Gap-Acceptance and Risk-Taking by Young and Mature Drivers, Both Sober and Alcohol-Intoxicated, in a Simulated Driving Task

SY Leung
GA Starmer

The University of Sydney, Department of Pharmacology, Blackburn Building D06, Sydney, NSW 2006, Australia

Background
The ability to detect and estimate the relative speed of other vehicles, and consequently judge time-to-collision (TTC), is critical for the execution of a number of common traffic manoeuvres such as intersection crossing, merging and overtaking. Acute awareness and accurate judgements of time are therefore imperative for effective and safe driving, as even split seconds can differentiate an achievable manoeuvre from an imminent accident. It has been shown, however, that estimates of TTC are generally very inaccurate and manifest as underestimates of time (1-3). Such underestimation, while being regarded at face value as inaccuracy, also translates to added safety. That is, by judging the available time before a “collision” as being less than the actual time, drivers afford themselves a greater margin of safety in which to complete an intended manoeuvre, subsequently minimising the risk involved. The decision to engage in risky driving, however, is not always conscious and is often inadvertently the result of faulty choices of timing and speed, particularly with the young driver population (aged 17-21). This study thus aimed to examine the capacity of drivers to detect hazards, estimate the TTC of approaching vehicles, to perform complex overtaking manoeuvres in a simulated driving task, and to establish whether these abilities differed between young and mature drivers, in both sober and alcohol-intoxicated conditions.

Method
Sixteen (8 male and 8 female) healthy young volunteers (age range = 18-21 y; M = 20 y; SD = 0.9 y) and sixteen (10 male and 6 female) healthy mature volunteers (age range = 25-35 y; M = 28 y; SD = 2.7 y) were recruited for this study. Participants were paid for their involvement in the study and, as incentive to drive as safely as possible, were offered a monetary bonus for maintaining a clear experimental driving record across both sessions.

Using a mixed model design, participants attended two sessions on the driving simulator; once after administration of alcohol (target BAC = 0.08 g/100ml) and once after administration of a placebo beverage (target BAC = 0.00 g/100ml). Participants were given an orange juice beverage at the commencement of each experimental session. They were not informed which treatment they had received. For the alcohol treatment, alcohol (0.7 g/kg) was administered orally as a 1:3 solution of vodka (37.5 % alcohol by volume) diluted with orange juice, with the dose adjusted for gender according to the Widmark factor (4). The placebo beverage comprised of an equivalent amount of orange juice with 5 ml of vodka floated on the surface to provide olfactory masking (5). Participants were allowed 20 min to consume the beverage. The Alco Sensor III (St Louis, Mo.) was used to measure blood alcohol levels prior to the simulation test drive. The instrument employs a blood:breath factor of 2100:1, and readings were corrected to the true mean blood:breath factor of 2285:1 (6). Previous studies
have shown a correlation in excess of 97% between BACs determined from breath and directly from venous blood (7).

The involvement of hazard detection, speed perception, time perception, distance perception and risk perception in performing overtaking manoeuvres was monitored via performances on the fully-interactive STISIM Model 400 driving simulator. The simulator incorporated a full car cabin fitted with a steering wheel, dashboard speedometer, indicators, horn, accelerator and brake pedals. Computer-generated visual images were projected onto three screens resulting in a 135° field of view. The experimental tasks included:

(a) Detection time - Participants were required to press the horn as soon as they detected an approaching vehicle on the horizon. This task was designed to measure the level of hazard awareness of the participants at the different experimental times and conditions.

(b) TTC estimations - Participants were required to estimate when the bonnet of the approaching vehicle would have reached the bonnet of their own vehicle (i.e. when the vehicles would have passed each other), had the approaching vehicle not disappeared. At this point, participants were instructed to press the horn. This task provided a measure of the participants’ perception of time, and relative speed and distance.

(c) Overtaking manoeuvre - Participants were required to overtake a vehicle being followed against a succession of approaching vehicles, as soon as they deemed it to be safe. This task provided a measure of the participants’ perception of, and willingness to take, risks in the light of variable margins of safety.

Data were collected from the driving simulator at a rate of 20 Hz, which included the measurement parameters detection time, TTC, overtaking responses, lane deviation, speed deviation, and headway distances. These results were analysed by a mixed model ANOVA with planned orthogonal contrasts. The Type I error rate was set at $\alpha = 5\%$.

Results

Blood alcohol concentration
In the test condition, young participants attained a mean BAC of 0.059 g/100ml (SD = 0.013 g/100mll) at the time of testing (60 min after commencing drinking), while mature participants attained a mean BAC of 0.064 g/100ml (SD = 0.010 g/100ml). There was, however, no significant difference between the mean BACs of the two age groups ($t_{30} = 1.048, p > 0.05$). In the placebo condition, participants recorded a zero BAC at all times.

Detection time
Age was a significant factor in a driver’s ability to detect oncoming vehicles on straight and curved sections of road ($F_{(1,31)} = 8.92, p < 0.01$). As Figure 1 shows, averaged across the BAC conditions, mature participants were slower ($M_m = 4.38 \text{ s}, \ SE_m = 0.25 \text{ s}$) than young participants ($M_y = 3.65 \text{ s}, \ SE_y = 0.24 \text{ s}$) to detect the presence of approaching vehicles when on a curved road but, in contrast, they had marginally better mean detection times when on a straight road ($M_m = 0.77 \text{ s}, \ SE_m = 0.19 \text{ s}; \ M_y = 1.10 \text{ s}, \ SE_y = 0.19 \text{ s}$).

Alcohol consumption also significantly ($F_{(1,31)} = 4.94, p < 0.05$) influenced detection times such that, averaged across age, responses appeared not to be influenced by alcohol when participants were travelling on straight roads ($M_p = 0.94 \text{ s}, \ SE_p = 0.15 \text{ s}; \ M_a = 0.93 \text{ s}, \ SE_a = 0.15 \text{ s}$), but when negotiating a curve, detection times were slower in the alcohol-affected
condition ($M_a = 4.31 \text{ s}, \ SE_a = 0.19 \text{ s}$) than when in the placebo state ($M_p = 3.72 \text{ s}, \ SE_p = 0.23 \text{ s}$) (Figure 2).

![Figure 1: Mean ($\pm$ SE) detection times for young and mature participants, when travelling on a straight and curved section of road.](image1)

![Figure 2: Mean ($\pm$ SE) detection times in the alcohol and placebo conditions, when travelling on a straight and a curved section of road.](image2)

**Time-to-collision**

The TTC between the participant’s vehicle and the approaching vehicle, when it disappeared from view, was programmed at 3 s. No significant effect of BAC or age was found on mean TTC estimations.

**Overtaking task**

No significant effect of age or BAC was observed with the gap-acceptance results in the overtaking task. However, in considering the headway distances participants chose to adopt immediately before commencing the overtaking manoeuvre, a significant effect of age was found ($F_{(1,24)} = 13.15, \ p < 0.005$). That is, while headway distances did not vary between approaching vehicles speeds with young drivers ($M_{50} = 14.18 \text{ m}, \ SE_{50} = 1.14 \text{ m}; M_{90} = 14.15 \text{ m}, \ SE_{90} = 1.41 \text{ m}$), mature drivers maintained a more cautious distance from the vehicle being overtaken when the oncoming traffic was approaching at 90 km/h ($M_{90} = 16.05 \text{ m}, \ SE_{90} = 1.40 \text{ m}$) compared to approaching at 50 km/h ($M_{50} = 12.59 \text{ m}, \ SE_{50} = 1.13 \text{ m}$) (Figure 3).

The participant’s mean speed of travel in the opposing lane (while executing an overtaking manoeuvre) was also measured. Analysis of the mean speed results revealed that on average, across all variables, all participants exceeded the sign-posted speed limit of 100 km/h. A significant overall effect of age was found with mean speed ($F_{(1,31)} = 6.24, \ p < 0.05$). As Figure 4 shows, while executing an overtaking manoeuvre, mature drivers ($M_m = 106.05 \text{ km/h}, \ SE_m = 0.92 \text{ km/h}$) tended to speed to a greater extent than young drivers ($M_y = 102.86 \text{ km/h}, \ SE_y = 0.89 \text{ km/h}$).
Discussion

Detection time

In this study, mature drivers were recorded as having marginally faster vehicle detection times than young drivers on straight roads, and slower detection times on curves. This finding can be attributed to the variable visual function strategies adopted by drivers of different ages and experiences. That is, on a straight expanse of road, experienced drivers direct their line of sight to the horizon in anticipation of events ahead (8) and rely heavily on their peripheral vision (9). Novice drivers, on the other hand, focus their attention on the road and lane markings close to the bonnet of their vehicle, and are consequently less equipped to notice or deal with unexpected occurrences on the road ahead (9). On the other hand, given the relative complexity of curve negotiation to driving on straight roads, it is possible that young drivers demonstrate reduced confidence in their driving abilities when on curves and compensate by fixating longer on points ahead on the road in an attempt to preempt unexpected occurrences. Meanwhile, the gaze of experienced drivers switches frequently between points close-by and points further away (10), such that their attention is concentrated elsewhere when an approaching vehicle appears on a curve.

In everyday traffic, drivers are often confronted with two or more tasks concurrently, and are required to execute these tasks in an efficient and safe manner. In order to do so, however, it is essential that a driver possesses the ability to efficiently divide attention. The act of general driving, for example, has been described as a skilled divided attention task (11), whereby drivers scan the surroundings while simultaneously maintaining vehicle control. Many studies have investigated the ability of a driver to divide attention under the influence of alcohol, and have found progressive deterioration of performance with increasing BAC (12-14). It was postulated that alcohol had the effect of reducing the spare attentional capacity of the driver (13), thus rendering the task too demanding. The concept that impairment of performance is conditional upon task demands, even after moderate doses of alcohol (15), bears relevance to the outcomes of this experiment. That is, given the relative complexity of curve negotiation in comparison to driving on straight roads, it follows that the attentional demands are greater on curves and the ability to divide attention is depleted after the consumption of alcohol.
Moreover, it has also been shown that the usable field of view shrinks at the point of fixation (perceptual narrowing) with an increase in demand (16). Thus, after alcohol consumption, drivers are relegated to using a narrow and misrepresented field of view and deteriorated optical functions to process information about objects on the road. It is, therefore, not surprising that detection times after the consumption of alcohol were significantly worse, on curves rather than on straight sections of road.

**Time-to-collision**
It was hypothesized that alcohol would negatively affect TTC by further limiting a driver’s spare attentional capacity and consequently causing the driver to concentrate disproportionately on handling the vehicle. However, in this study, a significant effect of alcohol on TTC estimations was not observed. This result concurs with the findings of a study that examined the effects of alcohol on a driver’s perception of his/her own vehicle speed (17). The lack of statistical significance in that study was attributed to the relative ease of the task, such that the intoxicated participants retained sufficient spare attentional capacity to make speed judgments. It appears, therefore, that in the present study, alcohol did not exert an identifiable effect on time judgments because the task was not sufficiently complex and/or BACs were not sufficiently high to elicit impairment.

**Overtaking task**
Headway distance was found to interact significantly with age and approaching vehicle speed. This result suggests that mature and young participants perceived different degrees of risk in overtaking in the face of a slow vehicle (50 km/h) as opposed to a fast vehicle (90 km/h). The actual risk involved, however, was designed to be constant regardless of the approaching vehicle’s speed. Thus, theoretically, drivers should have approached all overtaking manoeuvres in the same manner. It would seem, however, that mature drivers were more casual in preparing to overtake the faster vehicles, presumably because these vehicles emerged from further (although same time) away. This finding is consistent with the literature, whereby younger drivers judged time more accurately than mature drivers (18, 19). It would thus appear that, unlike their younger counterparts, mature participants made overtaking decisions based largely on the relative distance of the approaching vehicle, rather than on relative speed and time.

Age was also found to have an overall influence on the participant’s mean speed when overtaking such that mature participants adopted faster speeds than young participants. It was interesting to note, however, that both young and mature drivers found it necessary to overtake at speeds in excess of the 100 km/h sign-posted speed limit for the area, even though they were following a vehicle travelling at only 80 km/h. The significance of such information has implications for risk-involvement. That is, although experienced drivers tended to hasten the manoeuvre by speeding excessively, they also demonstrated more caution by making it a priority to return to their own lane as quickly as possible. On the other hand, the inexperienced drivers spent relatively more time in the opposing lane and thus engaged in riskier behaviour. These results reinforce the belief that younger and less experienced drivers, whether consciously or not, take more risks when driving (20, 21).

**Conclusion**
It is evident from the results of this study that differences exist in driver behaviour of young and mature individuals. In most cases, young drivers demonstrated an increased tendency to engage in risky tactics compared to mature drivers. However, it is still unclear whether the
increased aggression and risk-taking exhibited by young drivers is a result of a lack of driving skills, poor consciousness of a potentially hazardous situation, or a combination of both factors. On the other hand, mature drivers demonstrated deficits in their ability to detect the presence of potential hazards on curved sections of road, showed relative inaccuracy in judgments of arrival-time, and engaged in excessive speeding while overtaking in an attempt to remove themselves from risky situations. Further research into the behaviours and attitudes of young, middle-aged and elderly drivers in high and low-risk situations is therefore necessary to verify the appropriate focus for education. In addition, experimental scenarios in which participants receive immediate feedback about their performance would assist the driver in recognizing a potentially dangerous situation and, at the same time, instil in the driver an awareness of their capabilities and limitations on the road.

References


