into their level of sleepiness and are able to report specific signs of sleepiness.

1.2 Usage of Sleepiness Countermeasures

When a driver becomes aware of experiencing certain signs of sleepiness, the individual can choose to implement a sleepiness countermeasure. A number of sleepiness countermeasures are available to the driver. These sleepiness countermeasures can be grouped broadly into categories based on where they are implemented, being at the roadside or in-vehicle. When implementing a roadside sleepiness countermeasure, the driver must first cease driving by pulling their vehicle over to the roadside – this action automatically eliminates the possibility of the driver falling asleep while driving.

Roadside sleepiness countermeasures include: stopping and taking a rest break (which could also include eating and or having a drink (e.g., coffee), ‘stretching’ ones legs, amongst other activities), stopping and napping, or swapping drivers. Experimental studies suggest that napping and consuming caffeine are the most effective countermeasures for reducing physiological and subjective sleepiness (De Valck & Cluydts, 2001; Horne & Reyner, 1996; Watling, Smith, & Horswill, 2014). Direct comparisons of napping and caffeine, suggest caffeine produces the most consistent effects (Horne & Reyner, 1996); this is likely due to ease of administering caffeine versus the obvious difficulty of napping on cue. Rest breaks are a commonly employed roadside countermeasure (Anund, Kecklund, Peters, & Åkerstedt, 2008); although, experimental studies suggest the effectiveness of rest breaks are short lived when compared to nap breaks (Watling, Smith, et al., 2014). Swapping drivers is a commonly promoted countermeasure although its effectiveness in relation to the other roadside countermeasures is unknown. Last, Cummings, Koepsell, Moffat, and Rivara (2001) demonstrated drivers who used a highway rest break area had a lower relative risk of being involved in a crash along a rural interstate highway.

In-vehicle sleepiness countermeasures are actions the driver initiates while driving to increase their level of arousal. These can include listening to music and opening the window or turning on the air conditioner. Overall, experimental studies suggest the effectiveness of in-vehicle countermeasures is relatively low. For instance, listening to music has a small effect for reducing subjective sleepiness, with a less pronounced effect for reducing physiological sleepiness (Reyner & Horne, 1998a; Schwarz et al., 2012). Similarly, opening the window/turning on the air conditioner has a small, albeit, transient effect on subjective sleepiness; however, the effect on physiological sleepiness is negligible to non-existent

(Reyner & Horne, 1998a; Schwarz et al., 2012). Overall, in-vehicle countermeasures have limited effectiveness for reducing sleepiness. However, these two in-vehicle countermeasures are popular with drivers and are utilised more so than the more effective roadside sleepiness countermeasures (Anund et al., 2008; Armstrong, Obst, Banks, & Smith, 2010; Nordbakke & Sagberg, 2007).

It is possible that a number of demographic, work, driving, and sleep-related factors could influence an individual's use of a sleepiness countermeasure. Demographic factors such as age (being younger) and sex (being male) have been previously related to driving while sleepy, employing rest breaks (Phillips & Sagberg, 2013; Radun, Radun, Wahde, Watling, & Kecklund, 2015; Watling, 2014), and having a sleep-related crash (Åkerstedt & Kecklund, 2001). Work related factors might influence the choice of sleepiness countermeasure as shift workers and professional drivers have greater experience with sleepiness and driving (Anund et al., 2008; Di Milia, 2006) and this could predispose them to utilise the more effective roadside countermeasures.

Another set of factors that could influence the choice of a sleepiness countermeasure could be the individual's previous experiences with driving while sleepy. That is, previous experiences with having a sleep-related close call or crash might lead an individual to use roadside sleepiness countermeasures as they are more effective. Additionally, survey studies suggest drivers also perceive roadside countermeasures as effective sleepiness countermeasures (Anund et al., 2008; Armstrong et al., 2010). Sleep health related factors might also influence an individual's choice of sleepiness countermeasure. Individuals that experience frequent daytime sleepiness or have poor sleep quality are likely to suffer from excessive daytime sleepiness (Bartlett, Marshall, Williams, & Grunstein, 2008) and might be inclined to utilise the more effective roadside sleepiness countermeasures.

The utility of outcomes derived from laboratory and simulator studies restricts the generalisation of these studies to the general driving population. Specifically, it is unknown what proportions of Australian drivers have previously experienced specific signs of sleepiness and the associations between specific signs of sleepiness and sleepy driving behaviours are also unknown. The usage of the various countermeasures has yet to be quantified in a large sample of Australian drivers and identifying factors associated with implementing a roadside or in-vehicle countermeasure needs to be performed with a large sample of Australian driver. Understanding the associations with the signs of sleepiness and countermeasure usage with driving behaviours and individual factors could be important information for road safety educational campaigns. The first aim was to examine the proportion of drivers who have previously experienced the signs of sleepiness and how these signs of sleepiness were associated with the two sleepy driving behaviours of continuing to drive while sleepy and having a sleep-related close call. The second research aim sought to identify the sleepiness countermeasures that are used by drivers and what individual factors were associated with using a roadside or in-vehicle sleepiness countermeasure.

2. Method

2.1 Participants

In total, 1518 participants took part in the study. The inclusion criteria for participation were being aged 17 years or older, having a current drivers licence, driving a work or private vehicle more than one hour per week, and having previously experienced sleepiness while driving. These inclusion criteria were chosen to ensure that participants had sufficient and regular on-road driving experience. The recruitment of a sample of drivers from the Australian state of New South Wales and the neighbouring Australian Capital Territory was stratified based on the number of vehicles registered in each of the statistical divisions. The statistical divisions are a general purpose spatial unit that are the largest and the most stable spatial unit within each state/territory of Australia without any gaps or overlapping of the spatial units (Australian Bureau of Statistics, 2011). The sample was also stratified based on age, with half of the participants below or at the age of 30 years, and sex, with equal numbers of males and females, to ensure the results were not biased from under- or over-sampling of demographic variables.

2.2 Measures

Previous and comparable studies that have examined sleepy driving behaviours typically have used recall periods "in the last 12 months" of "ever/over the lifetime of driving" (e.g., Nordbakke & Sagberg, 2007; Radun et al., 2015; Vanlaar, Simpson, Mayhew, & Robertson, 2008). Crashes and close calls are relatively infrequent events (Shinar, 2007) and thus a recall period of 12 months might lead to previous events being excluded from analysis. Yet, studies using the "ever/over the lifetime of driving" recall periods are faced with their own measure difficulties. As it might be difficult for participants to correctly recall behaviour over a life-time these studies often ask participants to think about the most recent event. However, without quantifying the time of the most recent event this range could be vary considerably across participants. As such, to balance the above concerns, the current study sought to limit the period of recall to the last five years.

After examination of the driver sleepiness peer reviewed literature, a questionnaire was designed to assess several factors associated with driver sleepiness. Regarding the signs of driver sleepiness, eight signs of driver sleepiness were utilised in the study. These signs of sleepiness included physical and psychological signs (i.e., yawning, changing position frequently, frequent eye blinks, difficulty keeping eyes open, and a dreamlike state of consciousness) as well as signs of sleepiness associated with vehicle control (i.e., difficulty concentrating on driving, slower reaction to traffic events, and increased variation in speed). Participants responded on a dichotomous scale (yes or no) to "have you ever felt these signs of sleepiness while you were driving in the last five years". The variable 'total signs of sleepiness' was computed by summating the eight signs of sleepiness scale items, which had a possible range of 0-8; higher scores indicate having experienced more signs of sleepiness.

Assessing which sleepiness countermeasures the participants had used in the past, utilised the item "On any occasion in the last five years when you have felt sleepy while driving, what have you done to make yourself feel more alert?" Participants were then presented with a list of 19 sleepiness countermeasures; eight of these countermeasures were a roadside countermeasure, with the remaining an in-vehicle countermeasure (see Table 4). No limit was set for the number of countermeasures that a participant could choose. The questionnaire assessed demographic (e.g., age, sex), work (e.g., professional driver [yes or no], shift worker [yes or no]), driving (e.g., in the last five years have you ever: …continued to drive while sleepy [yes or no]; …had a sleep-related close call [yes or no]; …had a sleep-related crash [yes or no]), and the participants usual sleep-related factors (e.g., difficulties getting to sleep [yes or no], sleep quality [4-point Likert scale: 1-poor to 4-excellent], sleep duration [in hours], sleep apnoea status ["have you been told by a doctor that you have sleep apnoea" [yes or no]). A sleep-related close call was defined as "a near-crash when you were driving or if you drove outside of your designated lane because you were sleepy", while a sleep-related crash was defined as "where the vehicle was damaged or someone got hurt or the police were called when you were driving because you were sleepy"

The questionnaire was thoroughly piloted. The piloting was conducted over two consecutive days following the same call procedure as described in the section 2.3. The pilot participants were required to meet the same inclusion criteria as described in section 2.1. Regarding the terminology, fatigue and sleepiness are often used interchangeably in the literature – this possibly causes some confusion as the term "fatigue" can be understood in many ways, including actual experiences of sleepiness when driving but also muscle or mental fatigue while driving. The authors choose a more clearly defined term, “sleepiness”, and this term was understood by all pilot participants.

2.3 Procedure

The research protocol was approved by the University Human Research Ethics Committee. A telephone surveying methodology using a Computer Assisted Telephone Interview system was utilised to collect the data. The data collection was conducted by an independent data collection agency by a team of experienced interviewers. The interviewing schedules for weekdays were between 16:30 to 20:30 and on the weekends were between 09:00 and 17:00. Participants were sourced from the Association of Market and Social Research Organisations Random Digit Dialling system. When an interviewer made a connection with a potential participant, an introductory statement was read that explained the purpose of the study and that their responses were completely confidential. Informed consent via a verbal confirmation from the participant was obtained for all participants. In total, 17577, calls were made, of these 1518 were completed interviews, with 91 partial interviews, 2426 refusals, 1739 non-contact, 550 other (language issues, physically or mentally unable/incompetent), and 7483 outside of the sample strata (based on the number of vehicles registered in each of the statistical divisions, no licence, and too few hours of driving, business number). Based on these figures and using the guidelines provided by the The American Association of Public Opinion Research (2015), the response rate was 17.31%, the cooperation rate was 33.11%, the refusal rate was 27.66%, and the contact rate was 52.27%.

2.4 Statistical Analyses

To examine the first aim, the associations between the signs of sleepiness and the two sleepy driving behaviours of continuing to drive while sleepy and having a sleep-related close call, two logistic regressions were performed with the outcome variables being the two sleepy driving behaviours. The second aim utilised a logistic regression to establish which demographic, work, driving, and sleep-related factors were associated with using a roadside countermeasure. The dependant variable was coded such that using a roadside sleepiness countermeasure was the criterion being predicted in the logistic regression with implementing an in-vehicle sleepiness countermeasure as the reference. Consequently, participants that responded to implementing both countermeasures (10.41% of participants) could not be included in the analyses concerned with countermeasure usage. As there are several measures of goodness of fit for logistic regression each with its limitations and as there is no agreed upon measure of goodness of fit for logistic regression that are considered analogous to the R^2 for linear regression (Cohen, Cohen, West, & Aiken, 2013), the Hosmer and Lemeshow test and the Nagelkerke R^2 statistic were provided for each of the logistic regression models. Independent variables that were dichotomous were coded such that the criterion category is displayed in the brackets. In order to control for the influence of age and sex, these two variables were entered at the first steps of all the regression analyses as age and sex have consistently been found to be associated with several sleepy driving behaviours, including the use of sleepiness countermeasures.

3. Results

Table 1 displays the descriptive statistics (percentage for dichotomous variables and means and standard deviation for continuous variables) of the study variables. In total, 69.83% of participants (n = 1060) reported having previously continued to drive when sleepy. A smaller proportion of participants reported having had a sleep-related close call (16.73%, n = 254) and even fewer reported having a sleep-related crash (2.44%, n = 37). Approximately a half of the participants (48.88%, n = 742) reported using a roadside countermeasure in the past, 40.71% (n = 618) of participants reported having used an in-vehicle countermeasure, with 10.41% (n = 158) of participants responding to implementing both countermeasures –

these latter participants were not included in the subsequent countermeasure logistic regression.

Table 1. Descriptive statistics for the study variables

Study variables	Descriptive	*n*	Range
Continued driving when sleepy	69.83%	1060	-
Sleep-related close calls (yes)	16.73%	254	-
Sleep-related crashes (yes)[a]	2.44%	37	-
Use of a roadside countermeasure	48.88%	742	-
Total signs of sleepiness	4.05 ± 1.94	-	1-8
Age	36.85 ± 16.82	-	17-83
Sex (male)	50.13%	761	-
Education (tertiary level)	37.29%	566	-
Professional driver (yes)	35.11%	533	-
Shift worker (yes)	13.04%	198	-
Difficulties getting to sleep (yes)	38.01%	577	-
Frequent daytime sleepiness (yes)	16.70%	255	-
Sleep quality	2.54 ± 0.82	-	1-4
Sleep duration	7.31 ± 1.17	-	4-10
Sleep apnoea (yes)	3.29%	50	-

[a] Due to the small proportion of sleep-related crashes, this variable was not included in the subsequent logistic regression analysis.

3.1 Signs of Sleepiness and Sleepy Driving Behaviours

An examination of the percentages that each sign of sleepiness was experienced and its association with the two sleepy driving behaviours was performed. Table 2 displays the bivariate (phi correlation coefficients) relationships between the individual signs of sleepiness. Nearly all of the signs of sleepiness were positively correlated with one another, with the largest correlation found between difficulty concentration on driving and slower reaction to traffic events. Table 3 displays the percentages of participants that have experienced the signs of sleepiness, and the logistic regression Odds Ratios (OR) and 95% Confidence Interval (CI) for the Odds Ratios. Yawning and changing position frequently were the two most frequently experienced signs of sleepiness, with difficulty keeping eyes open, and dreamlike state of consciousness the least experienced signs of sleepiness. A pattern seems apparent in the proportions that signs of sleepiness were experienced; such that, the early signs of sleepiness (e.g., yawning, changing position frequently) were experienced with more frequency than the signs of advanced sleepiness (e.g., difficulty keeping eyes open, dreamlike state of consciousness).

Table 2. Phi correlation coefficients between the signs of sleepiness

Variable	1.	2.	3.	4.	5.	6.	7.	8.
1. Yawning	-							
2. Change position frequently	.06*	-						
3. Frequent eye blinks	.15**	.20**	-					
4. Difficulty concentrating on driving	.11**	.12**	.22**	-				
5. Slower reaction to traffic events	.06*	.13**	.20**	.33**	-			
6. Increased variation in speed	.05	.09**	.14**	.19**	.19**	-		
7. Difficulty keeping eyes open	.11**	.15**	.31**	.28**	.22**	.11**	-	
8. Dreamlike state of consciousness	.06*	.05	.15**	.17**	.17**	.16**	.23**	-

$^{*}p < .05$, $^{**}p < .01$

Table 3. Percentage of participants that have experienced a sign of sleepiness and the logistic regressions associations between the signs of sleepiness and "continuing to drive while sleepy" and "experiencing a sleep-related close call" (*n* = 1518 both regressions)

		Continued driving while sleepy		Sleep-related close call	
Sign of sleepiness	Percentage	OR	95% CI for OR	OR	95% CI for OR
Step one					
Age		**0.97****	**0.97-.98**	0.99	0.99-1.01
Sex (male)		**1.60****	**1.26-2.02**	**1.84****	**1.36-2.49**
Constant		**4.73****			
Step two					
Age		**0.98****	**0.97-0.98**	1.01	0.99-1.02
Sex (male)		**1.75****	**1.34-2.27**	**2.01****	**1.45-2.78**
Yawning	87.87%	**3.38****	**2.31-4.95**	1.31	0.72-2.39
Change position frequently	60.59%	1.22	0.94-1.59	1.34	0.94-1.91
Frequent eye blinks	52.50%	**1.82****	**1.39-2.40**	1.32	0.92-1.89
Difficulty concentrating on driving	52.35%	**1.95****	**1.48-2.58**	**1.94****	**1.34-2.80**
Slower reaction to traffic events	40.96%	**1.41***	**1.05-1.89**	1.09	0.78-1.53
Increased variation in speed	40.07%	1.07	0.81-1.42	1.35	0.97-1.89
Difficulty keeping eyes open	35.22%	**2.12****	**1.55-2.91**	**3.06****	**2.17-4.31**
Dreamlike state of consciousness	25.15%	1.33	0.96-1.86	**2.03****	**1.45-2.84**
Constant		**0.76****		**0.02****	

Note: Hosmer and Lemeshow test for continue driving while sleepy ($\chi^2(1, 8) = 12.61$, $p = .13$) and sleep-related close call ($\chi^2(1, 8) = 10.56$, $p = .23$), both indicated that the classification accuracy was adequate. Criterion category is displayed in the brackets.
$^{*}p < .05$, $^{**}p < .01$

In order to determine which signs of sleepiness were associated with the driving behaviour of continuing to drive while sleepy in the last five years a logistic regression was performed. The first step included the variables of age and sex which were both significantly associated with the outcome variable (χ^2 (1, 2) = 73.52, p < .001) and accounted for 7.41% of the variance. Age and sex were both significantly associated with the outcome variable. The second step included the signs of sleepiness variables which continued to be associated with the outcome variable (χ^2 (1, 10) = 302.55, p < .001) and accounted for 28.05% of the variance. Younger drivers, males, having previously experienced yawning, frequent eye blinks, difficulty concentrating on driving, slower reaction to traffic events, and difficulty keeping eyes open were all significantly associated with higher odds of continuing to drive while sleepy in the last five years. Yawning had the largest association with the outcome variable.

The second logistic regression examined the associations between the signs of sleepiness with the driving behaviour of having a sleep-related close call in the last five years. The first step included the variables of age and sex which were significantly associated with the outcome variable (χ^2 (1, 2) = 16.32, p < .001) and accounted for 2.06% of the variance. Sex was the only significant demographic variable associated with the outcome variable. The second step included the signs of sleepiness variables which continued to be significantly associated with the outcome variable (χ^2 (1, 10) = 180.24, p < .001) and accounted for 21.38% of the variance. Males, having previously experienced difficulty concentrating on driving, difficulty keeping eyes open, and dreamlike state of consciousness also significantly associated with higher odds of having a sleep-related close call in the last five years. Difficulty keeping eyes open having the largest association with the outcome variable.

3.2 Drivers use of Sleepiness Countermeasures

The second research aim sought to identify the sleepiness countermeasures used by drivers and what individual factors were associated with using a roadside or in-vehicle sleepiness countermeasure. The proportions of participants that have used a specific type of sleepiness countermeasure can be seen in Table 4. The most commonly used roadside countermeasures were stopping the vehicle and getting out of the car, having something to drink, and having something to eat (i.e., rest breaks). Presumably, the most effective countermeasures (napping/sleeping, consuming caffeine, or swapping drivers) were among the least used countermeasures. The most commonly used in-vehicle countermeasures were turn on the radio/stereo, open the window, and decrease the temperature in the vehicle. Overall, the three most commonly used countermeasures (roadside or in-vehicle) were turn on the radio/stereo, open the window, and stopping and getting out of the car.

Table 4. Proportion of participants having used the listed sleepiness countermeasure when feeling sleepy when driving

Type of countermeasure used	Percentage	*n*
Roadside		
Get out of the car	32.48	493
Have something to drink	22.86	347
Have something to eat	11.20	170
Have a nap	9.29	141
Change drivers	9.03	137
Consume caffeine	8.30	126
Refresh yourself (e.g., splashed water on face/body)	6.06	92
Have a sleep and continued after a few hours (or next day)	2.57	39
In-vehicle		
Turn up/on the radio or stereo	35.57	540
Open the window of vehicle	34.26	520
Decrease the temperature in the vehicle	9.95	151
Talk to a passenger	7.51	114
Sing out loud	4.74	72
Have something to drink	4.15	63
Have something to eat	3.10	47
Increase the temperature in the vehicle	2.90	44
Talk to oneself	2.17	33
Drive slower	0.59	9
Drive faster/more actively	0.33	5

Note: No limit was set for the number of countermeasures that a participant could choose.

A logistic regression was performed to examine which individual factors were associated with using a roadside or an in-vehicle sleepiness countermeasure (see Table 5). The first step included the variables of age and sex, which were significantly associated with the outcome variable (χ^2 (1, 2) = 60.55, p < .001) and accounted for 5.85% of the variance. At this first step older drivers had higher odds of using a roadside countermeasure than younger drivers.

The second step included the work, driving, and sleep-related factors, these variables were significantly associated with the outcome variable (χ^2(1, 13) = 130.43, p < .001) and accounted for 12.29% of the variance. At this last step being older, having a tertiary level education, being a professional driver, having previously experienced more signs of sleepiness, not continuing to drive when sleepy, and having difficulties getting to sleep were significantly associated with higher odds of implementing a roadside sleepiness countermeasure.

Table 5. Individual factors associated with implementing a roadside sleepiness countermeasure (n = 1360)

Study variables	B	S.E.	Wald	OR	95% CI for OR
Step one					
Age	**.03****	**.01**	**54.62**	**1.03**	**1.01-1.03**
Sex (male)	-.15	.11	1.86	0.86	0.69-1.07
Constant	**-.67**	**.15**	**20.96**	**0.51**	
Step two					
Age	**.02****	**.01**	**31.63**	**1.02**	**1.01-1.03**
Sex (male)	-.18	.12	2.24	0.84	0.66-1.06
Education (tertiary level)	**.39****	**.12**	**10.03**	**1.47**	**1.16-1.87**
Professional driver (yes)	**.31***	**.13**	**6.01**	**1.36**	**1.06-1.73**
Shift worker (yes)	-.20	.17	1.35	0.82	0.58-1.15
Total signs of sleepiness	**.08***	**.03**	**5.31**	**1.08**	**1.01-1.16**
Continue driving when sleepy	**-.90****	**.14**	**41.30**	**0.41**	**0.31-0.56**
Sleep-related close calls	.07	.17	0.19	1.08	0.77-1.49
Difficulties getting to sleep (yes)	**.32***	**.14**	**5.56**	**1.38**	**1.06-1.80**
Frequent daytime sleepiness (yes)	.02	.17	0.01	1.02	0.74-1.41
Sleep quality	-.08	.09	0.79	0.93	0.78-1.10
Sleep duration	.07	.06	1.73	1.08	0.97-1.20
Sleep apnoea (yes)	.57	.37	2.44	1.78	0.86-3.65
Constant	**-.70***	**.35**	**3.87**	**0.50**	

Note: Hosmer and Lemeshow test indicated the classification accuracy was adequate (χ^2(1, 8) = 3.63, p = .89). Criterion category is displayed in the brackets.
$^{*}p < .05$; $^{**}p < .01$

4. Discussion

Overall, this study has shown that a concerning proportion of drivers (69.83%) have continued to drive while sleepy in the last five years. Driving while experiencing acute sleepiness is a known risk factor for having a sleep-related crash (Connor et al., 2002; Kecklund et al., 2012) as sleepiness can impair a number of psychological processes that are needed to safely control a vehicle (e.g., Åkerstedt, Peters, Anund, & Kecklund, 2005; Campagne, Pebayle, & Muzet, 2004; Jackson, Croft, Kennedy, Owens, & Howard, 2012; Killgore, Balkin, & Wesensten, 2006). Moreover, in the last five years 16.73% of drivers reported having a sleep-related close call in the last five years, with 2.44% reported having a sleep-related crash in the last five years. These sleepy driving behaviours suggest that the drivers in this sample have a reasonable amount of experience with sleepy driving.

The first aim sought to examine the proportion of drivers who have previously experienced signs of sleepiness while driving and how these signs of sleepiness were associated with sleepy driving behaviours. The most common signs of sleepiness experienced by over half of the participants were, yawning, changing position frequently, frequent eye blinks, and difficulty concentrating on driving (see Table 3). Driver sleepiness simulator studies have shown that these early signs of sleepiness (e.g., yawning, postural changes, and frequent eye blinks) are common while experiencing low levels of sleepiness (Howard et al., 2014; Nordbakke & Sagberg, 2007; Rogé, Pebayle, & Muzet, 2001; Sagberg, Jackson, Krüger, Muzet, & Williams, 2004). Moreover, yawning, frequent eye blinks, and difficulty concentrating on driving were also significantly associated with continuing to drive while sleepy at the multivariate level after controlling for age and sex. The least experienced signs of sleepiness were difficulty keeping eyes open and dreamlike state of consciousness, which are presumably signs of sleepiness that are experienced when extremely sleepy (Ogilvie & Wilkinson, 1984).

At the multivariate level, three signs of sleepiness were associated with having a sleep-related close call. These were, difficulty keeping eyes open, difficulty concentrating on driving, and dreamlike state of consciousness. Difficulty keeping eyes open was the sign of sleepiness with the largest relationship with having a sleep-related close call, followed by dreamlike state of consciousness, and difficulty concentrating on driving. Support for the current findings are found with driving simulator studies, which have also shown that difficulty keeping the eyes open has a strong relationship with variation of lateral positioning (Howard et al., 2014; Sagberg et al., 2004) and is a sign of sleepiness often experienced just prior to falling asleep while driving (Nordbakke & Sagberg, 2007). Consequently, when an individual is having difficulty keeping their eyes open, alpha and theta intrusions are apparent in the waking EEG (Åkerstedt & Gillberg, 1990; Gillberg, Kecklund, & Åkerstedt, 1994). It has been suggested that some drivers consider signs of sleepiness as trivial (Dinges, 1995) and or may fail to appreciate the seriousness of some signs of sleepiness (Horne & Reyner, 2001). Considered together, the current findings reinforce that concerted efforts are still needed with road safety campaigns regarding the dangers of driving while sleepy.

The second aim of the current study was to examine the usage of roadside or in-vehicle sleepiness countermeasures. Overall, the three most commonly used countermeasures were turning on the radio/stereo, followed by stopping the vehicle and getting out of the car, and opening the window. These prevalence rates are somewhat concerning, as two of the three most commonly used countermeasures were the least effective countermeasures for reducing sleepiness (e.g., Reyner & Horne, 1998a; Schwarz et al., 2012). Nonetheless, the finding that drivers use the least effective sleepiness countermeasures is consistent with previous research (Anund et al., 2008; Vanlaar et al., 2008).

The more effective countermeasures of napping and consuming caffeine (e.g., De Valck & Cluydts, 2001; Horne & Reyner, 1996; Watling, Smith, et al., 2014) were only used by 9.29% and 8.30% of participants respectively. International (e.g., Anund et al., 2008; Nordbakke & Sagberg, 2007) and Australian driver surveys (e.g., Armstrong et al., 2010) reveal napping and caffeine are considered by most drivers as a highly effective sleepiness countermeasure. It is a concern that the use of napping and caffeine in the Australian sample are much lower than what has been reported in a Swedish (napping: 18.00%, caffeine: 45.00%: Anund et al., 2008), Norwegian (napping: 10.00%, caffeine: 15.00%: Nordbakke & Sagberg, 2007), and Canadian (napping: 14.80%, caffeine: 29.50%: Vanlaar et al., 2008) samples. Some of the differences with the use of caffeine as a sleepiness countermeasure could be explained by the per capita consumption (kg) of coffee, being 7.14 for Sweden, 9.51 for Norway, and 6.22 for Canada versus 3.73 for Australia (International Coffee Organization, 2011). However, the differences in napping use between Sweden, Canada and Australia are not so easily explained. Considered together, these outcomes suggest that other factors may be associated with use of certain sleepiness countermeasures other than how effective the countermeasure is regarded.

Several of the variables that were associated with drivers' use of a roadside or in-vehicle sleepiness countermeasure appear to be experience based. Age (being older) and being a professional driver were associated with implementing a roadside sleepiness countermeasure. Several studies have shown that older drivers are more likely to stop driving and employ the more effective sleepiness countermeasures such as a nap or rest break sleepiness countermeasure (Anund et al., 2008; Nordbakke & Sagberg, 2007; Watling, 2014) and the current results are consistent with previous research. In contrast, younger drivers are more likely to engage in various types of risky driving (Begg & Langley, 2001; Hatfield & Fernandes, 2009) including driving while sleepy (Phillips & Sagberg, 2013; Radun et al., 2015; Watling, 2014). It is likely that professional drivers have more on-road experience with sleepiness and thus use the more effective roadside sleepiness countermeasures (e.g., Asaoka, Abe, Komada, & Inoue, 2012).

A notable finding from the current study was that having experienced more of the signs of sleepiness was related to use of a roadside countermeasure. This result is an encouraging result for road safety, as it suggests that a proportion of drivers can self-regulate their sleepiness by ceasing driving after perceiving their heightened level of sleepiness and employ a roadside sleepiness countermeasure. Likewise self-reported difficulties getting to sleep were also associated with using a roadside sleepiness countermeasure. Individuals reporting sleeping difficulties are likely more cognizant of the impairing effect that sleepiness can have on neurobehavioural functioning (Philip & Åkerstedt, 2006) and in the context of the current study are seemingly more proactive with implementing a roadside sleepiness countermeasure.

The potential reasons that some drivers use in-vehicle countermeasures are also worth discussing. Implementing an in-vehicle sleepiness countermeasure allows the driver to continue their journey without stopping. In the current study, drivers who had continued to drive while sleepy in the last five years were associated with employing in-vehicle countermeasures. As such, notions of motivations to arrive at ones destination (Watling, Armstrong, Obst, & Smith, 2014) and time urgency (Fernandes, Hatfield, & Job, 2010) could facilitate implementing an in-vehicle sleepiness countermeasure. Surprisingly, survey data suggests that drivers are cognizant that in-vehicle sleepiness countermeasures are not as effective as roadside countermeasures (Armstrong et al., 2010; Nordbakke & Sagberg, 2007). It is also likely that risk perception of the dangerousness of sleepy driving could also be a contributing factor for wanting to employ the less effective, in-vehicle sleepiness countermeasure while continuing to drive. It must be noted that turning on the radio/stereo was the most commonly reported sleepiness countermeasure used by participants. Therefore, attitudinal and behavioural change is likely necessary regarding some drivers' choice of implementing an in-vehicle countermeasure to reduce their sleepiness.

The results of the current study need to be considered in light of its limitations. First, and foremost, the data was collected via self-reported methods and thus issues from recall and social desirability bias are a possibility. Additionally, given the retrospective and cross-sectional nature of the study design, causality of the obtained relationships cannot be inferred. It should also be noted that drivers aged of 22 years or less (23.21%) would not have five years of driving experience to draw upon and this lack of experience could have influenced their responses to the questionnaire. The roadside countermeasure logistic regression model accounted for a small amount of the variance and therefore, other factors such as motivations to continue driving and reaching ones destination could possibly account for a driver's utilisation of sleepiness countermeasures. Future research could seek to improve upon the current study limitations. For instance, longitudinal studies concerning use of sleepiness countermeasures and sleepy driving behaviours are lacking. More importantly, the effects of general driving experiences as well as the frequency of experiencing sleepy driving incidents, the driver's motivations to drive sleepy, and the usage of countermeasures is scantly understood and needs to be further explored to better understand the prevalence of sleepy driving instances.

In conclusion, the present study suggests that many drivers are aware of the signs of sleepiness as they have experienced them previously. To the authors' best knowledge, this is the first Australian study that has quantified what signs of sleepiness drivers have previously experienced and what sleepiness countermeasures are being used by a large sample of drivers and thus, the information detailed in this study is of benefit to road safety agencies. Many of these signs of sleepiness were associated with the sleepy driving behaviours of continuing to drive while sleepy and having a sleep-related close call. The current study also found the most commonly used sleepiness countermeasures were turning on the radio/stereo, opening the window, and stopping the vehicle and getting out of the car. Moreover, a number of individual factors were associated with using a roadside sleepiness countermeasure. These factors included age (being older), education (tertiary level), difficulties getting to sleep, not continuing to drive while sleepy, and having experienced many signs of sleepiness. No one individual is immune to the effect of sleepiness while driving and increasing the usage of the more effective roadside sleepiness countermeasures could lead to improvements in road safety outcomes and provide a safer road environment for all drivers.

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