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Hazard perception in novice and experienced drivers: the effects of sleepiness.

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Abstract

One driver skill that has been found to correlate with crash risk is hazard perception ability. The purpose of this study was to investigate how hazard perception latencies change between high and low sleepiness for a high risk group (novice drivers) and a lower risk group (experienced drivers). Thirty-two novice drivers (aged 17-24 years) and thirty experienced drivers (aged 28-36) completed a validated video-based hazard perception test, in which participants were asked to anticipate genuine traffic conflicts in footage filmed from the driver's perspective, with separate groups tested at either 10am (lower sleepiness) or at 3am (higher sleepiness). We found a significant interaction between sleepiness and experience, indicating that the hazard perception skills of the more experienced drivers were relatively unaffected by mild increases in sleepiness while the inexperienced drivers were significantly slowed. The findings suggest that the disproportionate sleepiness-related accident involvement of young, inexperienced drivers could be partly due to a slowing of their ability to anticipate traffic hazards.

Keywords: driving, hazard perception skill, age, expertise, sleepiness

1. Introduction

Sleepiness is regarded as a significant contributor to road crashes (Connor et al., 2002; Connor, Whitlock, Norton, & Jackson, 2001; Philip & Åkerstedt, 2006), with most estimates suggesting that at least 20% of all vehicle accidents are related to sleepiness (Garbarino, Nobili, Beelke, De Carli, & Ferrillo, 2001; Knipling & Wang, 1994; Lyznicki, Doege, Davis, & Williams, 1998; Philip, 2001). Further, sleepiness is a good predictor of crash risk (Åkerstedt, Connor, Gray, & Kecklund, 2008). Sleepiness-related crashes are also likely to be more severe, and more often fatal, than other types of crash (Akerstedt, 2000; Åkerstedt, 2000; Bunn, Slavova, Struttmann, & Browning, 2005). The mechanisms of sleepiness-related crashes can include deficits in attention, vigilance and information processing while drowsy, as well as complete performance failure during frank sleep episodes (Boyle, Tippin, Paul, & Rizzo, 2007; Durmer & Dinges, 2005; Moller, Kayumov, Bulmash, Nhan, & Shapiro, 2006; Van Dongen & Dinges, 2003). Note that self-reported sleepiness while driving corresponds closely to EEG and other objective measures of sleepiness (Kaida et al., 2006), as well as with both simulated and real driving performance (Åkerstedt et al., 2005; Philip et al., 2005).

Young adults (generally defined in this context as teenaged or early/mid-20s) are disproportionately involved in all car crashes (Williams, 2003) but are more likely to be involved in both night-time (Smith, Armstrong, Steinhardt, & Haworth, 2008) and sleepiness-related crashes than older adults (‘older’ in this context is generally defined as mid/late-20s and upwards) (Horne & Reyner, 1995; Knipling & Wang, 1994; Lyznicki et al., 1998; Maycock, 1996). We have previously reported that young drivers drive more frequently at times that they felt themselves to be sleepy (Smith, Carrington, & Trinder, 2005) and a number of social and demographic factors are implicated in this increased prevalence.

Another type of factor that differentiates younger novice drivers from more experienced older drivers is driving skill (Crundall, Underwood, & Chapman, 2002; Underwood, Crundall, & Chapman, 2002). In particular, one driving skill, hazard perception, has been associated both with novice/experienced differences (Horswill et al., 2008; McKenna & Crick, 1991; Milech, Glencross, & Hartley, 1989; Wallis & Horswill, 2007) and crash risk (Horswill & McKenna, 2004; Quimby, Maycock, Carter, Dixon, & Wall, 1986). Hazard perception requires scanning of the road environment, fixation on appropriate stimuli (Mayhew & Simpson, 1995), and a ‘holistic’ interpretation of the salience of hazards (Milech, Glencross, & Hartley, 1989). Hazard perception is therefore a multi-component cognitive skill that can improve with experience (Deery, 1999). Of all the identified components of driving skill, only hazard perception is reliably related to crash risk (see Horswill & McKenna, 2004, for a review). A number of jurisdictions now mandate a hazard perception test as part of licensing for novice drivers (e.g. four Australian states and the U.K.). Simulator-based assessment of the impact of sleepiness on driving typically focus on parameters such as speed, lateral position, line crossing or steering wheel angle. The impact of sleepiness on hazard perception skill is not known.

Adam, Rétey, Khatami, and Landolt (2006) found evidence that younger adults (21-31 years) were less resistant to the effects of sleep deprivation than older adults (61-70 years); however, the mechanisms of this resilience are unknown. There is a natural confound between age and driving experience, such that older drivers are typically more experienced than younger drivers and matching samples on either factor is fraught (Groeger, 2006). One possible mechanism is that older drivers are more experienced and more skilled in dealing with the effects of sleepiness. If this is the case then we might expect the driving performance of experienced drivers to be less affected by sleepiness than less experienced drivers. In the present project, our aim was to determine whether novice drivers' performance on a video-based hazard perception test was more affected by sleepiness compared with a more group of more experienced drivers.

2. Method

2.1 Participants

Thirty two novice drivers (mean age 19.88 years, *SD* 1.94, range 17-24, mean driving experience 1.65 years, *SD* 0.80) with up to 3 years post-test driving experience and 30 experienced drivers (mean age 31.78 years, *SD* 2.35, range 28-36, mean driving experience 14.41 years, *SD* 2.65) with a minimum of 10 years post-test driving experience were recruited via advertisements from within a University population. There were 33 females and 27 males overall (with 2 participants not reporting gender) and no significant difference in gender ratio between the two groups. All participants completed the Epworth Sleepiness Scale (Johns, 1991) and the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), and there was no evidence for the presence of any sleep disorders associated with excessive daytime sleepiness. All participants completed a sleep diary for one week prior to testing. Habitual sleep times for all participants were before 12 midnight. There were no significant differences between the novice and experienced drivers in hours sleep per night (novices: M = 7.65 hours, SD = 1.04; experienced: M = 7.45 hours, SD = 1.08; $t(58)$ = .73, p = .466), Epworth Sleepiness Scale score (novices: M = 8.33, SD = 2.97; experienced: M = 7.53, SD = 3.71; $t(58)$ = .92, p = .36), or Pittsburgh Sleep Quality Index composite score (novices: M = 5.33, SD = 1.99; experienced: M = 4.27, SD = 2.74; $t(58)$ = 1.73, p = .090). The study was approved by the Human Research Ethics Committee of The University of Queensland and participants were paid 80 AUD.

2.2 Design

The study was run as an independent samples design with two factors. The first factor was group (with two levels: novice or experienced), and the second factor was time of testing (with two levels: 10am and 3am).

2.3 Materials

2.3.1 Hazard perception test development and validation. We developed a new hazard perception test for this study, based on a method developed by McGowan and Banbury (2004). In previous hazard perception tests, participants typically press a response button or move a lever to indicate the presence of a hazard (Horswill & McKenna, 2004). One weakness of this approach is that there may be more than one potential hazard on screen at any one time, and the response can therefore be ambiguous. In McGowan and Banbury's measure, participants were asked to click on the hazard using a computer mouse. That is, participants had to identify the location, as well as the timing, of each hazard, in an attempt to reduce error variance.

The validity of the test was assessed using the approach of McKenna and Crick (1991), in which it was determined whether the test can differentiate between high crash risk drivers (novices) and lower crash risk drivers (experienced drivers). This is not a trivial step: many previous hazard perception tests have failed to yield differences in response latency between novices and experienced drivers (Crundall, Chapman, Phelps, & Underwood, 2003; Sagberg & Bjornskau, 2006).

Thirty novice (up to 3 years post-license experience) and 27 experienced drivers (at least 10 years post-license experience) were recruited via the School of Psychology Participant Pool or via acquaintances of the experimenters. The novices were, on average, 19.13 years of age (SD 3.20) and had 1.22 years (SD .45) post-test experience. They drove 13,425 kilometres per year (SD 26,825). The experienced group had a mean age of 48.15 years (SD 9.02) and had 29.63 years (SD 8.20) post-test experience. They drove 15,657 kilometres per year (SD 12,917). Twenty eight participants were female and 29 were male (the gender difference between the groups was not significant).

The video stimuli for the hazard perception test were created by filming genuine traffic scenes from the perspective of the driver (a car, with a forward-facing camera, was driven in normal traffic in daylight). Any potential traffic conflicts (situations that might result in the camera car having to brake or steer to avoid a collision) that occurred were extracted for use in the test. These were edited into a twenty minute video (note that the individual clips making up the video could have one conflict, multiple conflicts, or no conflicts). Examples of potential traffic conflicts included pedestrians stepping out into the road ahead, cars in front braking due to a blockage further ahead, and vehicles pulling out of side streets. Response latencies to potential traffic conflicts were measured using custom-developed software that recorded the location and timing of mouse clicks, and determined whether these responses were to the potential traffic conflicts. Participants' earliest responses to each potential traffic conflict was measured and converted into a reaction time. The overall hazard perception score was the mean response latency across all potential traffic conflicts. If a participant missed a potential traffic conflict, the mean reaction time for that event was substituted (this strategy was chosen as it favoured the null hypothesis though note that alternative strategies yielded the same pattern of results).

Participants in the initial validation study completed the hazard perception test in small groups in a computer laboratory, viewing the stimuli on 15 inch CRT monitors. They were instructed to use the computer mouse to "click on the road user(s) that you believe may be involved in a future traffic conflict with your vehicle", where a traffic conflict was defined as "situations in which a collision or near miss between you and another road user might occur, unless you took some type of evasive action (braking or steering)".

Cronbach's Alpha for the test was .90, indicating good reliability. The novice drivers were significantly slower (M = 3.40 seconds, SD = 0.55) to respond to potential traffic conflicts than the experienced drivers (M = 3.03 seconds, SD = 0.56), t(55) = 2.53, p = .014.

To give the option of following up with a repeated measures design (which, in the event, turned out to be problematic and was dropped – see Procedure for further details), two alternative forms of the hazard perception test were generated; the test was split into two halves and new footage was added to each half to make each version to approximately the same length (20 minutes). The first version had 46 potential traffic conflicts and the second version had 43. The second test was standardized to have the same mean and standard deviation as the first test. The alternate-forms reliability of the two versions of the test was tested to ensure they were equivalent. Twenty two participants (16 females and 5 males, with 1 participant who did not report their gender), who had a mean age of 22.36 years (SD = 3.43), completed both versions of the hazard perception test in a counterbalanced order. The correlation between the two versions was significant (r = .83, n = 22, p < .001) indicating that the alternate forms were equivalent.

2.3.2 Stanford Sleepiness Scale. Participants rated their level of alertness using the Stanford Sleepiness Scale (Hoddes, Dement, & Zarcone, 1972), on a seven-point Likert scale with 1 = ‘feeling active, vital, alert or wide awake’ through to 7 = ‘no longer fighting sleep, sleep onset soon, having dream-like thoughts’.

2.3.3 Simple Spatial Reaction Time Test. Participants completed a measure of simple spatial reaction time, designed to have an analogous response mode to the hazard perception test, in which they were asked to use the computer mouse to click on 33 high contrast rectangles of varying sizes that appeared consecutively on the computer screen at random intervals. The overall score was the mean of participants’ response times.

2.4 Procedure

Participants assigned to the high sleepiness group were asked to attend the laboratory at 12 midnight for the 3 am testing session while participants assigned to the low sleepiness group were asked to attend the laboratory at 10am. Both groups were asked to abstain from caffeine or other stimulants for at least five hours prior to testing. Participants were tested in groups of up to 6 people. They completed the Stanford Sleepiness Scale, and then were randomly assigned to complete one of the two alternate versions of the hazard perception test. The alternate forms of the hazard perception test were used because, as already noted, participants were scheduled to return to the laboratory for a second hazard perception testing session as an attempt to increase power by treating the day/night condition as a repeated measures rather than between-subjects variable, and we wished to counterbalance the tests. In the event, the repeated measures data was unpublishable for two reasons: (1) we asked some participants (53%) to complete a new test at the end of the session to collect pilot data (a change detection task involving hazards) but this was a misjudgement as subsequent data has indicated that this test substantially influenced subsequent attempts at the hazard perception test; (2) we discovered a problem of asymmetric transfer in the repeated-measures design, violating a key assumption of repeated-measures design (see Smith, Horswill, Chambers, & Wetton, in press, for full details of this analysis). The reaction times for the second alternate form of the hazard perception test were converted into a z-score and then re-standardised to have the same mean and standard deviation of the first alternate form of the hazard perception test.

Note that all hazard perception scenes shown were filmed in daylight, regardless of the time of testing. This was to avoid confounds between participant sleepiness and the properties of the stimuli. After completing the hazard perception test, participants completed the simple spatial reaction time task.

3. RESULTS

3.1 Time of testing and sleepiness manipulation check

Participants reported that they felt significantly more sleepy during the night session (Stanford Sleepiness Scale mean score 4.32, *SD* 0.99) than during the day session (Stanford Sleepiness Scale mean score 2.22, *SD* 1.16), $t(64) = 12.20$, $p < .001$, indicating that time-of-testing provided an appropriate manipulation of sleepiness. The 3am testing time represented an extension of wake of at least 3 hours for all participants. To determine whether there were any novice/experienced differences in sleepiness, we ran a 2x2 Analysis of Variance with Stanford Sleepiness Scale rating as the dependent variable and time of testing and novice/experienced group as the independent variables. There was no main effect for experience, $F(1,58) = .23$, $p = .633$, and no interaction between experience and time of testing, $F(1,58) = .23$, $p = .633$ (note that the effect sizes were indeed identical for these two effects).

3.2 The effect of time of testing and group on hazard perception response latencies

We performed an Analysis of Variance with hazard perception response time as the dependent variable and time of testing and group (novice/experienced) as independent variables (see Figure 1). There was a main effect of group, $F(1,58) = 24.32$, $p < .001$, with experienced drivers responding to the potential traffic conflicts faster than novices and a significant interaction between group and time of testing, $F(1,58) = 4.58$, $p = .037$. However, there was no significant time of testing main effect. Follow up analyses revealed that novices were significantly slower at night, $t(30) = -2.19$, $p = .036$, but there was no day/night difference for the experienced drivers $t(28) = .75$, $p = .463$.

While the hazard perception test was designed as a reaction time measure, we also measured the proportion of hazards that participants responded to. There was a main effect of group, $F(1,58) = 7.58$, $p = .008$, such that experienced drivers responded to a higher proportion of hazards (*M* 85.19%, *SD* 9.00%) than the novice group (*M* 76.89%, *SD* 13.79%). There was no significant time of testing or group/time of testing interaction. Note that the group differences in hit rate would not have influenced group differences in hazard perception response times because of the neutral strategy used to replace missing response times (if participants did not respond to a hazard they were assigned the mean response time of all participants who did respond).

We repeated the Analysis of Variance with simple spatial reaction time as the dependent variable. There was a main effect of group, $F(1,58) = 7.64$, $p = .008$, but in the opposite direction to hazard perception response time (the older experienced drivers were slower than the younger novice drivers). There was no significant effect of time of testing and no significant time of testing x group interaction for simple spatial reaction time. This indicates that the hazard perception findings are unlikely to be due to differences in simple reaction time or response mode. Note that, consistent with this, introducing simple spatial reaction time as a covariate into the Analysis of Variance with hazard perception response time as the dependent variable made no difference to the pattern of results.

4. Discussion

Novice drivers were significantly slower at anticipating traffic conflicts when tested at night compared with during the day time, in contrast to experienced drivers who were not significantly slowed. The mean difference in hazard response time (0.38 seconds) found between high and low sleepiness levels for the novice drivers is equivalent to 6.33 metres of travel at 60kph. This suggests that mild sleepiness has safety consequences for young novice drivers.

While a video-based driving test cannot capture all the complexity of real driving, the general finding of slower hazard perception in the less experienced drivers, during both day and night, is also consistent with previous work and can be regarded as evidence for the validity of our hazard perception test (Horswill et al., 2008; McKenna & Crick, 1991; Wallis & Horswill, 2007). This novice/experienced driver difference is consistent with both differences in crash risk between younger and older drivers (Williams, 1993) and the relationship between hazard perception latency and crash risk (Quimby et al., 1986;

McKenna & Horswill, 1999). As previously noted, there is a natural confound between age and experience inherent in the differences between these two groups. While the difference in crash risk between these two groups is likely to be both a result of inexperience and increased risk-taking propensity in the young novice group, previous factor analysis work has indicated that risk-taking propensity and hazard perception ability are independent of one another (McKenna & Horswill, 1997; Horswill & Helman, 2003) and hence it is likely that the differences in hazard perception found are a consequence of experience rather than age-related risk taking.

Attention and vigilance are influenced by sleep and circadian-mediated arousal mechanisms (Dinges et al., 1997; Froberg, 1977; Kraemer et al., 2000; Monk et al., 1997). While hazard perception requires attention and vigilance (McKenna & Horswill, 1999), these components did not result in increased hazard perception latency in the older, experienced drivers despite this group being significantly slower in the simple spatial reaction time task than the younger, less experienced drivers. The results should not be taken to indicate that more experienced drivers are protected from sleepiness-related impairment by their driving skills. The degree of sleep deprivation associated with the 3am testing was minor, although easily achievable in everyday life, and the test duration was relatively short. The degree of sleepiness-related impairment induced by the 3am testing strategy would be likely to vary from individual to individual, depending on their habitual sleep and wake times. However, the time-of-day manipulation increased the wake period for each participant by at least 3 hours, and this manipulation was supported by the participant's self-reported sleepiness scores. The validity of self-reported sleepiness as an index of sleepiness has previously been demonstrated (Åkerstedt et al., 2005; Connor et al., 2002) via strong associations with both EEG measures and severe and fatal road crash involvement. Individual estimates of the circadian nadir for each participant, or an intervention to produce chronic partial sleep deprivation, could produce a more effective manipulation of sleepiness. It remains possible that increased sleepiness and extended performance could produce impairment in hazard perception in experienced drivers.

Two intervention strategies are suggested by the current data. The first is to take steps to improve hazard perception skill in young, inexperienced drivers. Hazard perception skill can be improved with specific training (McKenna & Crick, 1997; McKenna, Horswill, & Alexander, 2006) and a number of regulators have developed tests to assess and improve hazard perception at the provisional stage of licensing (Senserrick, 2007). The second strategy is to reduce sleepiness in young, inexperienced drivers (Williams, 2003). Sleep education to improve knowledge about the mechanisms and impact of sleepiness has been tested in secondary schools (Cortesi, Giannotti, Sebastiani, Bruni, & Ottaviano, 2004), and a model for effecting behaviour change in this domain has been proposed (Senserrick, 2006). Night-time driving restrictions have been introduced in New Zealand during the provisional years of licensure and there is evidence for effectiveness of this strategy (Begg & Stephenson, 2003; Begg, Stephenson, Alsop, & Langley, 2001).

This study is the first to investigate the impact of sleepiness and driver experience on hazard perception and suggests that novice drivers are particularly vulnerable to a slowing of hazard perception responses under conditions of mild sleepiness.

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List of Figures

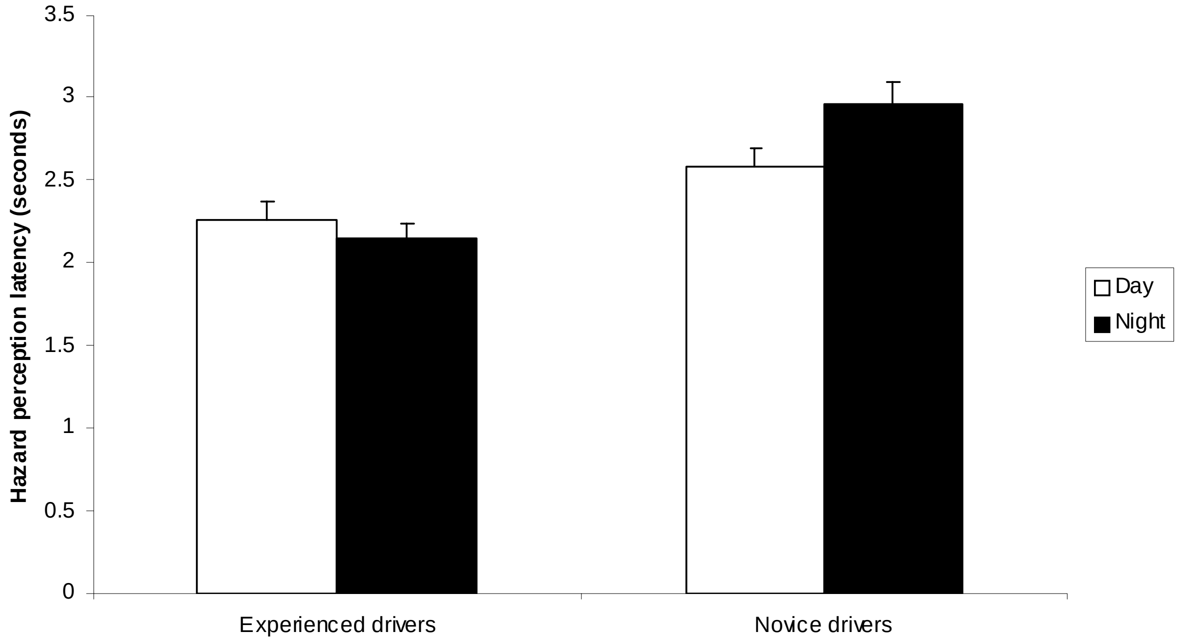

Figure 1. Hazard perception response times (Mean and Standard Error of the Mean)