

RESEARCH ARTICLE

Single- and dual-task performance during on-the-road driving at a low and moderate dose of alcohol: A comparison between young novice and more experienced drivers

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Abstract

Driving experience and alcohol are two factors associated with a higher risk of crash involvement in young novice drivers. Driving a car is a complex task involving multiple tasks leading to dividing attention. The aim of this study was to compare the single and combined effects of a low and moderate dose of alcohol on single- and dual-task performance between young novice and more experienced young drivers during actual driving. Nine healthy novice drivers were compared with 9 more experienced drivers in a three-way, placebo-controlled, cross-over study design. Driving performance was measured in actual traffic, with standard deviation of lateral position as the primary outcome variable. Secondary task performance was measured with an auditory word learning test during driving. Results showed that standard deviation of lateral position increased dose-dependently at a blood alcohol concentration (BAC) of 0.2 and 0.5 g/L in both novice and experienced drivers. Secondary task performance was impaired in both groups at a BAC of 0.5 g/L. Furthermore, it was found that driving performance in novice drivers was already impaired at a BAC of 0.2 g/L during dual-task performance. The findings suggest that young inexperienced drivers are especially vulnerable to increased mental load while under the influence of alcohol.

KEYWORDS

alcohol, dual-task performance, highway driving test, novice drivers

1 | INTRODUCTION

Young novice drivers are overrepresented in motor vehicle crashes (MVCs) in most countries. In the United States, drivers between 18 and 20 years old accounted for 65.5% of fatalities in MVCs between 1999 and 2012 (Hadland et al., 2017). In addition, young drivers involved in fatal MVCs are often at fault as is evidenced by statistics of fatal MVC in Queensland, Australia. These statistics state that of the fatal MVCs involving young drivers that occurred between 2006

and 2011, a considerable 80.9% were deemed to be at fault (Department of Transport and Main Roads Queensland Government Australia, 2011). Research has shown that driving-related skills (e.g., hazard perception, attentional control, and dual-task performance) of young novice drivers are inferior compared with older and more experienced drivers (Campagne, Pebayle, & Muzet, 2004; Groeger & Chapman, 1996; Mayhew, Simpson, & Pak, 2003). Both age and experience seem to independently contribute to this difference. Campagne et al. (2004) reported that road-tracking performance of younger drivers becomes

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impaired at lower levels of drowsiness as compared with older drivers, suggesting that older drivers can handle drowsiness better. Arguably, this is irrespective of driving experience because driving errors were operationalized as gross deviations in the lateral position and/or speed. Given that the task composed of a prolonged nighttime drive on a simulated motorway, it seems likely that these measures reflect vigilance decrements instead of (in)experience. In addition, Groeger and Chapman (1996) pose that younger drivers tend to underrate dangers irrespective of driving experience. Furthermore, Mayhew et al. (2003) demonstrated that driving experience contributes to lower crash rates after 6 months of driving experience in young novice drivers, indicating that driving experience is an independent factor as well.

Alcohol consumption is another factor that is associated with an increase of MVC risk in all ages, particularly inexperienced young drivers (Gonzales et al., 2014). Among these drivers, 25% of MVC fatalities in female and 20% in male drivers involve driving under the influence of alcohol at a blood alcohol concentration (BAC) of equal to or higher than 0.8 g/L (Hadland et al., 2017). However, from various studies, it appears that a significant increase in accident risks for novice drivers already occurs at BACs lower than 0.5 g/L (Cooper, Pinili, & Chen, 1995; Shope & Bingham, 2002). Zador and colleagues (2000) explained a 55% increase in MVC fatalities in young (i.e., 16–20 years old) males and a 35% increase among young females when BAC levels increased from 0.1 to 0.2 g/L.

Operating a vehicle requires the driver to engage in multidimensional tasks, such as controlling electronic dash equipment and maintaining lane position and speed. In addition, nearly one fifth (19%) of the drivers are engaged in a secondary task such as speaking, eating, drinking, smoking, or using a mobile phone at any time during their trip (Gras et al., 2010). This secondary task increases the mental load of the driver. To compensate for this increased load, attention allocated to operating the vehicle (i.e., the primary task) is redirected to engage in the secondary task, hence leading to divided attention (Harrison & Fillmore, 2011). Such activities have been shown to impair simulated driving performance (Irwin, Monement, & Desbrow, 2015) and to increase the risk of MVCs in novice drivers (Chen, Baker, Braver, & Li, 2000; Wikman, Nieminen, & Summala, 1998).

It has repeatedly been reported that alcohol as low as 0.2 g/L leads to impairment of performance under divided attention (Jongen, Vuurman, Ramaekers, & Vermeeren, 2016; Moskowitz & Fiorentino, 2000). Research interest has increased in assessing the combined effects of alcohol and divided attention. Rakauskas and colleagues (2008) conducted a driving simulator study and showed that the combined effects of alcohol and a distractor led to larger impairment compared with the single (i.e., isolated) effects of alcohol or distraction. It was shown that distraction had a general impairing effect on primary safe headway and secondary standard deviation of lateral positioning (SDLP), whereas alcohol only impaired secondary lane positioning. Similarly, a simulator study by Freydier, Berthelon, Bastien-Toniazzo, and Gineyt (2014) found that lateral position maintenance was significantly poorer when drivers had a BAC of 0.5 g/L while completing a secondary task, as compared with performance under lower BACs or single-task performance alone. Harrison and Fillmore (2011) assessed the effects of divided attention and alcohol on SDLP in a driving

simulator and found no effect of dividing attention in sober drivers. However, driving impairment (i.e., an increase of SDLP) became apparent with the combination of dividing attention and alcohol intoxication. However, as these studies were conducted in driving simulators, little is known about the combined effects of alcohol and secondary task performance in actual traffic conditions in novice drivers.

The aim of the present study was to assess the single and combined effects of a low (i.e., to reach a BAC of 0.2 g/L) and a moderate (i.e., to reach a BAC of 0.5 g/L) dose of alcohol and dual attention on actual driving performance in young novice drivers. Driving performance was measured with SDLP, a measure of "road-tracking error," whereas dual-task performance was measured with an auditory word learning test during driving. It was hypothesized that young novice drivers would show a higher degree of driving impairment (i.e., an increase of SDLP) after alcohol, dual-task performance, and its combined effects in comparison with more experienced drivers.

2 | METHODS

2.1 | Participants

Eighteen healthy volunteers (age range 18–25 years) were recruited for this study and divided in two groups. The first group consisted of nine novice drivers (four males, five females, mean age 19.2 ± 1.4 years) and was recruited at the office of the Driving Examination Board immediately after passing their driving license exam. Novice drivers were required to have less than 1,000 km of independent driving experience and to have held a drivers' license for no longer than 1 month. The second group consisted of nine experienced drivers (four males, five females, mean age 21.1 ± 2.3 years) recruited via newspaper advertisements. Experienced drivers were required to have at least 7,500 km of driving experience and be in possession of a valid driving license for at least 1 year.

Volunteers were required to be in good health as confirmed by a medical history questionnaire and physical examination and have a body mass index within the range of 19 to 30 kg/m². Candidates were excluded from study participation for any of the following: pregnancy or lactating; history of severe mental or physical disorders; alcoholism or substance abuse; use of systemic medication (except oral contraceptives and paracetamol); participation in any other clinical trial in the previous 3 months; excessive caffeine consumption (>five standard units a day); excessive smoking (>10 cigarettes a day); known allergic reactions to alcohol; and total alcohol abstinence.

Volunteers agreed not to use drugs of abuse or systemic medication (except oral contraceptives and paracetamol) from study enrollment until completion. Caffeine and/or alcohol consumption was prohibited from 24 hr before arrival at the site during treatment days until the completion of the testing day. Volunteers had to refrain from smoking on treatment days.

The study was approved by the Ethics Review Committee of Maastricht University and the Academic Hospital Maastricht and was conducted in accordance with the Code of Ethics on Human

Experimentation established by the World Medical Association Declaration of Helsinki (1996) and subsequent amendments. Written informed consent was obtained from each volunteer prior to enrollment.

2.2 | Study design and alcohol administration

The study was conducted according to a three-way, randomized, double-blind, placebo-controlled, cross-over design. Treatments were placebo alcohol (i.e., to maintain a BAC of 0.0 g/L), a low alcohol dose (i.e., to reach a BAC of 0.2 g/L) and a medium alcohol dose (i.e., to reach a BAC of 0.5 g/L). Treatments were administered on three testing days, each separated by a washout period of at least 7 days. Alcohol challenges were prepared with ethanol (70%) mixed with orange juice. The low and medium alcohol doses were individually calibrated based upon the formula by Watson (1989). The total individual alcohol dose needed to achieve a BAC of either 0.0, 0.2, or 0.5 g/L was administered in five alcohol doses at 10-min intervals. If necessary, the amount of alcohol in a subsequent dose was adjusted to reach the target BAC. For each individual dose, the required amount of ethanol was mixed with orange juice in a 25 cl container until this was 75% full. Placebo alcohol consisted of orange juice with a single drop of ethanol (± 0.041 ml) for masking purposes (Fillmore et al., 1998). The individual breath alcohol concentrations were obtained through collection of breath samples using a SD-400 Alcoholmeter[®] (Lion Laboratories Ltd, UK), which subsequently uses the breath alcohol concentration to estimate the BAC. Henceforth, BAC will be used as the independent parameter reflecting alcohol concentration.

2.3 | Assessments

2.3.1 | Highway driving test

In the standardized on-the-road highway driving test (O'Hanlon, 1984), participants' drove a specially instrumented car over a 100 km (61 miles) primary highway circuit accompanied by a licensed driving instructor having access to dual controls. The participant's task was to maintain a constant speed of 95 km/hr (58 miles/hr) and a steady lateral position between the delineated boundaries of the slower right traffic lane. The vehicle's speed and lateral position relative to the left lane delineation were continuously recorded. These signals were digitally sampled at 4 Hz and edited off-line to remove data recorded during overtaking maneuvers or disturbances caused by roadway or traffic situations. The remaining data yielded the SDLP and speed for each successive 5-km segment and, as the square root of pooled variance over all segments, for the test as a whole. The primary outcome variable, the SDLP (in cm), is a measure of road-tracking error or "weaving." The clinical relevance of performance changes in the on-the-road driving test have previously been determined by establishing the relationship between BAC and SDLP (Louwerens, Gloerich, DeVries, Brookhuis, & O'Hanlon, 1987). A mean increase in SDLP of 2.5 cm was previously found at a BAC of 0.5 g/L as compared with placebo (Jongen et al., 2017) and from that point onwards associated with a significant higher risk of traffic accidents (Borkenstein, Crowther, & Shumate, 1974). The highway driving test

has been used in more than 100 studies and has proven sensitive to many sedating drugs and alcohol in blood concentrations as low as 0.35 g/L (Vermeeren, Ramaekers, & O'Hanlon, 2002; Vuurman et al., 1996).

2.3.2 | Secondary task performance: Auditory word learning task

During the driving test, participants performed an auditory word learning task (AWLT, adapted from Brand, 1985) to assess the processing and recall of verbal information. Participants were presented with a list of 30 monosyllabic nouns at a rate of one per 2 s, presented through a loudspeaker in the car. Immediately, thereafter, they were required to verbally recall as many words as possible. This procedure was repeated on two more trials, and the words recalled were recorded for off-line scoring using a voice recorder. The sum of the number of correctly recalled words on the three trials was the immediate recall score. Segments of the highway driving test, in which participants performed the AWLT, were marked during off-line editing for further analysis.

2.4 | Procedure

All volunteers participated in a practice session to be individually familiarized with the procedures of the driving test and with operating the vehicle. The structure of the testing session was identical to the actual testing days with the exception of alcohol or placebo alcohol administration. On treatment days, volunteers were transported from their home to the testing site and started the testing day at noon, 1 or 2 pm, based on individual convenience ($t_0 = 0:00$ hr). Upon arrival, inclusion and exclusion criteria were checked. Next, volunteers received a standardized bread meal accompanied by orange juice, water, or decaffeinated coffee / tea ($t_1 = 0:10$ hr). One hour after the meal was provided, volunteers were administered a series of five alcohol treatment doses ($t_2 = 1:10$ hr), separated by a 10-min interval between doses. After the last treatment dose ($t_3 = 2:00$ hr), volunteers were transported to the starting point of the driving test and performed ($t_4 = 2:30$ hr) the highway driving test that lasted for 60 min. The AWLT was performed 30 min into the driving test ($t_5 = 3:00$ hr). BAC estimates were derived before the start and after completion of the driving test. Upon completion of the driving test ($t_6 = 3:30$ hr), volunteers were transported back to the testing site for debriefing. Volunteers could return to their homes as soon as their BAC level was below 0.2 g/L.

2.5 | Statistical analysis

A power calculation for repeated measures revealed that a sample of 18 participants in total permits detection of a clinically relevant change in SDLP of 2.5 cm, with a power of at least 90% for within-group and within-group \times between-group comparisons, and at least 70% for between-group comparisons. Due to the lack of power for between-group comparisons (i.e., possible Type II error), nonsignificant differences between groups will not be interpreted as an absence of effects. Assumptions for the power calculations are an alpha of 0.05, two groups, three test moments, a test-retest reliability of 0.8 for

SDLP (Verster & Roth, 2011), a within-subjects *SD* of 2.97 cm (Theunissen et al., 2013), and a between-subjects *SD* of 4.3 cm (Jongen et al., 2017). All measures were analyzed using general linear model repeated measures. The model included three factors: Experience (between, two levels), Alcohol (within, three levels) and Task (within, two levels). Main effects of Alcohol were further analyzed by two alcohol placebo contrasts. These simple contrasts were corrected with Least Significant Difference (LSD). All statistical analyses were conducted using the Statistical Package for Social Sciences for windows (version 24.0.0.0., SPSS Inc., Chicago, IL, USA). Power calculations were performed using G*Power (version 3.1.9.2; Faul, Erdfelder, Lang, & Buchner, 2007).

3 | RESULTS

3.1 | Blood alcohol concentrations

Mean (\pm SE) BAC for the low and moderate alcohol challenge at the start of the driving test was 0.24 ± 0.01 mg/ml and 0.52 ± 0.01 mg/ml for novice drivers and 0.26 ± 0.01 mg/ml and 0.51 ± 0.01 mg/ml for experienced drivers.

3.2 | Highway driving test

Analyses showed significant effects of Alcohol ($F_{2,15} = 13.46, p < .01$) and Experience ($F_{1,16} = 7.87, p = .01$) on SDLP, but no significant interaction between Experience \times Alcohol ($F_{2,15} = 0.22, p = .81$). Mean [95% CI] increase in SDLP at a BAC of 0.2 g/L and a BAC of 0.5 g/L, compared with placebo were +1.12 cm [0.06, 2.18] and +3.33 cm [1.82, 4.83], respectively. Simple contrast analyses showed that SDLP increased at a BAC of 0.2 g/L ($F_{1,17} = 5.01, p < .05$) and at a BAC of 0.5 g/L ($F_{1,17} = 21.61, p < .01$) compared with alcohol placebo.

3.3 | Secondary task performance: Memory

Analyses showed significant effects of Alcohol ($F_{2,34} = 4.87, p = .01$), but no significant effect of Experience or the interaction between Experience \times Alcohol. Simple contrast analysis showed a

nonsignificant mean [95% CI] decrease of 2.78 [-7.53, 1.97] words at a BAC of 0.2 g/L and a significant mean decrease of 7.22 [-12.79, -1.65] at a BAC of 0.5 g/L ($F_{1,17} = 7.48, p = .01$).

3.4 | Dual-task performance

Figure 1 shows mean SDLP (\pm SE) for both groups in each of the three alcohol conditions, while either performing a road tracking or a dual task (i.e., primary road tracking and secondary AWLT). Analysis showed a significant effect of dual-task performance ($F_{1,16} = 17.91, p = .01$) and a three-way interaction effect between Task \times Experience \times Alcohol ($F_{2,32} = 3.42, p = .04$). The SDLP during dual-task performance was significantly higher (+1.13 cm [0.56, 1.70]) as compared with performing the road-tracking test.

The three-way interaction showed that the SDLP of novice drivers during dual-task performance at a BAC of 0.2 g/L was significantly higher than during road tracking at a BAC of 0.2 g/L. In contrast, for experienced drivers, the increase in SDLP during dual-task performance, as compared with road tracking, was only observed at a BAC of 0.5 g/L. The SDLP during dual-task performance at a BAC of 0.5 g/L did not differ significantly from SDLP during road tracking at the same BAC for novice drivers ($p = .23$).

4 | DISCUSSION

The aim of this study was to assess the single and combined effects of alcohol and dual-task attention on actual driving performance in young novice drivers in comparison with more experienced drivers. Results indicated that SDLP increased dose-dependently in both novice and experienced drivers at a BAC of 0.2 and 0.5 g/L. The mean SDLP increase of 3.3 cm in this study is comparable with the clinical relevant cut-off point at a BAC of 0.5 g/L (Jongen et al., 2017; Louwerens et al., 1987), as the predefined +2.5 cm fell well within the 95% CI [1.82, 4.83] of the mean change in SDLP. This is the first study showing that road tracking during highway driving in actual traffic is already impaired at a BAC as low as 0.2 g/L and demonstrated the sensitivity of the on-the-road driving test for the effects of alcohol in a group of young inexperienced drivers.

In addition, secondary task performance was impaired at a BAC of 0.5 g/L in both novice and experienced drivers. The overall effect at a BAC of 0.5 g/L on both primary and secondary task performance is in contrast with a previous driving simulator study showing that alcohol impaired only secondary task performance, while leaving primary task performance unimpaired (Rakauskas et al., 2008). The difference in findings could be either explained by the use of primary and secondary tasks, as this study included lateral positioning as primary and memory recall as secondary task in contrast to safe headway to a leading vehicle as primary and lateral positioning as secondary task. Another driving simulator study on the effects of single- and dual-task performance and alcohol did include SDLP as a primary outcome measure yet did not find a significantly impairing effect at a BAC of 0.2 g/L as compared with placebo (Freydier et al., 2014). Also, no significant interaction was found between BAC and task or between BAC and driving experience. An explanation for these differing results might

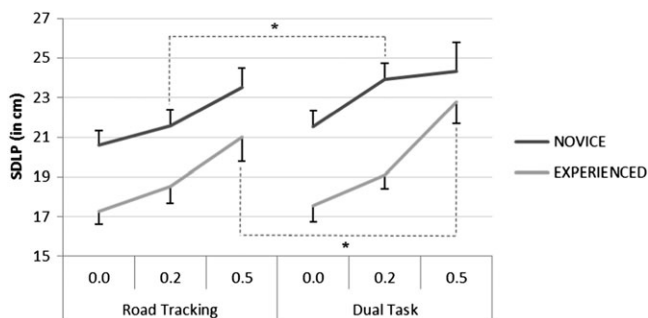


FIGURE 1 Mean (\pm SE) standard deviation of lateral position (SDLP) for each group in each of the three alcohol conditions, while either performing road tracking or a dual task (i.e., road tracking + auditory word learning task). Asterisks with dotted lines visualize the three-way interaction between Alcohol \times Task \times Experience

be in the application of a simulator test as opposed to an on-the-road driving test in actual traffic, which has a higher ecological validity in comparison (Liguori, 2009). It could be argued that different strategies are used in a driving simulator when compensating for the impairing effect of alcohol, that is, the participant might be aware of the danger of actual driving in traffic as opposed to simulated driving and adjust their driving behavior accordingly.

Interestingly, results showed that the SDLP of novice drivers during dual-task performance was higher compared with road tracking (i.e., single-task performance) at a BAC of 0.2 g/L. In contrast, SDLP of experienced drivers was higher during dual-task performance as compared with road tracking at a BAC 0.5 g/L. During the dual-task performance, the available but limited processing resources are divided over the primary and secondary task. An explanation could be that in novice drivers, the total demand is higher, as road-tracking performance is not yet automated (Sagberg & Bjørnskau, 2006). The interaction effect showed that driving in novice drivers is impaired at a BAC of 0.2 g/L under dual-task conditions, whereas driving impairment in experienced drivers occurred at a BAC of 0.5 g/L. This supports the notion that a lower legal limit of 0.2 g/L for novice drivers is warranted. Remarkably, performance of novice drivers did not differ significantly across single- and dual-task performance at BAC of 0.5 g/L. Arguably, this is due to a ceiling effect induced by the subjective experienced impairment that might cause the driver to prioritize headway maintenance over secondary task performance, hence causing a temporary stabilization of performance on the corresponding measure.

One limitation may be that only automated driving was measured, because SDLP is an outcome measure at the operational level of driving (Michon, 1989). Driving performance incorporates several components, such as risk assessment, decision making, and interaction with other traffic. Hence, the results of the highway driving test can be further expanded by incorporating city driving scenarios to maximize generalizability. Future studies should assess the effects of additional components of driving performance in order to generalize findings over multiple components of driving. In addition, research is needed to determine the duration of driving experience for lane-tracking performance to become more automated. In the Netherlands, the average length of driving examination is 40 hr of driving lessons. Formal driving education in the Netherlands is rather lengthy compared with other countries in the European Union, which could mean that the increased crash risk for novice drivers is further elevated in countries with a shorter licensing program.

Given the nature of the secondary task, which did not include visual distraction, it can be argued that these findings could be generalized to numerous other situations where the mental load of the driver is increased, for example, navigating through busy traffic while talking to a passenger. The findings seem to suggest that young inexperienced drivers are especially vulnerable to these effects while under the influence of alcohol. It is therefore of the utter most importance that young inexperienced drivers are aware of this vulnerability in order to promote serious and responsible attitudes regarding drinking and driving.

In conclusion, this study showed that road-tracking performance is already impaired at a BAC of 0.2 g/L in both novice and experienced

drivers. In addition, secondary task performance is impaired in both groups at a BAC of 0.5 g/L. Furthermore, it was found that driving in novice drivers was already impaired at a BAC of 0.2 g/L under dual-task conditions, whereas driving impairment in experienced drivers occurred at a BAC of 0.5 g/L. This provides further evidence for the lower legal limit of 0.2 g/L for novice drivers.

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CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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REFERENCES

- Borkenstein, R. F., Crowther, R., & Shumate, R. (1974). The role of the drinking driver in traffic accidents (The Grand Rapids Study). *Blutalkohol*, 11(Suppl), 1–131.
- Brand, N., & Jolles, J. (1985). Learning and retrieval rate of words presented auditorily and visually. *The Journal of General Psychology*, 112(2), 201–210.
- Campagne, A., Pebayle, T., & Muzet, A. (2004). Correlation between driving errors and vigilance level: Influence of the driver's age. *Physiology & Behavior*, 80(4), 515–524.
- Chen, L.-H., Baker, S. P., Braver, E. R., & Li, G. (2000). Carrying passengers as a risk factor for crashes fatal to 16- and 17-year-old drivers. *JAMA*, 283(12), 1578–1582.
- Cooper, P. J., Pinili, M., & Chen, W. (1995). An examination of the crash involvement rates of novice drivers aged 16 to 55. *Accident Analysis & Prevention*, 27(1), 89–104.
- Department of Transport and Main Roads, Queensland Government, Australia. (2011). 2010 year in review road crash report.
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39(2), 175–191.
- Fillmore, M. T., Carscadden, J. L., & Vogel-Sprott, M. (1998). Alcohol, cognitive impairment and expectancies. *Journal of Studies on Alcohol*, 59(2), 174–179.
- Freydier, C., Berthelon, C., Bastien-Toniazzo, M., & Gineyt, G. (2014). Divided attention in young drivers under the influence of alcohol. *Journal of Safety Research*, 49, 13–e1.
- Gonzales, K., Roeber, J., Kanny, D., Tran, A., Saiki, C., Johnson, H., ... Lepp, A. (2014). Alcohol-attributable deaths and years of potential life lost—11 States, 2006–2010. *MMWR. Morbidity and Mortality Weekly Report*, 63(10), 213–216.
- Gras, M. E., Planes, M., Font-Mayolas, S., Sullman, M. J. M., Jimenez, M., & Prat, F. (2010). *Driving distractions in Spain*. Paper presented at the proceedings of driving simulation conference, Paris, France.
- Groeger, J. A., & Chapman, P. (1996). Judgement of traffic scenes: The role of danger and difficulty. *Applied Cognitive Psychology*, 10(4), 349–364.

- Hadland, S. E., Xuan, Z., Sarda, V., Blanchette, J., Swahn, M. H., Heeren, T. C., ... Naimi, T. S. (2017). Alcohol policies and alcohol-related motor vehicle crash fatalities among young people in the US. *Pediatrics*, *139*, e20163037.
- Harrison, E. L., & Fillmore, M. T. (2011). Alcohol and distraction interact to impair driving performance. *Drug and Alcohol Dependence*, *117*(1), 31–37.
- Irwin, C., Monement, S., & Desbrow, B. (2015). The influence of drinking, texting, and eating on simulated driving performance. *Traffic Injury Prevention*, *16*(2), 116–123.
- Jongen, S., Vermeeren, A., van der Sluiszen, N. N. J. J. M., Schumacher, M. B., Theunissen, E. L., Kuypers, K. P. C., ... Ramaekers, J. G. (2017). A pooled analysis of highway driving studies in actual traffic measuring standard deviation of lateral position (i.e. "weaving") while driving at a blood alcohol concentration of 0.5 g/L. *Psychopharmacology*, *234*, 837–844. <https://doi.org/10.1007/s00213-016-4519-z>
- Jongen, S., Vuurman, E., Ramaekers, J., & Vermeeren, A. (2016). The sensitivity of laboratory tests assessing driving related skills to dose-related impairment of alcohol: A literature review. *Accident Analysis & Prevention*, *89*, 31–48.
- Liguori, A. (2009). Simulator studies of drug-induced driving impairment. In J. C. Verster, S. R. Pandi-Perumal, J. G. Ramaekers, & J. J. de Gier (Eds.), *Drugs, driving and traffic safety* (pp. 75–82).
- Louwerens, J. W., Gloerich, A. B. M., DeVries, G., Brookhuis, K. A., & O'Hanlon, J. F. (1987). The relationship between drivers' blood alcohol concentration (BAC) and actual driving performance during high speed travel. In P. C. Noordzij, & R. Roszbach (Eds.), *Alcohol drugs traffic safety - T86* (pp. 183–186). Amsterdam: Elsevier.
- Mayhew, D. R., Simpson, H. M., & Pak, A. (2003). Changes in collision rates among novice drivers during the first months of driving. *Accident Analysis & Prevention*, *35*(5), 683–691.
- Michon, J. A. (1989). Explanatory pitfalls and rule-based driver models. *Accident Analysis & Prevention*, *21*(4), 341–353.
- Moskowitz, H., & Fiorentino, D. (2000). A review of the literature on the effects of low doses of alcohol on driving-related skills.
- O'Hanlon, J. F. (1984). Driving performance under the influence of drugs: Rationale for, and application of, a new test. *British Journal of Clinical Pharmacology*, *18*(S1), 121S–129S. <https://doi.org/10.1111/j.1365-2125.1984.tb02590.x>
- Rakauskas, M. E., Ward, N. J., Boer, E. R., Bernat, E. M., Cadwallader, M., & Patrick, C. J. (2008). Combined effects of alcohol and distraction on driving performance. *Accident Analysis & Prevention*, *40*(5), 1742–1749.
- Sagberg, F., & Bjørnskau, T. (2006). Hazard perception and driving experience among novice drivers. *Accident Analysis & Prevention*, *38*(2), 407–414.
- Shope, J. T., & Bingham, C. R. (2002). Drinking-driving as a component of problem driving and problem behavior in young adults. *Journal of Studies on Alcohol*, *63*(1), 24–33.
- Theunissen, E. L., Street, D., Højer, A. M., Vermeeren, A., Oers, v. A., & Ramaekers, J. G. (2013). A randomized trial on the acute and steady-state effects of a new antidepressant, vortioxetine (Lu AA21004), on actual driving and cognition. *Clinical Pharmacology & Therapeutics*, *93*(6), 493–501.
- Vermeeren, A., Ramaekers, J., & O'Hanlon, J. (2002). Effects of emedastine and cetirizine, alone and with alcohol, on actual driving of males and females. *Journal of Psychopharmacology*, *16*(1), 57–64.
- Verster, J. C., & Roth, T. (2011). Standard operation procedures for conducting the on-the-road driving test, and measurement of the standard deviation of lateral position (SDLP). *International Journal of General Medicine*, *4*, 359.
- Vuurman, E., Muntjewerff, N., Uiterwijk, M., Van Veggel, L., Crevoisier, C., Haglund, L., ... O'Hanlon, J. (1996). Effects of mefloquine alone and with alcohol on psychomotor and driving performance. *European Journal of Clinical Pharmacology*, *50*(6), 475–482.
- Watson, P. E. (1989). Total body water and blood alcohol levels: Updating the fundamentals. *Human metabolism of Alcohol*, *1*, 41–58.
- Wikman, A.-S., Nieminen, T., & Summala, H. (1998). Driving experience and time-sharing during in-car tasks on roads of different width. *Ergonomics*, *41*(3), 358–372.
- Zador, P. L., Krawchuk, S. A., & Voas, R. B. (2000). Alcohol-related relative risk of driver fatalities and driver involvement in fatal crashes in relation to driver age and gender: An update using 1996 data. *Journal of Studies on Alcohol*, *61*(3), 387–395.

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