

Awareness of driving while sleepy and road traffic accidents: prospective study in GAZEL cohort

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Abstract

Objectives To examine the association between self assessed driving while sleepy and the risk of serious road traffic accidents (RTAs).

Design Prospective cohort study.

Setting France.

Participants 13 299 of the 19 894 living members of the GAZEL cohort, workers and recent retirees of a French national utility company followed up since 1989.

Main outcome measures Frequency of driving while sleepy in the previous 12 months, reported in 2001; rate ratios for serious RTAs in 2001-3, estimated by using generalised linear Poisson regression models with time dependent covariates.

Results The risk of serious RTAs increased proportionally with the frequency of self reported driving while sleepy. After adjustment for sociodemographic characteristics, driving behaviour variables, work conditions, retirement, medical conditions and treatments, depressive symptoms, and sleep disorders, the adjusted rate ratios of serious RTAs for participants who reported driving while sleepy in the previous 12 months "a few times" or "once a month or more often" were 1.5 (95% confidence interval 1.2 to 2.0) and 2.9 (1.3 to 6.3) respectively compared with those who reported not driving while sleepy over the same period. These associations were not explained by any reported sleep disorders.

Conclusions Self assessed driving while sleepy was a powerful predictor of serious RTAs, suggesting that drivers' awareness of their sleepiness while driving is not sufficient to prevent them from having RTAs. Messages on prevention should therefore focus on convincing sleepy drivers to stop driving and sleep before resuming their journey.

Introduction

Sleepiness in drivers is increasingly recognised as an important factor contributing to the burden of traffic related morbidity and mortality,¹⁻⁴ but proper assessment of its contribution is lacking.²⁻⁴ Published estimates of the proportion of road traffic accidents (RTAs) attributable to sleepiness range from 3% to 33% according to studies conducted in France,⁴ the United States,^{5,6} and Australia.⁷ In particular, little is known about the extent to which drivers are able to assess accurately that they are sleepy while driving.^{5,8}

In the 2005 "sleep in America" poll of the National Sleep Foundation, 60% of America's adults who drive or have a licence reported that they had driven a car or motor vehicle when feeling drowsy or sleepy within the previous year.⁹ A recent survey in France showed that 7 out of 10 French people report periods of

sleepiness in the course of the day, and about 6% admitted to having driven while sleepy at least once during the previous three months.¹⁰

We did a prospective study in a large cohort of French employees to examine the association between self reported frequency of driving while sleepy over the previous 12 months and the risk of subsequent serious RTAs over the next three years.

Methods

Participants

The participants were current employees or recent retirees of the French national electricity and gas company, who volunteered to participate in a research cohort known as the GAZEL cohort. The GAZEL cohort was established in 1989 and originally included 20 624 people working at Electricité De France-Gaz De France (EDF-GDF), comprising men aged 40-50 and women aged 35-50 at baseline. Since 1989, this cohort has been followed up with yearly self administered questionnaires and by data collection from the company's personnel and medical departments. Before inclusion in both the GAZEL cohort and the study on traffic safety, all participants received an information letter describing the main objective of the study and the non-compulsory nature of their participation.

Materials

We collected data on sleepiness and other driving behaviours in 2001 by using a self administered driving behaviour and road safety questionnaire. We collected data on incident accidents in 2001-3 from the yearly self administered annual GAZEL cohort questionnaire. Finally, when an accident was reported in the GAZEL cohort questionnaire, we sent participants a complementary accident form with 31 questions about the circumstances, the injuries, the reasons for the accident, and the responsibility of the driver.

Data from the GAZEL cohort database

We recorded sociodemographic and medical data, including self reported sleep disorders (treated or not) and alcohol consumption,¹¹ each year in 2001-3 from the GAZEL cohort questionnaire. We also added questions on mobility and accidents in the previous year to the questionnaire in this period. We asked drivers how many kilometres they drove a four wheeled or two wheeled vehicle in the previous 12 months. We also asked the participants to report whether in the previous 12 months they had been involved in one or more serious traffic accidents, defined as an accident that required at least a medical consultation. In the January 2002 questionnaire, we also asked participants to record the date of reported accidents. This

enabled us to exclude accidents that occurred before the completion of the 2001 driving behaviour and road safety questionnaire.

Driving behaviour and road safety questionnaire

In 2001, we mailed the driving behaviour and road safety questionnaire to the 19 894 living members of the GAZEL cohort.¹¹ We assessed driving while sleepy with the question, "In the 12 past months, have you ever driven while sleepy?" (1 = never, 2 = a few times in the year, 3 = about once a month, 4 = about once a week, 5 = more than once a week). We also recorded other potential confounders, including reported drinking and driving, drugs taken for anxiety, depression, another nervous disease, or sleeping problems, and work conditions (overtime work, time constraints, changing work schedules, and night shifts). We asked participants whether they had ever used connections to avoid paying the fine for a traffic violation. We also asked them to report their maximum speed in built-up areas, on rural roads, and on highways. We suspected participants of having a risky behaviour if they reported answering a phone call (with or without a car kit), whatever the driving circumstances, or if they reported not stopping the vehicle before starting a phone call. We coded the type of principal vehicle owned in January 2001 in five categories corresponding to increasing maximum speed. Finally, we took into account the participants' scores for the type A behaviour pattern assessed in 1993 by the Bortner rating scale.¹²

Statistical analysis

We regrouped the answers to the questions related to frequency of driving while sleepy into three categories (never, a few times in the year, once a month or more often). We fitted univariate logistic regression models to identify factors associated with reporting driving while sleepy, including medical conditions found to be associated with serious RTAs in previous research.¹³ We then included in a multivariate logistic regression model all the factors that were associated with driving while sleepy with a *P* value < 20% in the univariate analysis.

Because the mean and variance of the number of serious RTAs in 2001-3 did not differ in our study, we used generalised linear Poisson regression models¹⁴ with time dependent covariates to estimate the rate ratios of serious RTAs in 2001-3 associated with reported driving while sleepy in 2001. We used six nested Poisson regression models to test the impact of potential confounders. In model 1, sleepy driving was the only independent variable. In model 2, we further adjusted rate ratios for age, sex, occupational category in 2001, and annual mileage (a time dependent covariate). We applied a logarithmic transformation to annual mileage. In model 3, we further adjusted rate ratios for alcohol consumption (time dependent covariate); reported maximum speed in built-up areas, on rural roads, and on highways; risky use of mobile phones; drinking and driving; and fixing of traffic tickets as reported in 2001.¹¹ In model 4, we also included reported sleep disorders (a time dependent covariate); in model 5, we further adjusted rate ratios for working overtime, time constraints at work, and working night shifts. Finally, in model 6, we additionally adjusted rate ratios for depression, use of drugs, and treatment of medical conditions (a time dependent covariate). We fitted the same six nested models to the subsample of participants who did not report any sleep disorders or related treatment in the period.

A proportion of the participants who reported RTAs in one of the three GAZEL cohort questionnaires returned the complementary accident form. This allowed us to compare the characteristics of accidents between people who reported driving while

sleepy and others. In this complementary analysis, we included RTAs that did not result in injury but because of which a vehicle needed to be towed away, in addition to serious RTAs, in order to achieve a sufficient sample size. We used Levin's method to calculate the population attributable risk for driving while sleepy.¹⁵

Results

We received responses to the 2001 driving behaviour and road safety questionnaire from 14 226 of the 19 894 living members of the GAZEL cohort. We excluded some (*n* = 26) because of discrepancies in data with the general cohort database. We excluded another 326 respondents because they did not drive in 2001 and 200 respondents because their data on variables for driving while sleepy were missing. This left 13 674 participants (10 480 men; 3194 women). To the question "in the 12 past months, have you ever driven while sleepy?" 8597 (62.9%) participants responded never, 4917 (36%) a few times in the year, 104 (0.8%) about once a month, 35 (0.3%) about once a week, and 21 (0.2%) more than once a week. Table 1 shows factors associated with the odds of reporting driving while sleepy as determined by logistic regression analysis.

Serious road traffic accidents in 2001-3

We excluded a further 375 of the 13 674 participants because they did not respond to any of the three GAZEL cohort questionnaires of the years 2001, 2002, and 2003. Among the remaining 13 299 participants, 322 reported one serious RTA, eight reported two serious RTAs, and one reported three serious RTAs in 2001-3, ignoring 76 serious RTAs that were reported to have occurred before the completion of the 2001 driving behaviour and road safety questionnaire.

Self reported sleepy driving frequency and serious road traffic accidents

Table 2 presents results from generalised linear Poisson regression models fitted to estimate the impact of driving while sleepy on the risk of serious RTAs in 2001-3. Compared with participants who reported not driving while sleepy in the previous 12 months, the unadjusted rate ratio in model 1 was 1.6 (95% confidence interval 1.2 to 2.0) for participants who reported having driven while sleepy "a few times in the year" and 3.0 (1.6 to 6.0) for those who reported having done so "once a month or more often." These associations remained largely unchanged when further adjusted for several sets of potential confounders: the corresponding adjusted rate ratios were 1.5 (1.2 to 2.0) and 2.9 (1.3 to 6.3). When we restricted similar analyses to the subsample of participants who did not report any sleep disorders in 2001-3, the association measures were higher, particularly for participants who reported having driven while sleepy about "once a month or more often." These strong associations persisted after further adjustment for potential confounders. We estimated the population attributable risk for driving while sleepy as 19.2%.

Road traffic accident characteristics

We received 395 complementary accident forms related to traffic accidents in 2001-3. Examination of the 321 accidents in which the participant was driving showed that the participant was driving a car in 238 cases, a utilitarian vehicle in three cases, a two wheeled motorised vehicle in 19, and a bicycle in 23. Restricting the sample to the 260 accidents in a two to four wheeled motorised vehicle showed significant differences in the proportion of participants who reported at least one episode of

Table 1 Factors associated with reporting of at least one episode of driving while sleepy in 2001: unadjusted and adjusted odds ratios determined by logistic regression analysis (n=13 674)

Variables	No	Unadjusted odds ratio† (95% CI)	Adjusted odds ratio‡ (95% CI)
Sex (n=13 674):			
Female	3 194	1	1
Male	10 480	1.7 (1.5 to 1.8)****	1.3 (1.1 to 1.6)****
Occupational category (n=13 660):			
Unskilled workers	1 330	1	1
Skilled workers	7 397	1.2 (1.0 to 1.3)**	1.1 (0.9 to 1.4)*
Managers	4 933	2.2 (2.0 to 2.6)****	1.8 (1.5 to 2.2)****
Driving mileage (km) per year (n=12 163):			
<10 000	2 785	1	1
10 000 to 20 000	5 245	1.5 (1.4 to 1.7)****	1.6 (1.4 to 1.8)****
>20 000	4 133	2.5 (2.2 to 2.7)****	2.2 (1.9 to 2.5)****
Year of birth (n=13 674):			
1939-43	5 374	1	1
1944-8	7 080	1.3 (1.2 to 1.4)****	1.2 (1.0 to 1.3)**
1949-53	1 220	1.0 (0.9 to 1.2)	1.4 (1.1 to 1.8)***
Working overtime (n=13 672):			
Never	9 015	1	1
Occasionally	2 283	1.3 (1.1 to 1.4)****	1.3 (1.0 to 1.7)**
Often/always	2 374	2.4 (2.2 to 2.6)****	1.6 (1.2 to 2.1)***
Time constraints at work (n=13 673):			
Never	9 536	1	1
Occasionally	2 032	1.5 (1.4 to 1.7)****	1.1 (0.9 to 1.4)*
Often/always	2 105	2.4 (2.1 to 2.6)****	1.3 (1.0 to 1.6)**
Work schedules (n=13 673):			
Same every day	11 454	1	1
Different and fixed by company	727	1.4 (1.2 to 1.7)****	1.1 (0.9 to 1.4)
Different and fixed by yourself	1 492	2.2 (1.9 to 2.4)****	1.1 (0.9 to 1.3)
Working night shifts (n=13 670):			
Never	12 431	1	1
Occasionally	1 099	2.1 (1.8 to 2.3)****	1.2 (1.0 to 1.4)**
Regularly	140	2.9 (2.0 to 4.0)****	1.8 (1.1 to 2.9)**
Use of drugs (n=13 512):			
No	8 212	1	1
For anxiety	2 065	1.0 (0.8 to 1.1)	1.1 (1.0 to 1.3)**
For depression	684	1.1 (0.9 to 1.4)	1.2 (1.0 to 1.5)**
For other nervous disease	220	1.6 (1.1 to 2.2)***	1.5 (1.0 to 2.2)**
For sleep	2 325	1.2 (1.1 to 1.3)****	1.8 (0.6 to 5.5)
Retirement (n=11 764):			
No	7 311	1	1
Yes	4 453	0.5 (0.5 to 0.6)****	0.9 (0.8 to 1.4)
Depressive symptoms (CES-D) (n=11 272):			
No	9 236	1	1
Yes	2 036	1.5 (1.3 to 1.6)****	1.5 (1.3 to 1.7)****
Alcohol consumption§ (n=13 674):			
Non-drinker	7 673	1	1
Low quantity regular	888	1.1 (1.1 to 1.3)**	0.5 (0.2 to 1.5)
Low quantity episodic	172	1.6 (1.2 to 2.3)****	1.4 (0.9 to 2.0)*
High quantity regular	4 865	1.2 (1.1 to 1.3)****	1.2 (1.1 to 1.4)****
High quantity episodic	76	1.2 (0.8 to 2.0)*	1.1 (0.6 to 1.9)*
Sleep disorder reported in 2001 (n=12 831):			
No sleep disorder	10 432	1	1
Sleep disorder	2 061	1.2 (1.1 to 1.3)****	1.2 (1.1 to 1.4)****
Sleep disorder treated	338	1.2 (1.0 to 1.5)**	1.2 (0.9 to 1.7)
Divorce in 2001 (n=13 674):			
No	13 508	1	1
Yes	166	1.2 (0.9 to 1.7)*	0.9 (0.6 to 1.4)
Medical conditions treated in 2001 (n=13 674):			
No	12 733	1	1
Dental or gum problems	61	1.6 (0.9 to 2.7)*	1.6 (0.8 to 3.1)*
Cataract	10	-	-

Variables	No	Unadjusted odds ratio† (95% CI)	Adjusted odds ratio‡ (95% CI)
Renal colic or kidney stones	24	1.2 (0.5 to 2.7)	1.2 (0.4 to 3.1)
Glaucoma	106	1.0 (0.6 to 1.5)	0.9 (0.5 to 1.6)
Hiatus hernia	316	1.2 (1.0 to 1.6)**	1.4 (1.0 to 1.8)**
Gastric ulcers	63	1.5 (0.9 to 2.5)*	1.6 (0.8 to 3.0)*
Diabetes	361	0.8 (0.6 to 1.0)*	0.9 (0.7 to 1.2)
Traffic ticket fixing (n=13 526)			
No	9 879	1	1
Yes	3 647	1.3 (1.2 to 1.4)****	1.2 (1.1 to 1.3)***
Type A behaviour pattern scores (n=11 845):			
≤48	3 114	1	1
49 to 57	5 372	1.1 (1.0 to 1.2)	0.9 (0.8 to 1.1)
≥58	3 359	1.2 (1.2 to 1.3)***	0.9 (0.8 to 1.0)*

CES-D=Center for Epidemiologic Studies—depression scale.

*P≤0.20.

**P≤0.05.

***P≤0.01

****P≤0.001.

†Odds ratio of reporting at least one episode of sleepy driving for each variable assessed separately and as an independent variable.

‡Odds ratio of reporting at least one episode of sleepy driving adjusted for all variables.

§Low quantity drinkers defined as men reporting 1-13 (women 1-6) drinks over one week; high quantity drinkers reported 14-27 (men) and 7-20 (women) drinks over the same period; regular drinkers reported consuming alcohol on three or more days in the week; episodic drinkers reported drinking alcohol on less than three days a week.

driving while sleepy for two types of accidents: accidents due to sleepiness or worry and accidents in which the driver's responsibility was recognised by the insurance company.

Discussion

We found a robust association between self assessed driving while sleepy and the risk of serious road traffic accidents in the next three years; the risk increased with reported frequency of driving while sleepy. The association, as measured by adjusted rate ratios, was not modified by inclusion of a wide range of potential confounders. When we restricted the analysis to the subsample of participants who did not report any sleep disorders in 2001-3, the association was even stronger.

Strengths and limitations

Our results are consistent with previous findings from New Zealand, France, and the United States,³⁻⁵ and they support laboratory simulation studies suggesting that drivers are able to perceive that they are sleepy while driving.⁸ Our study is the only prospective study we are aware of, because participants were from a large cohort followed up on a regular basis, we were able to control carefully for a wide range of potential confounders, some of them updated each year. Additional analysis did not find any interaction effect with the nature of travel (commuting, professional, or private).

Both serious RTAs and driving while sleepy were self reported. Although self reported measures of risky driving behaviours have been found to have considerable validity in predicting risk of traffic accidents,¹⁶ they cannot account for all sleepy driving situations. This lack of accuracy is unlikely, however, to have biased our results—driving while sleepy does not constitute an offence against the Highway Code, and serious RTAs were recorded independently of risky driving behaviours. Furthermore, a recent study found that self reported sleepiness when driving was consistent with sleepiness as an independent model based on circadian and sleep factors.¹⁷ Finally, examination of the 260 complementary accident forms showed that participants who reported driving while sleepy at least once were more likely to report accidents due to sleepiness or worry

Table 2 Rate ratios (95% confidence intervals) of serious road traffic accidents in 2001-3 according to frequency of self reported driving while sleepy, determined by generalised linear Poisson regression models*

Participants	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
All participants						
Self reported frequency of driving while sleepy in 2001:						
Never (n=8597)	1	1	1	1	1	1
A few times in the year (n=4917)	1.6 (1.2 to 2.0)	1.5 (1.2 to 2.0)	1.5 (1.1 to 1.9)	1.5 (1.1 to 1.9)	1.5 (1.1 to 1.9)	1.5 (1.2 to 2.0)
Once a month or more often (n=160)	3.0 (1.5 to 6.0)	3.0 (1.4 to 6.2)	2.9 (1.4 to 6.0)	2.8 (1.3 to 5.8)	2.9 (1.4 to 6.0)	2.9 (1.3 to 6.3)
No of observations used†	37 540	34 854	32 440	32 440	32 426	28 362
Participants without sleep disorders reported or treated in 2001-3						
Self reported frequency of driving while sleepy in 2001:						
Never (n=6679)	1	1	1	-	1	1
A few times in the year (n=3657)	1.6 (1.2 to 2.1)	1.5 (1.2 to 2.0)	1.5 (1.1 to 2.0)	-	1.5 (1.1 to 2.0)	1.6 (1.2 to 2.2)
Once a month or more often (n=96)	4.5 (2.2 to 9.3)	4.7 (2.2 to 9.7)	4.7 (2.2 to 9.8)	-	4.9 (2.3 to 10.3)	4.8 (2.2 to 10.8)
No of observations used†	29 693	28 581	26 620	-	26 612	23 352

*Model 1=unadjusted rate ratios; model 2=rate ratios adjusted for sex (male/female), age (covariate of three categories), occupational category (time dependent covariate of three categories: unskilled workers, skilled workers, managers), and driving mileage per year (time dependent covariate logarithmically transformed); model 3=model 2 + alcohol consumption (five category, time dependent covariate describing quantity and frequency), maximum speed greater than ±10% of legal limits in built-up areas (yes/no), on rural roads (yes/no), and on highways (yes/no), risky use of mobile phone (yes/no), vehicle categories (four categories), and traffic ticket fixing (yes/no); model 4=model 3 + sleep disorder (three category, time dependent covariate: no sleep disorder, sleep disorder, sleep disorder treated); model 5=model 4 + working overtime (never, occasionally, often/always), time constraints at work (never, occasionally, often/always), and working night shifts (never, on occasion, regularly); model 6=model 5 + depressive symptoms in 2002 and use of drugs in 2001 (never, for anxiety, for depression, for other nervous disease, for sleep), medical conditions treated in 2001-3 (none, dental or gum problems, cataract, renal colic or kidney stones, glaucoma, hiatus hernia, gastric ulcers, diabetes); for analysis of participants without sleep disorders reported or treated in 2001-3, no adjustment was made for the sleep disorder variable in models 5 and 6.
†Cumulative person years of observation during three year follow-up.

and accidents in which the responsibility of the participant was recognised by the insurance company.

We recorded driving while sleepy and serious RTAs in different time periods, assuming that driving while sleepy is a somewhat consistent behaviour over several years for a given driver. In 2004, we sent a second driving behaviour and road safety questionnaire to the participants in an attempt to assess changes in drivers' behaviour from the 2001 reports. Participants were asked the same questions as in 2001. Comparison of answers between 2001 and 2004 showed a fair stability in terms of driving while sleepy ($\kappa=0.47$, $P=0.008$). We also compared the risk of having at least one serious RTA in 2001 according to the frequency of driving while sleepy reported over the same period (data not shown). We found a similar trend, but the statistical power was low.

For comparative purposes, we estimated the population attributable risk for sleepy driving as 19%, a figure consistent with data from a study in New Zealand (19%).³ Published estimates of the proportion of car crashes attributable to the driver's sleepiness range widely, from about 3% to 33%.^{3-5, 7} Our study sample, despite its large size, was not representative of French drivers as a whole. The participants had various jobs and were from different socioeconomic groups throughout France, but all were middle aged drivers.

The association between self assessed driving while sleepy and the risk of serious RTAs was stronger when we restricted the analysis to a subsample of participants who did not report any sleep disorders in 2001-3. Although people with sleep disorders were more likely to report driving while sleepy (table 1), the association measure between self reported sleep disorders and the risk of serious RTAs seemed to be lower. This suggests that drivers with previous sleep disorders may adopt self regulatory behaviours.

Implications

Our prospective data clearly identified driving while sleepy unrelated to any medical condition as a significant independent factor contributing to serious RTAs, with important consequences for public safety because of the high proportion of drivers concerned.¹⁸ Our results suggest that drivers are aware that they are sleepy when driving but do not act accordingly.¹⁹ This has already been noted by Reyner and Horne, who found that

perception of sleepiness does not result in cessation of driving in laboratory simulations.⁸ Drivers may either underestimate the impact of sleepiness on their driving performance or overestimate their capacity to fight sleepiness.⁵

As self assessment of sleepiness while driving seems possible, the role of policing should consist in the development and implementation of national campaigns to raise the awareness of all road users and to inform them how to avoid driving while sleepy through promotion of "sleep hygiene" or how to deal with sleepiness.²⁰ The only long lasting solution, however, is to stop driving and sleep or to let someone else drive.¹⁹⁻²¹ Prevention programmes should also include building or improving rest areas and installing shoulder rumble strips. In addition, legislative or regulatory initiatives should also be discussed,²² even if appropriate tools to measure drivers' sleepiness are still to be developed. Finally, development and evaluation of in-vehicle systems that can detect a sleepy driver should also be promoted.

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Contributors: HN analysed and interpreted data and wrote the report. EL conceived the study and contributed to the analysis and interpretation of data and to the preparation of the manuscript. AG was involved in analysing and interpreting data. MC, SL, and MZ contributed to study design and interpretation of data. All authors contributed to the final version of the report. EL is the guarantor.

What is already known on this topic

Retrospective studies suggest that sleepiness in drivers is an important factor contributing to the burden of traffic related morbidity and mortality

What this study adds

Self assessed driving while sleepy is a powerful predictor of serious road traffic accidents

This suggests that drivers are able to accurately assess sleepiness while driving but do not act accordingly

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