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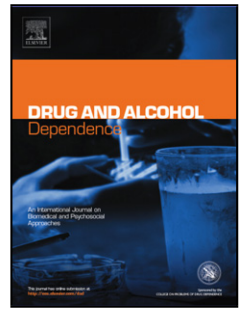

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Highlights:

- Simplified single-blind placebo-controlled experiment using different wine types and the same BAC.
- Natural, conventional, and dealcoholized wines were dispensed to 44 licensed young drivers.
- Different driving behaviours were observed between groups in ordinary and unusual road events.
- Lower BAC levels allow drivers to focus on a wider area ahead to monitor road events.
- Natural wine was less conditioning on visual reaction times than conventional wine.

ABSTRACT

Background. Alcohol consumption is responsible for a significant number of road fatalities. To contrast this phenomenon, a more responsible attitude to the wine consumption, especially among young, inexperienced drivers prone to risky behaviour on the road must be promoted. *Method*. This is a simplified single-blind, placebo-controlled experiment aimed at evaluating 44 young drivers monitored during a driving simulation following the consumption of natural and conventional wines, with a reference blood alcohol concentration (BAC) of 0.5 g/l. Two hypotheses are tested: (1) the legal consumption of wine has no significant impact on young drivers' performance in both ordinary and unusual road events; (2) natural and conventional wines are expected to produce negligible and acceptable impairments in young drivers the same BAC. Two reference groups (BAC = 0 g/l), one a placebo-controlled group with drivers treated with a dealcoholized wine, were included. *Results and Conclusions*. Significant differences between the groups in terms of perception and reaction times (PRT) to visual and auditory stimuli, and to speeding were observed, with young drivers treated with conventional wine displaying more aggressive behaviours. In contrast, participants treated with natural wine showed PRT which were not significantly different from those belonging to control groups. The gaze attention levels of wine treated drivers were found to be dose dependant, with young drivers of the two control groups and those of the treated ones with BAC < 0.3 g/l able to focus on wider area ahead and, thereby, collect more information from the road environment.

Keywords: road safety, young drivers, wine consumption, driving performance, blood alcohol concentration.

1. INTRODUCTION

The consumption of alcohol has a tremendous impact on road safety because it impairs the ability of drivers to maintain control over their vehicles (Du *et al.*, 2016). A more pronounced weaving movement of the vehicle trajectory in the lane (Helland *et al.*, 2013; van Dijken *et al.*, 2020), and a deterioration in speed and speed variation control is documented in literature (Rezaee-Zavareh *et al.*, 2017; Yadav and Velaga, 2019). Poor driving performances are the consequence of difficulties in negotiating road geometrics vis-à-vis actions performed on pedals and the steering wheel (Fillmore *et al.*, 2008). These difficulties are due to the challenge of coordinating the part of the brain controlling eye activity with that coordinating the physical actions performed on steering wheel and pedals (Marple-Horvat *et al.*, 2008). Finally, alcohol impairments are significantly dose-dependent, i.e. the higher the BAC, the poorer the driving performance (Calhoun *et al.*, 2004).

Another relevant aspect is the inclination to drink alcohol. In particular, younger drivers accept more risks because they are strongly attracted by the pleasant state of euphoria and inebriation quickly reached with alcohol (Pluddemann *et al.*, 1999), and perceived invulnerability (Potard *et al.*, 2018). Ferrero *et al.* (2019) observed that different alcoholic beverages with the same alcohol content consumed in the same quantities produce different BAC and neurotoxicity levels in young individuals. Natural wine (Galati *et al.*, 2019), which is produced without pesticides, chemicals or other additives by adopting traditional organic farming techniques, is metabolized differently from conventional wine due to their different compositions and characteristics (Pagliarini *et al.*, 2013). Dealcoholized wine was introduced into the market to contrast and reduce the incidence of drink driving, and to promote a healthier diet and lifestyle (Bucher *et al.*, 2018). The consumption of a moderate quantity of good wine is the premise for a responsible attitude to the consumption of alcohol before driving (Room, 2011; Dasgupta, 2011), especially for young drivers.

Notwithstanding major communication campaigns aimed at promoting a responsible and informed approach to the consumption of wine (Artero *et al.*, 2015; Beccaria and Rolando, 2016), there remains the need to assess the effects of a moderate consumption of different wines on the driving performances of young adults. To fill this knowledge gap, this study investigates the effects of the consumption of the three main types of wine (conventional, natural, and dealcoholized) on the driving performance of young adults. Recently, Ferrero et al. (2019) have demonstrated that, under the same quantity and intake conditions, the pharmacokinetic and metabolic effects produced by natural wine are superior to those produced by conventional wine.

This manuscript presents the results of a simplified single-blind and placebo-controlled experiment aimed at evaluating the modification in the driving behaviour of young drivers (< 30 years old) after a legal level of consumption of natural, conventional and dealcoholized wines, with a total of four different treatments including the control group (no drink). The experimental hypotheses are two: (1) the consumption of a quantity of wine not exceeding the legal drink-driving limit does not alter the performance of young drivers in ordinary and unusual (i.e., unexpected) road events; (2) different wine types with the same legal BAC level are expected to produce the same impairments in young drivers.

2. MATERIALS AND METHODS

2.1 Test drivers and experimental protocol

Forty-four young, licensed volunteers aged between 20 and 28 were randomized and stratified into four groups (Table 1) on the basis of gender, body mass index (BMI), and use of glasses. The drivers were all students, involved voluntarily in accordance with the Code of Ethics of the World Medical Association as described in the Declaration of Helsinki (World Medical Association, 2018). They were recruited from a sample of more than 400 students who responded positively to the invitation. No one received any benefit or payment. Before the experimental session, all participants signed an informed consent form as per the European General Data Protection Regulation (European Parliament, 2016).

Drivers were divided into four groups according to a semi-randomized procedure. Participants were first assigned to each group at random, then the composition of each group was adjusted so as to maintain a similar Male/Female ratio and to avoid large differences among groups in terms of the main personal characteristics of group members. Group A was administered the natural wine, Group B the conventional one, and Group C the dealcoholized one. The eleven drivers in Control Group D did not get any wine. As a result, this experiment considered one control Group (D) and one placebo Group (C). Table 1 lists the main characteristics of the participants in the four groups.

Consistent with the aim of this study, the BAC value of 0.05% (corresponding to 0.05 g of alcohol for 0.1 l of blood) was adopted in the treatment of Groups A and B. Test drivers drank the specific quantity of wine necessary to reach that reference BAC as per the Widmark formula (Widmark, 1981).

Test drivers were requested to respect the following rules before the test: (i) do not drink any alcoholic beverages the day before the test; (ii) have at least 8 hours sleep the night before; (iii) arrive at the laboratory using public transportation; (iv) do not have breakfast on the morning of the test; (v) do not assume other alcoholic substances for the rest of the day; and (vi) do not drive in the two hours after the test. The experimental sessions were conducted early in the morning on an empty stomach to avoid any influence on the rate of alcohol metabolization and in order to achieve the reference BAC (0.05%) as soon as possible. Each test lasted on average 52 minutes according to the protocol included in Figure 1. A pre-drive questionnaire was dispensed to collect information about the use of eye corrections, and the scores on the perceived amount of alcohol in the wine (Table 1).

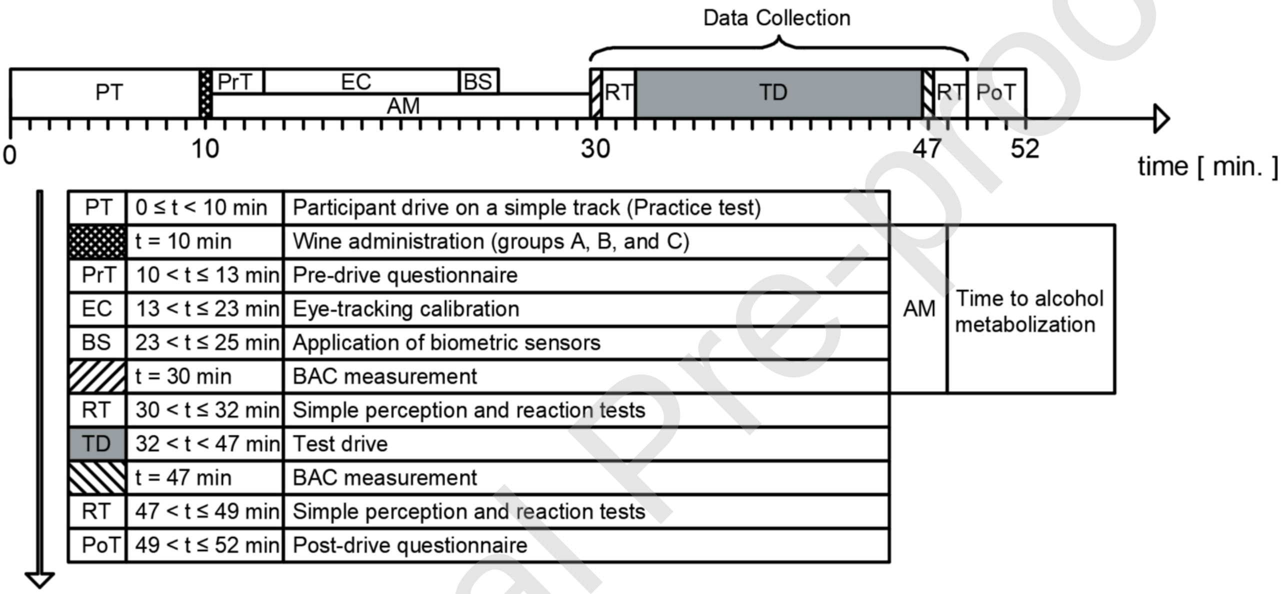


Figure 1. Experimental protocol vs. time

2.2 Natural, conventional and dealcoholized wines

Table 2 shows the characteristics of the three wines used in this experiment: the natural and conventional ones are two white wines made from *Cortese* grapes grown in vineyards located within 10 km of each other in the Piedmont region (North-west of Italy). The natural wine was cultivated without pesticides and agrochemicals, fermented with wild yeasts, unfiltered, with no fining agents and a lower level of sulphur dioxide. Differences between this wine and the conventional wine are evident in the levels of sulphur dioxide and pesticides present (natural wine contains a significantly lower volume of natural sulphur dioxide, and no pesticides). The third wine was a commercial product obtained from the dealcoholisation of a rosé wine. The alcohol is removed through osmotic distillation with a porous hydrophobic membrane acting to separate the alcohol from the water.

Table 2 includes the subjective evaluation score of the amount of alcohol given by the participants on the basis of personal judgement only. A scale from 1 (almost absent) to 5 (excessive) was adopted in the questionnaire dispensed to test drivers. The dealcoholized wine obtained an average rate of 2.32 (SD = 0.64) significantly higher than 1 ($t_{10} = 6.80$, $p < 0.001$). The majority of the observed values were between 2 and 3, with only one evaluation equal to one. This result supports the existence of the placebo effect for almost all the drivers involved in the “dealcoholized” group, in contrast to the results from previous studies involving placebo groups (Helland *et al.*, 2013).

2.3 Equipment

Driving simulations were carried out at a fixed-base simulator (AV Simulation) that includes passive pedals, an actuated steering wheel with force feedback, and three 32-inch full HD LCD monitors (refresh rate equal to 100 Hz, 130° horizontal angle view of the road scenario). The simulation software (*SCANeR*™ *Studio*) collected all data on vehicle dynamics and driver actions on commands at a frequency of 10 Hz. The equipment achieved absolute and relative validity for driving speed and vehicle trajectory on rural highways (Bassani *et al.*, 2018; Catani and Bassani, 2019). A head-mounted binocular eye-tracker (PupilLab Core) was used by those drivers that did not wear eyeglasses. The eye-tracking software recorded the world view and the participant’s gaze position at a frequency of 30 Hz on Full-HD frame and of 120 Hz on VGA (640×480 pixel) frame, respectively. The BAC value was recorded by means of a breathalyser (Alcoscan AL 8000 NFC).

2.4 Auditory and Visual Cognitive Tests

Visual and auditory reaction levels were monitored before and after the driving simulation task. At 30 and at 47 min (Figure 1), all participants were asked to complete the two attentional tests. Each test included ten trials per phase, and both tests were retrieved from “Cognitive Fun!” website (http://cognitivefun.net/). In the auditory perception and reaction time (PRT) test, participants had to focus on a fixed point on the computer monitor and press the spacebar as soon as they heard a sound. Similarly, in the visual PRT test they had to focus on a fixed point on the monitor, and press the spacebar as soon as they perceived a green dot on the screen.

2.5 Driving scenarios

Drivers travelled along a two-lane rural highway (lane width of 3.75 m, paved shoulder width of 1.5 m) designed in line with Italian policy (*Ministero delle Infrastrutture e dei Trasporti*, 2001).

The track consisted of fourteen curves and fourteen straight segments for a total length of 9,450 m. Spiralled transitions between straight and circular arcs were adopted to facilitate steering manoeuvres and gradually adapt the lane cross slope between tangents (2.5%) and curves (7%).

The drivers operated in free-flow conditions without any other vehicles directly ahead. Some unusual events were created to assess the decision-making ability of drivers. The measurements were aimed at detecting drivers' reactions. The following unusual localized (LE) and distributed (DE) events were recreated (Figure 2): (LE1) a truck parked along the shoulder and protruding for 20 cm out onto the travelled lane at the end of a rightward curve with a sight limitation (Figure 2A); (LE2) a queue of vehicles along a rightward curve with sight limitations (i.e., a continuous wall in the inner part of the curve), with drivers first becoming aware of the queue of vehicles ahead when they were at a distance of 140 m away (Figure 2C and Figure 2D); (DE) a series of traffic cones placed along the road centreline of a rightward curve again with a sight limitation (Figure 2B). Driver behaviour in ordinary driving conditions were extracted from two straights of equal length (290 m) and from a left- and a rightward curve of the same radius length.


(A) Truck parked across the shoulder and the lane (LE1)


(B) Roadworks along the shoulder (DE)


(C) Emergency stop before a queue of vehicles 140 m in front (LE2)

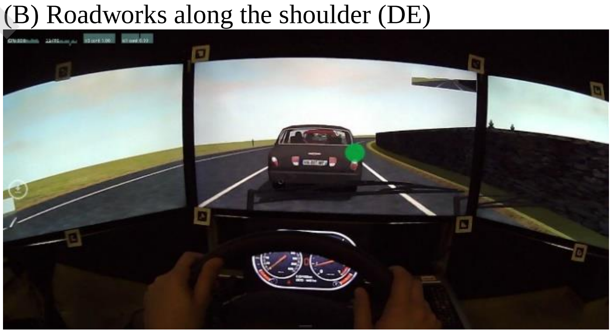

(D) Queue of vehicles (LE2)

Figure 2. Images taken from the driver's point of view of monitored section

2.6 Dependant variables and data analysis

Longitudinal and transversal behaviour in ordinary and unusual conditions were monitored through speed, lateral position, and standard deviation of lateral position (SDLP) (Verster and Roth, 2011). Higher SDLP values indicate lower levels of lateral control of the vehicle. The eye-tracking device was used to collect information on driver fixations in the 0.2 - 2 s range on the aforementioned straight and curved road sections. Heat-maps indicating the elements in the road scenario on which the drivers focused most of their attention were evaluated in a descriptive way.

Statistical tests on driving behaviour and performance in ordinary and unusual road events as well as on speed limit violations were conducted using Jamovi 1.1.9.0 (Navarro and Foxcroft, 2018). Comparisons among groups, as well as correlations, were conducted using a classical parametric approach (e.g., ANOVA and Pearson's r) or a non-parametric approach (e.g., Kruskal-Wallis test), depending on the distributional properties of individual variables. Auditory and visual reaction times were analysed separately using R 3.6.3 statistical packages (R Core Team, 2019). For the latter analyses, due to the data distribution (R package "fitdistrplus", Delignette-Muller and Dutang, 2015), the inverse Gaussian family distribution (Anders et al., 2016; Schmiedek et al., 2007) was set as a reference point for implementing the generalized linear models (*glm*), with the reaction times as dependent variables. Following a comparison of the models, the best fitting models were determined according to the Akaike Weights comparison (Wagenmakers and Farrell, 2004). The models with Group (A, B, C, D), Gender (Male, Female) and Phase (Before and After driving simulation task) as fixed effects, and the interaction between Phase and Group were selected and used for the *glm* fitting. Post-hoc tests were finally conducted using the "Emmeans" R package (Lenth et al., 2019).

3. RESULTS AND DISCUSSION

3.1 BAC levels

Twenty minutes after being administered, the natural wine resulted in BAC levels in a slightly wider interval (M_A = 0.047 g/dl, SD_A = 0.018 g/dl) than the conventional one (M_B = 0.049 g/dl, SD_B = 0.011 g/dl), although the similarities between the two wines and the dosage dispensed was a function of the BMI value (Widmark, 1981). However, the BAC of Group A drivers remained practically unchanged after the driving test (M_A = 0.047 g/dl, SD_A = 0.015 g/dl), while in the case of Group B a slight increase in the average value was observed (M_B = 0.055 g/dl, SD_B = 0.009 g/dl). These results are consistent with those of Ferrero *et al.* (2019). Group A and B before (A vs B: $t_{16.2} = -0.290$, $p = 0.775$) and after the driving task (A vs B: $t_{16.3} = -1.509$, $p = 0.150$) exhibited non-significant differences. As a result, in this study differences in driving behaviour do not depend on differences in the BAC level between groups but on other independent experimental factors (e.g., wine type).

3.2 Driving behaviour and performance in ordinary driving conditions

3.2.1 Speed and SDLP along straight sections

Two straight road sections of 290 m in length and with a 70 km/h speed limit were considered in the data analysis to compare the drivers' performances under ordinary conditions. Results showed that, despite a correlating increase in SDLP with an increase in BAC in Groups A and B, no significant differences were evident between them (t_{20} = 0.572, p = 0.575). Moreover, the SDLP values observed clearly fall in the same range recorded for Groups C and D which were not treated. However, the BAC was found to be positively correlated to the lateral control capability of treated drivers (Pearson's r = 0.429, p = 0.046).

In the case of speeds, no significant differences were observed between the two alcohol treated groups (A vs. B: t_{20} = 0.009, p = 0.993), and the BAC was not correlated with the longitudinal behaviour of drivers (Pearson's r = 0.228, p = 0.308). The results do not provide evidence of a significant impact on young drivers and there are no significant differences with the control and placebo groups, neither for SDLP ($F_{3,41}$ = 0.95, p = 0.43), nor for speed ($F_{3,41}$ = 1.10, p = 0.36). Finally, although 4 drivers out of the 11 in Group B adopted speeds in excess of 80 km/h, only one driver out of the 11 in Group A did so. This descriptive datum may indicate a more conservative behaviour on the part of the participants treated with natural wine.

3.2.2 Speed and SDLP along curved sections

No significant differences were found between alcohol treated groups for mean speeds (A and B vs. C and D, leftward curves: t_{39} = 0.192, p = 0.849; A and B vs. C and D, rightward curves: t_{39} = 0.807, p = 0.425), and SDLP (A and B vs. C and D: t_{39} = 0.86, p = 0.83). In addition, no significant differences were found between alcohol treated groups, neither for mean speeds (A vs. B, leftward curves: t_{18} = 0.65, p = 52; A vs. B, rightward curves: t_{18} = -0.96, p = 0.34) nor for SDLP (A vs. B, leftward curves: t_{18} = 0.21, p = 0.83; A vs. B, rightward curves: t_{18} = -0.34, p = 0.73).

3.3 Driving behaviour and performance in unusual road events

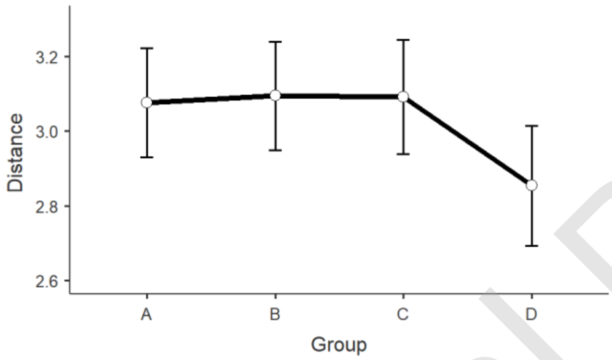
Figure 3 shows the lateral position (i.e., the distance of the centre of gravity of the vehicle from the right lane edge) and speed distributions observed in the case of LE1. Data in Figure 3A indicate that (i) drivers moved toward the road centreline, (ii) some of them partially occupied the opposite lane to avoid any contact with the unexpected obstacle, and (iii) the mean of the recorded lateral distributions of the reference group was slightly lower than the values recorded for the three wine treated groups (M_A = 3.08 m; M_B = 3.09 m; M_C = 3.09 m; M_D = 2.86 m). Differences in lane position among the four groups were not significant ($F_{3,20.4}$ = 0.596, n.s.).

However, this unexpected event led to significant differences between the mean speeds for the three treated groups with respect to the reference one (Figure 3B). The mean speeds for the four groups differed significantly from each other ($F_{3,19.6}$ = 38.562, p < 0.001). More specifically, planned comparisons showed that the wine-treated groups (M_A = 66.9 km/h; M_B = 70.4 km/h; M_C = 68.3 km/h) reported significantly higher speeds than the control Group D (M_D = 46.9 km/h; t_{37} = -6.295, p < 0.001). Although they passed closer to the parked truck, drivers in the reference group were prudent when overtaking it along the right shoulder. Post hoc analysis revealed that both the alcoholised groups (A and B) drove faster than the control Group D (A: t_{20} = 19.9, p < 0.001; B: t_{20} = 23.5, p < 0.001). Surprisingly, the placebo Group C which had consumed dealcoholized wine also drove at a significantly higher speed than the untreated group D (t_{20} = 21.3, p < 0.001). No statistically significant differences were found between Groups A and B (t_{20} = 0.913, p = 0.367). Results suggest that treated drivers were surprised by and did not react prudently to this unexpected event.

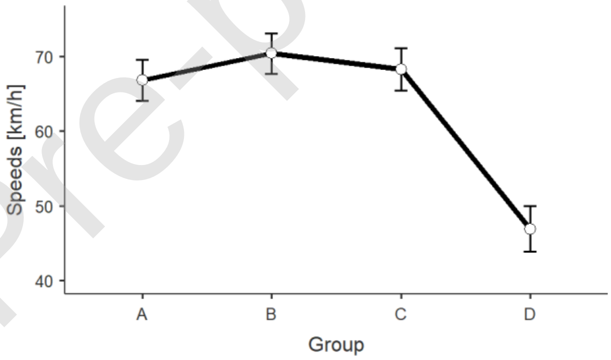
The placing of traffic cones aligned along the road centreline in a curve with limited visibility served as the distributed unusual event (DE). The SDLP was always found to be very low (M_A = 0.14 m; M_B = 0.18 m; M_C = 0.12 m; M_D = 0.14 m), and pairwise comparisons did not reveal any significant differences between groups at the 95% confidence level. Conversely, significant speed differences among groups were revealed by the Kruskal-Wallis test, which was conducted because of the particular data distribution (χ^2_3 = 7.71; p = 0.05). Post-hoc pairwise comparisons, conducted according to the Dwass-Steel-Critchclow-Fligner method, highlighted a significant difference between each of the wine treated groups (A, B, C) and the control one (A vs. D: W = -5.32, p < 0.001; B vs. D: W = -5.32, p < 0.001; C vs. D: W = -5.20, p < 0.001). Drivers in Group D felt more comfortable with the unusual situation and exhibited more self-confidence in managing speeds which were higher than for the wine treated groups.

In the last unusual event (Figure 2C and Figure 2D), a queue of vehicles came into view unexpectedly around the last curve of the track affected by a sight limitation (LE2), with an available sight distance of 140 m. At station 9+350 m drivers were able to detect the line of traffic ahead and had to come to an emergency stop within the available distance ahead (i.e., 140 m). The evaluation of their behaviour was based on the (i) initial speed at station 9,350 m, (ii) the station at which they modified their initial speed with the accelerator release, and (iii) the average deceleration.

Results indicate that the drivers in Group A approached the curve at a lower, albeit not significantly lower, speed than the other groups (A vs. B: t_{37} = -1.04, p = 0.72; A vs. C: t_{37} = -0.80, p = 0.85; A vs. D: t_{37} = -1.53, p = 0.42). Although all the drivers pressed on the brake pedal more or less at the same point, thereafter, the deceleration rate for natural wine treated drivers was not significantly lower than for other drivers (A vs. B: W = -1.022, p = 0.888; A vs. C: W = -0.598, p = 0.975; A vs. D: W = -2.257, p = 0.381).



(A)



(B)

Figure 3. Lateral position in the lane (A) and speed (B) distributions at station 2+403 m (in correspondence to the parked track along the shoulder).

3.5 Speed limit violations

Table 3 summarizes the percentage of track length on which drivers exceeded the speed limit(s). As expected, this generally occurred along straights rather than on curves. Nonetheless, mostly due to the high within group variability, the ANOVA on these data did not reveal any significant differences among groups for any of the depicted track sections (Straights: $F_{3,37}$ = 0.578, p = 0.67; Leftward curves: $F_{3,37}$ = 1.39, p = 0.26; Rightward curves: $F_{3,37}$ = 1.08; p = 0.37; Overall: $F_{3,37}$ = 0.95, p = 0.42). From a descriptive point of view, we observe that Group B drivers committed a higher percentage of speeding violations (54.3) than any of the other three groups, with the control Group (D) at 51.9%, Group A at 36.7%, and Group C at 37.1%. Drivers who are under the effects of alcohol tend to adopt higher speeds than sober ones (Du *et al.*, 2016; Zhang *et al.*, 2014; Van

Dyke and Fillmore, 2014). However, this study revealed a different dynamic between groups than that expected following a perusal of the available literature. In particular, drivers in control Group D displayed a level of self-confidence that induced them to assume higher speeds than the drivers in other groups.

This evidence does not contrast with the Figure 3B outputs where in the case of LE1 the Group D drivers slow down more than all the others when passing the parked truck. Although control Group (D) drivers were the most prudent when reacting to that unusual event, they were also more confident in accepting higher risks along the rest of the track under more favourable driving conditions. A minor difference between the two alcohol treated groups (A and B) was observed.

Drivers treated with natural wine appeared to be more conservative. This evidence needs further investigation to determine whether the wine type may be the basis for this significant difference in longitudinal behaviours. In fact, a very high dispersion was observed in the data, thus ruling out the possibility of arriving at a more solid conclusion on this aspect. The fact that Group B participants tend to adopt higher speeds may be due to the different decomposition process of the wine highlighted in Ferrero et al. (2019). This particular process may induce drivers to be less aware of the risks associated with alcohol impaired driving. The causal relationship between this behaviour and the type of wine dispensed to the group needs further insight and increased attention in future works.

Du *et al.* (2016) observed that the curve direction was significant in affecting longitudinal driver behaviour. Differently from this study, they observed that drivers with a BAC = 0.08% were found to drive at higher speeds along rightward curves than along left-ward ones, while drivers with a BAC $\leq$ 0.05% have a similar behaviour to that observed in this study.

Comparisons between the placebo and the control group provide evidence of a significant difference in longitudinal behaviour between those who believe themselves to be alcohol impaired (Group C) and those who know that they are unaffected (Group D).

3.6 Eye gaze analysis

The analysis of gaze distribution was carried out on the selected sub-sample of drivers who did not wear corrective glasses (Table 1). The eight heat-maps in Figure 4 show the results for drivers travelling along a straight. The results are representative of the observations for the rest of the drivers belonging to the same group and presenting a comparable BAC level.

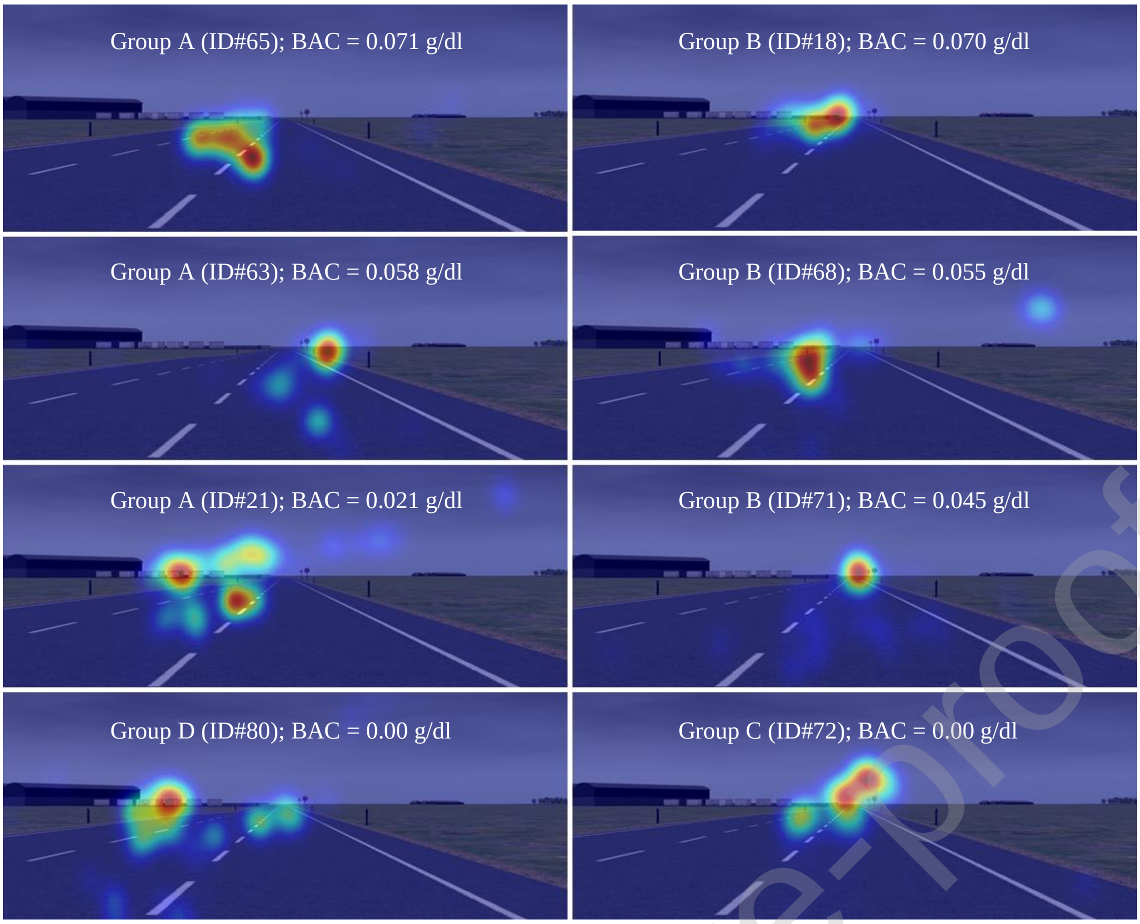


Figure 4. Heat-maps of eye gaze visualization recorded on some test drivers along straights. BAC data reported are the mean values of the two measured at 30 and 47 min (Note: the background image is the same for all drivers).

Along the straights, their visual attention was focused on the vanishing point (Salvucci and Gray, 2004) where the road markings converge. It is worth noting that the size of heat-maps is greater for those who present a null or very low BAC level (e.g., ID#21, ID#20, and ID#72). Conversely, drivers with higher BAC levels exhibited more concentrated heat-maps along the point of interests which are used to control the vehicle (Shiferaw *et al.*, 2019).

Results in Figure 5 show the heatmaps for gaze position along the curved section for other drivers with respect to those considered in Figure 4. Once again, the change in size of heat-maps depends on the BAC, similar to the findings observed along straights.

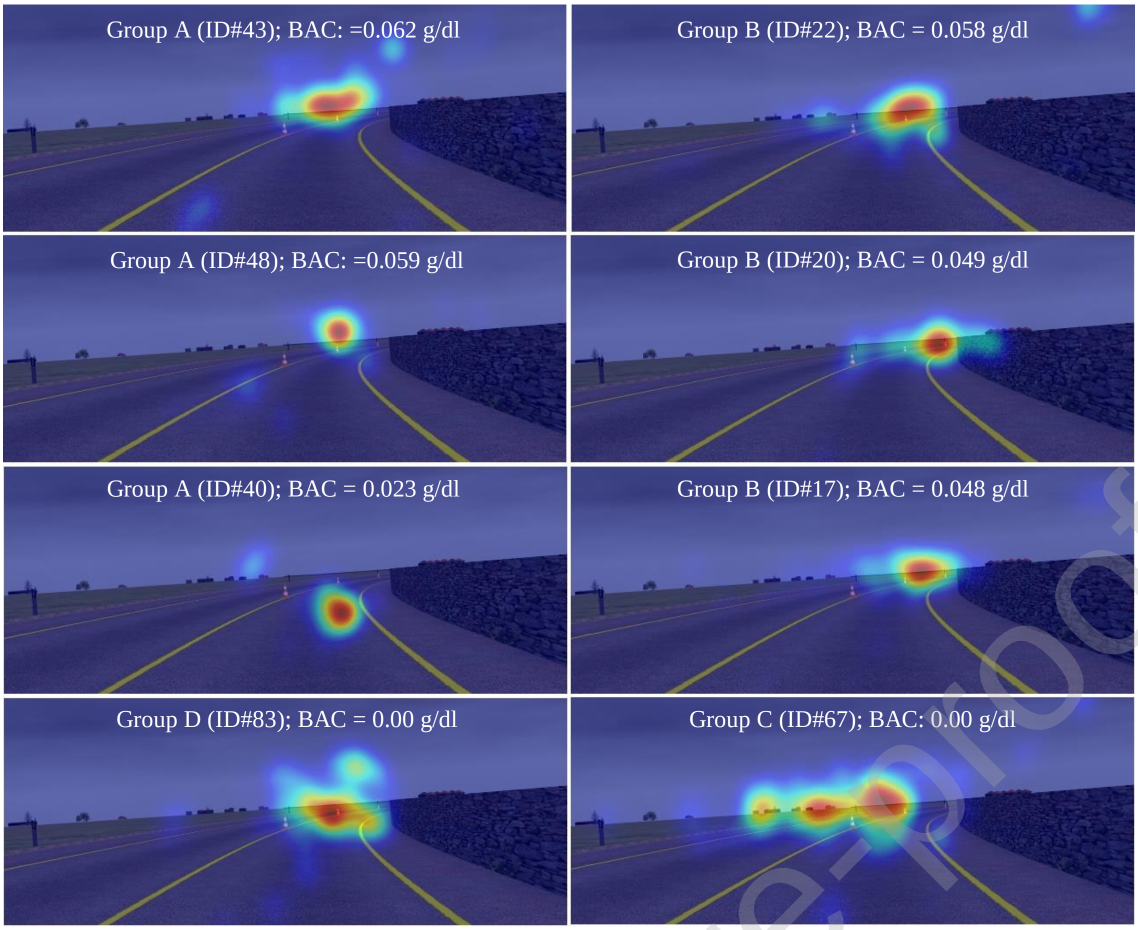


Figure 5. Heat-maps of eye gaze visualization recorded for selected test drivers along a rightward curve with sight limitations. BAC data reported is the mean value of the two values measured at 30 and 47 min (Note: the background image is the same for all drivers).

3.7 Auditory and visual cognitive reaction times

In the next two sections, results for the fitting of the *glm* are presented for the auditory and the visual tasks separately.

3.7.1 Auditory Task

No significant effect for Phase was observed ($\chi^2_{(1)} = 1.03$, $p = 0.3$), while men resulted faster than women in this task ($\chi^2_{(1)} = 84.03$, $p < 0.001$; $M_M = 204.77$, $SD_M = 43.54$; $M_w = 241.89$, $SD_w = 87.44$). At the same time, we observed an overall effect for Group ($\chi^2_{(3)} = 53.47$, $p < 0.001$). Post-hoc analysis showed a significant difference between the Control Group and each of the remaining groups (D vs. A: $z = -6.56$, $p < 0.001$; D vs. B: $z = -6.21$, $p < 0.001$; D vs. C: $z = -5.06$, $p < 0.001$). This result indicates that the Control Group participants respond faster than all the other groups to the auditory tasks ($M_D = 195.6$ ms, $SD_D = 52.9$ ms; $M_A = 229.7$ ms, $SD_A = 83.2$ ms; $M_B = 227.2$ ms, $SD_B = 57.3$ ms; $M_C = 220.6$ ms, $SD_C = 59.4$ ms).

Moreover, a significant interaction between Group and Phase was detected ($\chi^2_{(3)} = 13.37$, $p = 0.003$). Differences between groups were only observed before the driving simulation, with significant differences in the auditory reaction times between the Control Group and the other groups ($M_A = 238.6$ ms, $SD_A = 105.3$ ms; $M_B = 231.3$ ms, $SD_A = 54.2$ ms; $M_C = 224.5$ ms, $SD_C = 63.7$ ms; $M_D = 186.5$ ms, $SD_D = 36.0$ ms). Figure 6 displays the mean plot for the four groups and the two phases. No differences were observed in the final phase of the experiment, after the driving simulation task.

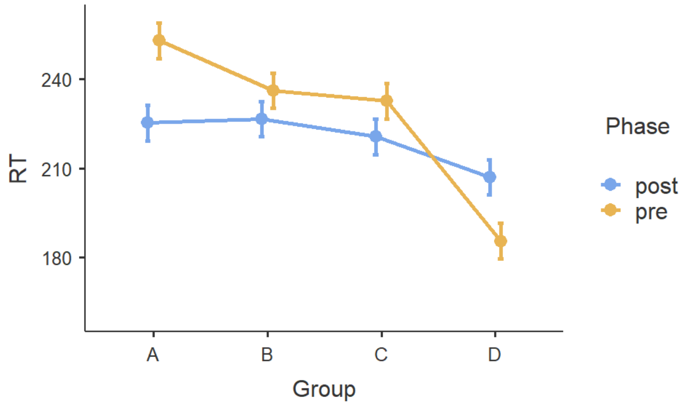


Figure 6. Interaction plot with error bars of auditory reaction times per group (A: natural wine; B: conventional wine; C: dealcoholized wine; D: control), divided per phase (pre- and post-drive tests)

3.7.2 Visual Task

Even in this task men resulted faster than women ($\chi^2_{(1)} = 6.70$, $p = 0.007$. $M_M = 332.4$ ms, $SD_M = 65.6$ ms; $M_F = 344.7$ ms, $SD_F = 71.1$ ms). An overall effect of the Group factor was observed ($\chi^2_{(3)} = 12.42$, $p = 0.006$): post-hoc analysis showed a significant difference between Group B (conventional wine) and Group C (dealcoholized wine; $z = -2.71$, $p = 0.03$) and between Group B and D ($z = -3.28$, $p = 0.005$).On the other hand, the performance of participants who drank natural wine (Group A) did not differ from that of the two groups who did not assume alcohol (A vs. C: $z = -0.79$, $p = 0.85$; A vs. D: $z = -1.36$, $p = 0.52$). Since even the performances of the two groups that consumed alcohol (either conventional or natural) did not significantly differ ($z = 1.92$, $p = 0.21$), it can be argued that the performance of Group A lies somewhere between that of the most compromised group (Group B) and that of the least compromised ones (Groups C and D). Figure 7 depicts the visual reaction times for the four groups ($M_A = 337.1$ ms, $SD_A = 56.0$ ms; $M_B = 349.8$ ms, $SD_A = 73.7$ ms; $M_C = 332.1$ ms, $SD_C = 72.3$ ms; $M_D = 328.6$ ms, $SD_D = 66.5$ ms).

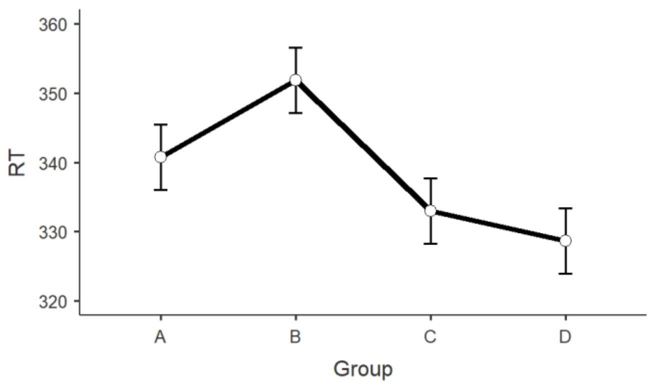


Figure 7. Plot with error bars of visual reaction times per Group (A: natural wine group; B: conventional wine group; C: dealcoholized wine group; D: control group).

4. CONCLUSIONS

In this study, two hypotheses were tested and both were only partially confirmed.

Regarding hypothesis (1), differences between groups in terms of longitudinal (speed) and transversal (SDLP) behaviours under ordinary road conditions along curves and straights were statistically not significant. Hence, the performances of drivers who operate under the legal BAC limit were similar to those of the drivers treated with the dealcoholized wine (placebo-controlled Group C) as well as the control Group D.

However, in the case of unusual events, some differences between groups were observed. When drivers encountered a truck parked across the right shoulder and part of the lane at the end of a right-hand curve with limited visibility, some differences became evident between wine treated groups (A, B, and C) and the Control Group, with the former overtaking the vehicle ahead from further away and at higher speeds than the Control Group. Conversely, when drivers encountered a continuous sequence of cones in the centreline, all them adapted appropriately with no significant differences between the groups in longitudinal and transversal behaviours. Finally, when a queue of cars first comes into view around a rightward curve with limited visibility, the braking reaction and the subsequent deceleration rate was similar between groups, with just one fast driver belonging to the conventional wine treated Group B crashing into a car ahead.

Differences in auditory reaction times were observed between the control condition (no wine) and the other three groups, indicating faster responses for participants in the control condition. This result shows the usefulness of the placebo condition (Group C) in the auditory task, albeit only before the driving simulation phase. In fact, after the driving task the control auditory performance is comparable to that for the other conditions.

With respect to hypothesis (2), although no significant differences were found under ordinary driving situations, observations on longitudinal behaviour and reaction time to stimuli revealed that the two alcoholised groups performed differently. The young participants in the commercial wine treated Group B had a significantly higher speed violation rate than the natural wine treated Group A independently of the road elements (i.e., straight, left- and rightward curves).

Interestingly, differences in overall visual reaction times were observed between the conventional wine group and the two alcohol-free groups (C and D), but not among conventional and natural wine treated groups. In this last case, a faster reactivity of the natural wine treated group (A) above the conventional treated one (Group B) was observed. This result shows the tendency of natural wine to be less conditioning on visual reaction times, an effect that merits greater study in future research to understand the role of different alcohol beverages on visual reaction levels while driving.

Finally, a marked difference was observed between males and females in both auditory and visual reaction times, with men being faster than women. This effect is also worthy of investigation and it is consistent with the results of previous studies into the influence of gender on reaction times (Yadav *et al.*, 2020, Jain *et al.* 2015, Shelton and Kumar 2010). Nonetheless, it must be treated with caution due to the small sample size for each group, and the unbalanced presence of drivers of different Gender within each group.

An additional contribution made by this experiment regards the analysis of gaze of the subgroups of drivers who did not wear correction devices for glasses and who were then subjected to an eye-tracking test. A qualitative analysis revealed that the higher the BAC the smaller the area of gaze distribution. This output reveals that higher BAC levels reduce attentional resources, so alcohol impaired drivers were induced to focus their attention only on the most important road elements that are necessary to guide the vehicle (i.e., the vanishing point along straights, tangent point along curves).

The results of this study require further evaluation to overcome possible limitations. Wines were selected from those available on the market, so uncontrolled factors may have had an influence on the drivers' behavioural outputs. Initial conditions under unusual effects were different for all the drivers (i.e., different initial speeds when they came face to face with the unusual event); initial conditions (i.e., speed) equal for all the drivers for each specific event could be tested in future experiments. Finally, the reduced sample size (which was due to the length of the whole protocol and to the limited number of tests that could be carried out in a single working day) affected the statistical power of some of the conclusions drawn. As a result, future research should find a way to increase the database size while preserving the reliability of the collected data.

AUTHOR CONTRIBUTIONS

The authors confirm contributions to the paper as follows: (i) study conception and design: M. Bassani, P. Passalacqua, L. Catani; (ii) data collection: P. Passalacqua, L. Catani, G. Bruno; (iii) analysis and interpretation of results: M. Bassani, P. Passalacqua, L. Catani, G. Bruno, A. Spoto; (iv) draft manuscript preparation: M. Bassani, L. Catani, G. Bruno, A. Spoto.

All authors reviewed the results and approved the final version of the manuscript.

Conflicts of Interest Statement

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Table 1. Main characteristics of the four groups of drivers involved in the experiment (M = mean value, SD = standard deviation, M = male, F = female, Y = yes, N = no)

Group		A	B	C	D
Age (y)	M	23.9	24.1	23.7	24.5
	SD	2.3	2.5	2.1	2.4
	Min.	20	20	20	22
	Max	27	28	27	30
Average distance driven by car per year [km/y]	M	2077	2495	2991	3627
	SD	2067	2955	3563	3981
Weight [kg]	M	68.0	69.7	63.9	70.0
	SD	10.6	6.9	10.1	13.5
Height [cm]	M	177	178	173	171
	SD	14.0	8.5	10.7	7.8
Body mass index, BMI [kg/m^2]	M	21.8	22.1	21.2	23.9
	SD	2.6	1.5	1.5	2.5
Volume of wine dispensed to participants [ml]	M	204	208	250	-
	SD	48	38	0	-
	Min.	137	155	250	-
	Max	271	255	250	-
Gender (number of participants)	M	7	7	7	7
	F	4	4	4	4
Glasses corrections (number of participants)	Y	4	4	2	4
	N	7	7	9	7

Table 2. Characteristics of the three wines, and subjective evaluation of alcohol content of test drivers with a score ranging from 1 to 5 (1 = absent; 2 = little; 3 = average; 4 = above average; 5 = excessive)

Wine type	Natural	Conventional	Dealcoholized
Actual alcoholic strength by volume (vol %)	13.2	13	0
Grapes	white	white	rosé
Volatile acidity (mEq/L)	20	4.5	N/A
Total sugar content (g/L)	<1.5	<1.5	21.7
Total dry extract (g/L)	25	18	N/A
Total sulphur dioxide (g/L)	0.02	0.11	N/A (but present)
Pesticides (*)	not present	present	N/A
Group of drivers	A	B	C
Alcohol content evaluation score, mean	2.86	2.82	2.32
Alcohol content evaluation score, st. deviation	0.78	0.72	0.64
Alcohol content evaluation score, min - max	2 - 4	2 - 4	1 - 3

Note: (*) Over 200 pesticides were analysed. Traces of iprovalicarb (45 μg/kg) and fenhexamid (120 μg/kg) were found in the conventional wine (Ferrero *et al.* 2019).

Table 3. Synthesis of speed violations committed by participants. Data indicates the percentage of records (with the acquisition frequency of 10 Hz) where drivers exceeded the speed limit.

Group	Straights (%)	Leftward curves (%)	Rightward curves (%)	Overall (%)
A	47.3	31.2	32.0	36.7
B	61.6	56.3	47.8	54.3
C	44.6	34.5	33.1	37.1
D	57.3	48.3	50.2	51.9