Effect of alcohol and divided attention task on simulated driving performance of young drivers

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EFFECT OF ALCOHOL AND DIVIDED ATTENTION TASK ON SIMULATED DRIVING PERFORMANCE OF YOUNG DRIVERS.

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ABSTRACT

The aim of this study is to evaluate driving impairment linked to divided attention task and alcohol and determinate whether it is higher for novice drivers compared to more experienced drivers. Sixteen novice drivers and sixteen experienced drivers participated in three experimental sessions corresponding to blood alcohol concentration (BAC) of 0.0 g/L, 0.2 g/L and 0.5 g/L. They performed a divided attention task (car-following task combined with a number parity identification task), and their results were compared to baselines obtained in reference single-tasks. Driving performance was evaluated by standard deviation of lateral position and minimum inter-vehicular distance. Response time and accuracy on additional task were also measured. Overall, ANOVA showed a driving impairment from BAC of 0.5 g/L with an increase of lateral position variability and a decrease of correct response percentage. In addition, novice drivers seem to be particularly disrupted by negative impact of alcohol because they adopt more risky behavior as to tailgate the vehicle in front of them. In divided attention task, driving impairment was found for all drivers. With respect to accuracy, information processing impairment was highlighted, notably in peripheral vision. Results are interpreted in terms of limited information processing capacity. Thus, the divided attention task used here provides a relevant method to isolate and identify effects of acute alcohol intoxication on cognitive functions and could be used in psychopharmacological research.

Keywords: alcohol; divided attention; driving experience; simulator

INTRODUCTION

Driving is a complex activity of dynamic processes control which requires accurate diagnosis of the situation and relevant decision-making. Drivers have to select relevant information in traffic in order to anticipate and react effectively to sudden events. Many factors can influence driver behaviour and lead to crashes.

Among them, alcohol is recognized as one major factor of driving impairment and researchers demonstrate a linear relationship between blood alcohol concentration (BAC) and crash risk notably for young drivers (Peck et al., 2008; Zador et al., 2000). Alcohol consumption impairs skills necessary to safe driving (Moskowitz and Fiorentino, 2000) and disrupts the information processing (Harrison and Fillmore, 2011; Fillmore, 2003). In psychopharmacological studies, driving performance is traditionally measured by standard deviation of lateral position (SDLP). After alcohol intake, studies indicate an increase of SDLP (Meskali et al., 2009; Rakauskas et al., 2008), a delay in reaction time to sudden events and an impairment of vigilance, visual and divided attention (Koelaga, 1995).

Otherwise, the lack of experience is also recognized as a main factor of crash. Indeed, young drivers are widely overrepresented in road accidents so that, in France, it is the first cause of death among drivers under 25 (ONISR, 2011). There is a wide field of research showing that skills necessary to safe driving improve significantly with experience (Mc Cartt et al, 2009; Mayhew and Simpson, 1995). Ability to control vehicle is one of the first skills acquired by training and it is mastered in few hours (Hall and West, 1996), perceptive and cognitive abilities are then developed. They are slower processes which include attentional allocation (Crundall and Underwood, 1998), matching between task demands and driving skills (Brown and Groeger,

1988) and contribute to driver's potential ability to detect hazards. These crucial skills improve with experience (Deery, 1999; Underwood, 2007).
Another factor of crash is driver distraction (Klauer et al, 2006) which can occurs when driver attention is captured intentionally or not by a secondary task unrelated to driving task (Regan, 2011). Actually, 19% of drivers are engaged in an additional task like speaking, eating, drinking, smoking or using the mobile phone while driving (Gras et al., 2010). Performing an additional task is known to reduce driving performance and increase reaction time (Andersen et al., 2011; Cantin et al., 2009; Bian et al., 2000). For example, using a mobile phone during a car following task increases the mental load which results in a delay in brake reaction time (Lamble et al., 1999) and in the reaction time to headway changes (Brookhuis and De Waard, 1994). Driver's distraction by an additional visual task leads to an increase of mistake production (Young and Salmon, 2012) and when novice driver is texting message, he spends less time to look the driving scene (Hosking et al., 2009). Performance impairment linked to an additional task, often measured in simulated environment, is confirmed by study carried out on real-environment (Blanco et al., 2006) and can be interpreted in terms of limited information processing capacity (Kahneman, 1973). When driver performs simultaneously several tasks, he is placed in divided attention situation and he has to divide adequately its attentional resources between driving and additional task. Thereby, mental load related to driving task increases when driver has to divide his attentional resources between two tasks (Lemercier and Cellier, 2008). Recently, researchers showed that the impairment linked to divided attention is even more pronounced when driver is under the influence of alcohol (Harrisson and Fillmore, 2011).
Alcohol, lack of experience and divided attention are thus recognized as three factors contributing to road-accident. Many studies are focused on the effects of each of these factors, but few have investigated their possible interaction. The aim of the present research is to evaluate driving-impairment linked to divided attention and alcohol and to determinate if this impairment is higher for novice drivers compared to more experienced drivers.

METHOD

Participants

32 students separated in two groups depending on driving experience took part in this study. The first group consisted of 16 novice drivers (7 female and 9 male) aged 18 who had less than 2 months of driving experience and drove less than 5000 km. The second group consisted of 16 experienced drivers (8 female and 8 male) aged 21 who had three years of driving experience and drove more than 20,000 km. All participants obtained their driver's license at 18 years. This two groups correspond to the beginning and end of probationary license in France.
Participants underwent a medical examination in order to confirm their good physical condition, the absence of sleep disorder and of any treatment at the time of inclusion and during the previous 15 days. Volunteers completed questionnaire that provided demographic information and drinking habits in order to control they did not have a substance abuse disorder. Only social drinkers, defined as individuals with alcohol moderate consumption (about two alcohol glasses, not every day) chiefly in a social context, are included in this experiment.

To avoid any learning effect, participants carried out training before the experimental sessions. They provided written informed consent and received 120 euros for their participation. The experimental protocol was approved by local Ethics Committee.

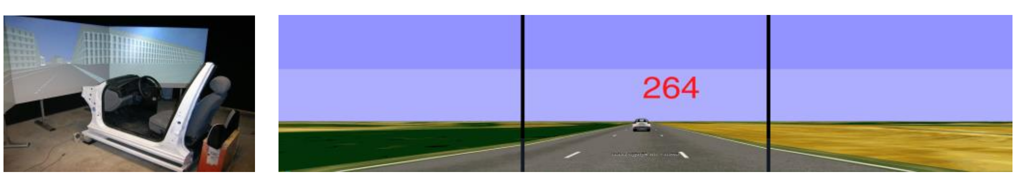
Experimental Design

The driving experiment was carried-out on the SIM^2-IFSTTAR fixed base driving simulator equipped with an ARCHISISM object database (Espié et al., 2005) (See Figure 1a). Driving simulator is a relevant tool in our study because there is a large degree of similarity in the relationship between the BAC levels and driving impairment observed in driving simulator and on real driving (test-track) (Helland et al., 2013).

Three experimental sessions were carried-out according to a single-blind, balanced, cross-over design. Before each session, participant had a drink (vodka and orange juice) in order to obtain a BAC of 0 (placebo), 0.2 or 0.5 g/L. BAC was measured with a breathalyzer (SD-400 DJP/LION) 15 min after alcohol intake, and then each 10 min until the desired BAC was obtained. All volunteers participated in the three sessions held at intervals of at least one day.

Each session includes three tasks and had a total duration of 30 min. The order of presentation of the two single tasks was counterbalanced between each experimental session. Single task of car-following was performed in order to evaluate baseline of driving performance. Drivers had to follow a lead vehicle while keeping a constant distance with this vehicle. In order to prevent learning effect the lead vehicle speed varied with sixteen accelerations and sixteen decelerations either with high or low amplitude. The driver was placed in the middle of three-lane road, so that the visual environment was perfectly symmetrical. Single task of number parity identification was carried-out, in order to ensure that its cognitive cost is similar for experienced and novice drivers. Number parity identification task required to identify even and odd numbers and to activate the right control of the steering wheel if the target was even or the left control if the target was odd. A three-figure number appeared in 1.5 seconds to 2.5 seconds intervals with a duration of 400 milliseconds, either in a central or peripheral (left and right) vision. Then, volunteers performed a divided attention task which implies performing simultaneously a car-following task while identifying parity numbers which can appear on central or peripheral vision (left or right) (See Figure 1b).The interference related to the divided attention task was computed and compared with baseline measures obtained in single-tasks.

The main driving task has been specifically chosen on the basis of previous study showing that car-following situation involve behavioral impairment in case of alcohol intoxication (Meskali et al., 2009) and the secondary-task has been chosen apart from driving context in order to avoid possible learning effect linked to driving experience. In addition, while driving most of information used are visual information (Sivak, 1996) and the divided attention task use the same perceptual channel (visual) for the two tasks. According to multiple resources theory of Wickens (1984, 2002), it is a good way to highlight interference between two tasks.



a. b.

Figure 1 a. Driving simulator; b. Visual scenario of divided attention task

Measures

Driving performance was evaluated through lateral and longitudinal vehicle control. Lateral control was measured by the standard deviation of the lateral position (SDLP) which was defined as an indicator of the degree of adjustment that a driver implements to maintain a desired position within the lane (Harrison and Fillmore, 2011). Thus, SDLP reflects keeping-lane skills. Many research established that SDLP is a valid and sensitive indicator of impaired behavior (Harrison and Fillmore, 2005; Rakauskas et al., 2008; Shinar et al., 2005) and an increase of SDLP indicates an impairment of vehicle control ability (Harrisson and Fillmore, 2011). Longitudinal control was measured by the minimum inter-vehicular distance (min IVD) e.g the minimum distance adopted between the rear of the lead vehicle and the front of the following vehicle.
Additional task performance was measured by reaction time (RT) and percentage of correct response (CR).

Data Analyses

Results from the divided attention task were compared to results obtained in the reference tasks (single task of car-following and single task of number parity identification).
Firstly, the effects of BAC, task and driving experience on driving performance were analyzed by 2 (driving experience)* 3 (BAC) * 2 (task) repeated measure analyses of variance (ANOVA). Secondly the effects of BAC, task, number location and driving experience on response-time and accuracy of number parity identification were analyzed by a 2 (driving experience) * 3 (BAC) * 2 (task) * 3 (number location) ANOVA. Statistical analyses were performed using Statistica software. The data were tested for significance threshold of $p < 0.05$. Bonferroni post-hoc tests were subsequently used for pairwise comparisons.

RESULTS

Driving Performance

<u>Standard Deviation of Lateral Position</u>

As expected, ANOVA showed a significant main effect of driving experience ($F(1, 30) = 3.92$, $p < 0.05$). SDLP was higher for novice drivers than for experienced drivers (respectively, M = 14.72 cm; SD = 4.2 and M = 12.71 cm; SD = 3.4).
A significant main effect of task was also highlighted ($F(1, 30) = 13.64$, $p < 0.001$). Overall, SDLP was higher in divided attention task compared to single task of car-following (respectively, M = 14.4 cm; SD = 3.8 and M = 13.07 cm; SD = 3.3).
In accordance with our assumption, ANOVA revealed a significant main effect of BAC ($F(2, 60) = 9.5$, $p < 0.001$). Drivers' SDLP with a BAC of 0.5 g/L (M = 14.95 cm; SD = 4) was higher than those with a BAC of 0.2 g/L (M = 13.47 cm; SD = 4) and 0.0 g/L (M = 12.7 cm; SD = 2.8). Any significant difference was found between placebo and BAC of 0.2 g/L.
A trend toward significant interaction between BAC and task was found ($F(2, 60) = 2.44$, $p = 0.09$). Pairwise comparisons showed that an increase of SDLP in divided attention task compared to single-task was only significant with a BAC of 0.5 g/L (respectively, M = 16.07 cm; SD = 4.5

and M = 13.83 cm; SD = 3.5). When drivers were in divided attention task with a BAC of 0.5 g/L, their SDLP was significantly higher than in all others conditions of BAC and task (see Figure 2).

No significant interaction was found between driving experience and BAC on SDLP (F (2, 60) = 1.68, p = 0.19), neither between driving experience and task (F (1, 30) = 0.48, p = 0.49).

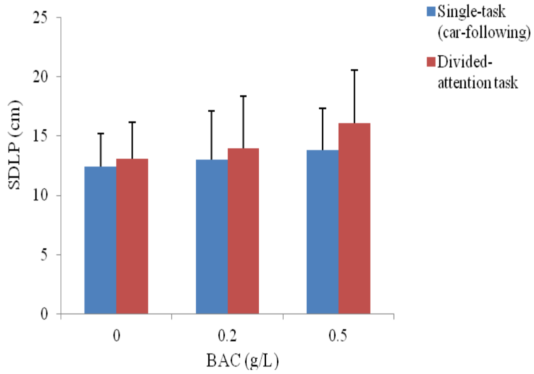


Figure 2 Standard Deviation of Lateral Position depending on BAC and Task

<u>Minimum Inter-Vehicular Distance</u>

A significant main effect of task was demonstrated (F (1, 30) = 7.38, p < 0.05). Overall, min IVD was shorter in divided attention task compared to single-task of car-following (respectively, M = 17.55 m; SD = 4.5 and M = 18.73 m; SD = 4.6). An interaction between task and driving experience (F (1, 30) = 6.9, p < 0.05) showed that a decrease of min IVD in divided attention task was only significant for experienced drivers (See Figure 3).

ANOVA revealed a significant main effect of BAC on min IVD (F (2, 60) = 16.36, p < 0.001). Overall, drivers' min IVD with a BAC of 0.5 g/ L (M = 16.22 m; SD = 4.4) were shorter than those of drivers with a BAC of 0.2 g/L (M = 18.85 m; SD = 4.4) and with placebo (M = 19.35 m; SD = 4.4). Any significant difference was found between placebo and BAC of 0.2 g/L. In accordance with our assumption, a significant interaction between BAC and driving experience (F (2, 60) = 6.6, p < 0.01) specified that the decrease of minimum IVD with alcohol was only significant for novice drivers (See Figure 4).

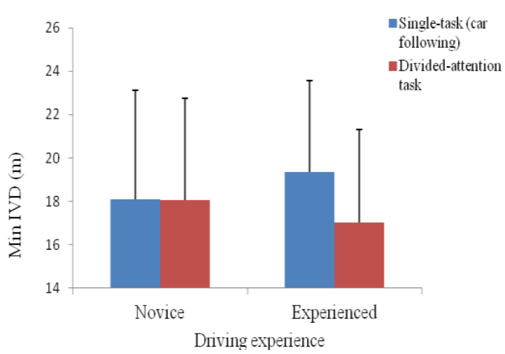


Figure 3 Minimum Inter-vehicular Distance depending on Task and Driving Experience

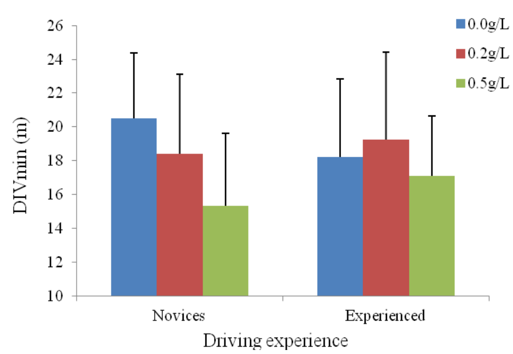


Figure 4 Minimum Inter-vehicular Distance depending on BAC and Driving Experience

Additional Task Performance

<u>Response-time</u>

As expected, a significant main effect of driving experience was found (F (1, 30) = 4.43, p < .05). Overall, novice drivers had slower response-time compared to experienced drivers (respectively, M = 0.88 s; SD = 0.12 and M = 0.84 s; SD = 0.1).
ANOVA showed a significant main effect of task (F (1, 30) = 11.01, p < .005). Overall, drivers had slower response-time in single task of number identification compared to divided attention task (respectively, M = 0.87 s; SD = 0.1 and M = 0.85 s; SD = 0.10).
A significant main effect of number location was also found (F (2, 60) = 629.54, p < .001). Drivers had slower response time when number appeared in the peripheral vision –right (M = 0.93 s; SD = 0.09) and left (M = 0.90 s; SD = 0.09) - compared to central vision (M = 0.77 s; SD = 0.08). Response time difference between right and left peripheral identification was significant.
A trend toward significant interaction between number location and driving experience was obtained (F (2, 60) = 2.49, p = 0.09) showing that only experienced drivers response time was slower when number appeared in right peripheral compared to left peripheral vision (see Figure 5).
No significant main effect of alcohol was found on response time, neither interactive effect between BAC and driving experience (F (2, 60) = 0.86, p =.43), BAC and task (F (2, 60) = 0.21, p = .81), BAC and number location (F (4, 120) = 0.52, p = .72).

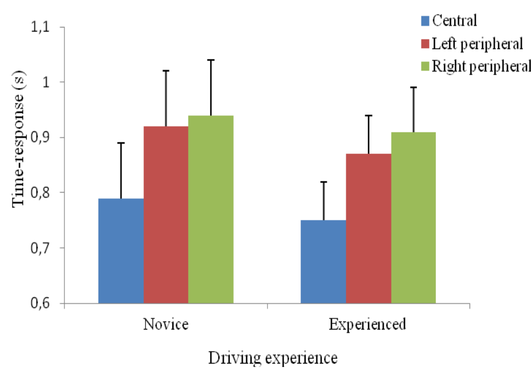


Figure 5 Reaction time depending on Driving experience and Number location

<u>Accuracy</u>

In accordance with our assumption, ANOVA revealed a significant main effect of BAC (F (2, 60) = 4.03, p < .05). Correct response percentage was lower for drivers with a BAC of 0.5 g/L (M = 86.8 %; SD = 8.6) than those of drivers with a BAC of 0.2 g/L (M = 89 %; SD = 9) and 0.0 g/L (M = 89.6 %; SD = 7.4).
A significant main effect of number location was found (F (2, 60) = 81.27, p < .001). Pairwise comparisons indicated that correct response percentage was lower when number appeared in peripheral vision, either the right (M = 87.2 %; SD = 9) or left side (M = 81.7 %; SD = 11.8), compared to when number appeared in central vision (M = 96.1 %; SD = 4.3). Moreover,

percentage of correct response in right peripheral vision was significantly lower than those in left peripheral vision.

A significant interaction between BAC and number location ($F (4, 120) = 3.1$, $p < .05$) specified that decrement of correct response percentage with highest BAC was only significant when the number appeared in peripheral vision (right and left side). In addition, a significant decrease of correct response percentage was found with a BAC of 0.5 g/L compared to a BAC of 0.2 g/L only when number appeared in the right peripheral vision (see Figure 6).

ANOVA also revealed a significant main effect of the task, ($F (1, 30) = 28.88$, $p < .001$) showing a decrease of correct response percentage in divided attention task compared to baseline performance in single-task of number parity identification (respectively, M = 86.2 %; SD = 9.7 and M = 90.8 %; SD = 7).

A significant interaction between task and number location, ($F (2, 60) = 21.76$, $p < .001$) pointed out that this decrease of correct response percentage in divided attention task was only significant when number appeared in right peripheral vision (See Figure 7).

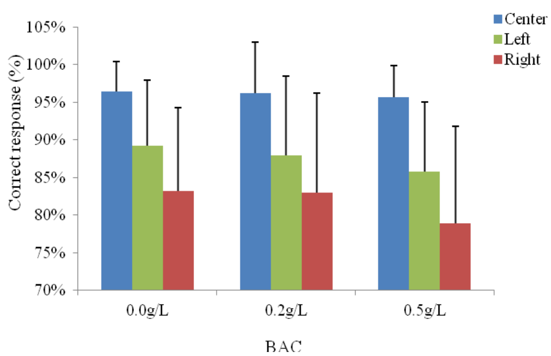


Figure 6 Correct responses depending on BAC and Number location.

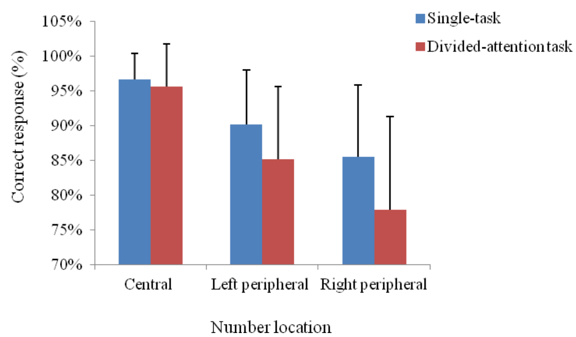


Figure 7 Correct responses depending on Task and Number location

DISCUSSION

In the present study, the relationships between BAC, divided attention and driving experience on simulated driving performance was investigated. The hypothesis was that the combination of alcohol and divided attention task would interact to impair driving performance, especially for novice drivers.

Alcohol effects

Analyses revealed that alcohol consumption impaired lateral and longitudinal control from BAC of 0.5 g/L. With respect to lateral control measured by SDLP, findings are consistent with those of previous studies in which a dose-response relationship between BAC levels and SDLP was demonstrated (Helland et al., 2013; Harrisson and Fillmore, 2011; Meskali et al., 2009). Therefore, our data confirm that SDLP is a valid and sensitive indicator of driving impairment related to alcohol consumption. Overall, alcohol impairs lateral control independent of driving experience. It seems to be worthwile to compare this result with those found by Meskali et al. (2011) because both studies used the same driving simulator and car-following task. In Meskali et al (2011), SDLP increase was only found significant with a BAC of 0.8 g/L, but subjects were experienced drivers with a mean age higher than our participants. This might suggest that lateral control impairment appeared earlier for young drivers, as low as 0.5 g/L, but this hypothesis has yet not been tested statistically. With respect to longitudinal control measured by min IVD, only novice drivers adopt shorter inter-vehicular distance with BAC of 0.5 g/L e.g. alcohol impairs the longitudinal control ability of novice drivers but not that of experienced drivers. Thus, Min IVD is a relevant parameter to investigate specifically novice driver's skills and differentiate them from experienced drivers.

With respect to additional task performance, cognitive processing accuracy was impaired from BAC of 0.5 g/L, but not response time. This differential effect of alcohol depending on parameters measured has been explained by Schweizer and Vogel-Sprott (2008) which showed that cognitive processing speed tends to develop acute alcohol tolerance, but not accuracy. Regarding accuracy, alcohol-impairment occurred only when number appeared in peripheral vision. This result replicates the common effect of tunnel vision induced by alcohol, as suggested by driver's inability to disengage their attention from central visual field toward peripheral visual field (Do Canto-Pereira, 2007).

In spite of dose-response effect, any significant driving impairment related to the low dose of alcohol (BAC of 0.2 g/L) on performance was found. Otherwise, some epidemiological studies indicated that the crash severity increases as low as 0.1 g/L (Phillips and Brewer, 2011) and fatal crash risk is twice for a BAC of 0.2 g/L compared to BAC of 0.0 g/L, especially for young novice drivers (Peck et al., 2008). Two hypotheses could explain this result. Firstly, it might suggest that driving impairment induced by alcohol occurs with a BAC superior to 0.2 g/L as in others studies which indicate driving impairment only from 0.3 g/L (Schnabel et al, 2010). Thereby, this research contributes to precise the minimum level of BAC that impairs driving skills. Indeed, the limit of BAC for safety driving could be situated between 0.2 g/L and 0.3 g/L. Moreover, some countries have reduced the tolerated BAC at 0.2 g/L for specific population as novice and professional drivers and they record a decrease of crash number (Andreuccetti, 2011; Dupont et al, 2000). Secondly, another explanation concerns our task characteristics. In this study, driving scenario is relatively easy and contains only a straight road. In the extent that novice drivers are already in difficulty in complex situation without alcohol (Damn, 2011) and that alcohol particularly impairs complex task (Schnabel et al, 2010) it might be that a more complex task could highlight driving impairment of novice drivers with low doses of alcohol. Thus, future research should include more complex situations to specify these results.

Divided attention task effects

Performance impairment was observed in divided attention task compared to reference single-task, that is car-following task or number identification task. Overall, driving performance (SDLP) and accuracy (CR) on additional task were impaired in divided attention task whatever driving experience. This result confirmed that performing an additional task while driving leads to a driving-impairment and disrupts the information processing. Difficulties observed in divided attention task can be explained by the limited information processing capacity. Indeed, the amount of attentional resources mobilized in divided attention task increases compared to each task alone and can exceed the amount of available resources (Kahneman, 1973).

With respect to longitudinal control, only min IVD of experienced drivers decrease in divided attention task compared to single task of car-following. Novice drivers' min IVD also decrease in divided attention task compared to baseline measure obtained in single task of car-following but difference are not significant certainly due to high heterogeneity of performance. In addition,

our participants are exclusively students' drivers which can reduce the difference between the two groups. It is actually well recognized that students drivers with high educational background are less involved in crash than general population at the same age (Murray, 1998).
Regarding additional task performance, drivers had a lower correct response percentage in divided attention task compared to single-task of number parity identification only when number appeared in right peripheral vision. Response time was also impaired in right peripheral vision compared to left peripheral vision whatever the task. These results highlight different information processing depending on stimuli locations, and notably depending on peripheral side of vision. Response time difference depending on peripheral side was only found for experienced drivers suggesting that it takes place gradually with driving experience. Indeed, when the task is more demanding, as in divided attention task or when drivers are novice, gazes are focused on central visual field (Lemercier and Cellier, 2008; Williams, 1995).
Surprisingly, subject response times are slower in single task of number parity identification task compared to divided attention task. Noted that number identification task responses are given with vehicle commands situated near of steering-wheel and that different hand position was observed depending on task. Indeed, in the single task of number parity identification, participants' hand position was variable whereas in divided attention task, their hands do not leave the steering wheel. Hand position in space may be is a relevant index of load related to the task demands and it seems to be necessary to control this factor in future research.

Driving experience effects

Finally, results revealed that SDLP of novice drivers was higher than those of experienced drivers, which reflects a poorer lateral vehicle control. This result confirms the assumption that driving skills of novice drivers are lower than those of experienced drivers and is consistent with previous studies showing that experienced drivers exhibited an active control of their lateral position during urban scenario, contrary to novice drivers (Damn et al., 2011). In a similar way, novices' response times on additional task were slower than those of experienced driver which can be explained by involvement of different cognitive processes depending on driving experience. Indeed, the main task of car-following involved controlled processes for novice drivers, while these processes become automatic with experience. As a consequence, this task mobilized the quasi totality of attentional resources for novice drivers, and, few resources are available to process an additional task.

CONCLUSIONS

To sum up, results classically showed that alcohol, divided attention task and lack of experience were independently related to driving impairment. In addition, our hypothesis is also confirmed: alcohol and driving experience interact to lead to a higher driving impairment for young novice drivers than for young experienced drivers. It is particularly interesting because the bound used to differentiate novice and experienced drivers was very thin. Indeed, only three years of driving experience and age separated novice and experienced drivers. As a result, this research contributes to improve knowledge on specific probationary period applied in France. In addition, the divided attention task used here provides a relevant method to isolate and identify effects of acute alcohol intoxication on cognitive functions and could be used in psychopharmacological research.

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