Accident Analysis and Prevention 41 (2009) 445–452

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Video-based road commentary training improves hazard perception of young drivers in a dual task

Robert B. Isler[a,*], Nicola J. Starkey[a], Amy R. Williamson[b]

[a] Traffic and Road Safety Research Group (TARS), University of Waikato, Psychology Department, Private Bag 3105, Hamilton, New Zealand
[b] Monash University Accident Research Centre, Victoria 3800, Australia

ARTICLE INFO

Article history:
Received 20 August 2008
Received in revised form 3 December 2008
Accepted 27 December 2008

Keywords:
Driving behaviour
Hazard perception
Road commentary
Young drivers
Dual task

ABSTRACT

This study used a video-based hazard perception dual task to compare the hazard perception skills of young drivers with middle aged, more experienced drivers and to determine if these skills can be improved with video-based road commentary training. The primary task required the participants to detect and verbally identify immediate hazard on video-based traffic scenarios while concurrently performing a secondary tracking task, simulating the steering of real driving. The results showed that the young drivers perceived fewer immediate hazards (mean = 75.2%, n = 24, 19 females) than the more experienced drivers (mean = 87.5%, n = 8, all females), and had longer hazard perception times, but performed better in the secondary tracking task. After the road commentary training, the mean percentage of hazards detected and identified by the young drivers improved to the level of the experienced drivers and was significantly higher than that of an age and driving experience matched control group. The results will be discussed in the context of psychological theories of hazard perception and in relation to road commentary as an evidence-based training intervention that seems to improve many aspects of unsafe driving behaviour in young drivers.

1. Introduction

There is a plethora of research evidence emphasising the increased crash risk of young novice drivers in their first months of solo driving in comparison to any other driving period. The situation in New Zealand is particularly telling, with young drivers being relatively safe during the supervised driving period (normally six months) of the Graduated Driver Licence system (GDLS), but as soon as they drive independently on their restricted license (often as early as 15½ years), their crash risk increases dramatically to about 8 times the risk level of the supervised period. However, it then decreases by about 50% in the following six months (Lewis-Evans and Lukkien, 2007). This might reflect a strong interaction between age and risk factors related to driving experience, both of which are compounded in New Zealand through an early licensing age of 15 years (learner's license).

There is much evidence to suggest that young novice drivers learn basic car handling skills and traffic laws quickly (e.g., Hall and West, 1996) but need much longer to acquire the complex, higher-order perceptual and cognitive skills (Deery, 1999), in particular the skills of hazard perception (Horswill and McKenna, 2004), visual search and attention (Underwood, 2007) and calibration (Kuiken and Twisk, 2001). However, it seems that these skills can be trained effectively and safely off-road (Chapman et al., 2002; Crick and McKenna, 1991; Engström et al., 2003; McKenna et al., 2006; Fisher et al., 2006; Senserrick, 2006).

A particularly important higher-order driving skill is hazard perception, which according to Horswill and McKenna (2004) seems to be the only component of driving skills that has been found to be related to accident involvement. Hazard perception has been defined as being able to 'read the road' (Horswill and McKenna, 2004) or more comprehensively as 'situation awareness' (see also Endsley, 1995) in relation to potentially dangerous situations in the traffic environment (Horswill and McKenna, 2004). Hazard perception skills involve having a continuous and always changing composite representation of current traffic situations. Good hazard perception skills result in a holistic assessment of risk, which combines information from multiple sources, 360° around the car. This allows drivers to anticipate and predict traffic constellations in the near future which will then enable them to plan appropriate courses of action.

It seems plausible, that good hazard perception skills draw substantially on cognitive resources as they are considered to be conscious and effortful processes and are unlikely to become automated (Horswill and McKenna, 2004). In support of this, McKenna and Farrand (1999) found that a secondary workload (a random letter generation task) heavily interfered with hazard perception in novice as well as in experienced drivers. In fact, the interference of

* Corresponding author. Tel.: +64 7 838 4466x8401.
E-mail address: r.isler@waikato.ac.nz (R.B. Isler).

0001-4575/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.aap.2008.12.016

the additional workload can reduce the hazard perceptions skills of experienced drivers to a level much lower than that of novice drivers (McKenna and Farrand, 1999), indicating that even after many years of driving experience, these skills place high demands on conscious attentional resources. There is much evidence from a number of studies which clearly indicate that more experienced drivers have shorter hazard perception reaction times and respond more frequently to hazards in comparison to novice drivers. However, the reason for this is still a subject of debate (Horswill and McKenna, 2004, for a review).

One explanation for any performance discrepancy between drivers of different ages could be related to less well developed frontal lobe executive functions of the brain (such as goal directed behaviour, visual search, impulse control, divided attention and working memory) in teenage drivers (Lenroot and Giedd, 2006; Dahl and Spear, 2004; Keating, 2007; Isler et al., 2008). For example, those executive functions which control voluntary eye movements may not yet be fully developed in young drivers. Evidence for this comes from studies such as Munoz et al. (1998) and Klein et al. (2005), who found age related performance of young people in voluntary saccadic eye movement tasks which was attributed to delayed maturation of their frontal lobes. This could suggest that young drivers may be disadvantaged in their search behaviour by not being able to move their eyes fast and frequently enough to fixate on all important traffic information. Indeed, research indicates that young and novice drivers fixate longer on irrelevant traffic information and move their eyes less frequently (Mourant and Rockwell, 1972). However, the inefficient eye scanning behaviour of novice drivers may also stem from the fact that they have not encountered a sufficient number of hazardous situations, to allow them to draw on a broad knowledge base, or a mental map that could assist them in determining what to look out for in different traffic situations (see also Horswill and McKenna, 2004; Underwood, 2007).

Underwood (2007) suggested that in novice drivers, the steering task, including changing gears and speed control has not been automated enough to free up the attentional capacities required to enable effective road situation awareness. Other studies have suggested that young, less experienced drivers simply have a response bias when it comes to detecting hazards. A recent study by Wallis and Horswill (2007), using fuzzy signal detection theory, found that trained and experienced drivers applied more liberal criteria and responded to hazards more often and had faster hazard perception reaction times than the young, less experienced drivers. However, replicating the findings of Farrand and McKenna (2001), they found no difference in their ability to discriminate the traffic scenes according to the level of hazardousness. This indicates that compared to experienced drivers, young drivers respond more slowly to hazards (particularly to less hazardous ones) even though they rated the anticipatory cues of the level of the hazards equally. Or in simpler terms, it could indicate that the novice drivers are simply less willing to label traffic scenarios as hazardous and therefore do not appreciate the need to respond, as quickly as experienced drivers do. However, as Horswill and McKenna (2004) pointed out, there is indirect evidence indicating that a response bias alone cannot explain the slower hazard perception reaction time. For example, as outlined earlier, experienced drivers seem to engage in more efficient and effective search of hazards and this should allow them to detect hazards earlier and to respond faster. Also, to date no relationship between drivers' rating of the level of risk in traffic scenarios and their hazard perception reaction time has been found (Horswill and McKenna, 2004), which seems to indicate that perceived risk does not necessarily affect the response bias in hazard perception.

Taking this research evidence together, it seems reasonable to propose that while novice drivers might be able to rate hazardous scenarios in the same way as experienced drivers, they do not experience the same urgency to search and respond to them in real driving as the experienced drivers. Aside from having insufficient driving experience to develop efficient road search strategies (see Underwood, 2007), it could be that novice drivers simply consider the steering task as a higher priority than searching for hazards, thereby explaining some of the unsafe response bias outlined above. There is some evidence for this suggestion as research using secondary tasks indicates that drivers do prioritise different workloads which could then impact on their driving performance. For example, Cnossen et al. (2004) found that drivers attended to a navigational secondary task rather than to their performance on a memory task indicating that drivers prioritise their task goals. This reinforces the finding of Farrand and McKenna (2001), cited in Horswill and McKenna (2004), that instructions on how to perform the hazard perception task influenced the rate of responding, indicating that any response bias in hazard perception could possibly be subject to relative simple behavioural modification.

Most hazard perception studies used video-based traffic scenarios, filmed from the perspective of a driver with the participants required to respond whenever they detected a hazard (Horswill and McKenna, 2004, for a review). These tests allow the drivers to focus their full visual attention on finding hazards in the front view traffic scene and also provide unrestricted visual search, which is something real driving does not permit. During on-road tasks, drivers need to devote some of their visual search and attention workload to inform the steering task to keep track of the road and to maintain appropriate lateral displacement. For example, when approaching a curve, up to 30% of the eye fixations are located at the tangent point (Laya, 1991) and once the driver has entered the curve the tangent point becomes the main focus of attention, with fixations increasing from 30 to up to 80% (Land and Lee, 1994). Also drivers need to frequently check the rear view mirrors for possible hazards as well as gather information from the different displays on the dashboard.

The current study used a hazard perception dual task paradigm, which included video-based traffic simulations with greater external validity than the standard hazard perception tests. The primary task was detecting and identifying hazardous traffic scenarios in front of the car and also in the three rear view mirrors. The secondary task required the participants to keep track of a moving target that was superimposed over the front view traffic scenarios. The objective of this study was firstly to compare the hazard perception skills of young drivers with those of experienced drivers using this demanding dual task that may prompt the participants to prioritise their workload between the primary and secondary tasks. Secondly, we wanted to assess the effect of brief video-based road commentary training trials on participants' hazard perception performance. Road commentary training has been found to decrease hazard perception reaction times both when performed during real driving (Mills et al., 1998) and while watching video-based traffic scenarios (cited in Horswill and McKenna, 2004). The training requires the participants either to provide a verbal running commentary which points out any hazards they can detect and how they would respond to them, or to listen to an expert providing the commentary for them. This training technique seems to encourage drivers to actively search for hazards and may improve their situation awareness and lead to a better appreciation of the risks involved (McKenna et al., 2006).

2. Method

2.1. Participants

Thirty-two New Zealand drivers volunteered for this study. Twenty-four of the recruited participants (19 females and 5 males) were 18 or 19 years old. They were considered young, less experienced drivers, holding a NZ driver license for an average of 1.5 years, and travelled on average an estimated 60 km (37 miles) per week. Thirteen of these participants held a full NZ driver license, eight held a restricted license and three held a learner license. They were all first year students at the University of Waikato with 19 of them enrolled in Psychology. Their ethnic background was predominantly Caucasian (20) with two NZ Maori participants. Eight other participants (all females) were 25 years and older (mean age of 35.5 years) and were considered to be experienced drivers. They had held a NZ full driver license for an average of 15.5 years end estimated their weekly distance travelled to be about 200 km (124 miles). They all considered themselves to be Caucasian. Of the eight experienced driver participants, four were first year psychology students, three were graduate psychology students, one was an University administrator. First year psychology students gained a 1% course credit and the others were given a $10 petrol voucher for their participation in this study. All participants had normal or corrected vision. The imbalanced gender ratio reflected the fact that more females than males volunteered for the experiment.

2.2. Measures

A computer based digital video system was used to display video-based traffic simulations on an 800 mm (32 in.) computer monitor. The participants were seated in a small sound proof laboratory, approximately 750 mm in front of the screen and had access to a computer 'mouse' device that could be operated on a flat surface. There was also a digital audio recording device.

The hazard perception dual task was specifically designed and software engineered for this study. It required the participants to search for immediate hazards on video-based traffic scenarios (size: 500×180 mm) as the primary task, while concurrently performing a secondary tracking task. The aim of the primary task was for the participants to detect and verbally identify as many immediate hazards as possible on video-based traffic simulations displayed from a driver's perspective on the computer monitor. Immediate hazards were defined as hazards that would require some preventative or evasive actions from the driver (e.g., braking or being prepared to brake, sounding the horn or/and changing direction) in order to avoid a potentially dangerous interaction with another road user. The participants were required to click the computer 'mouse' device each time they detected an immediate hazard. Each mouse click was accompanied by a high pitched 'peep' sound which prompted the participants to provide a verbal identification of the hazard. Each mouse click event was individually 'time stamped' in milliseconds by the computer denoting the time passed from the start of the trial to the click event and then stored on a hard disk. The digital audio device recorded the verbal hazard identifications by the participants, including the 'peep' sound after each 'mouse' click. For each immediate hazard, a 'reaction window' was defined as the critical period during which the participant was expected to react by clicking a mouse button. It started from the earliest point of time when the immediate hazard became visible to the participant, and ended at the point where the hazard was no longer visible. Each time stamped mouse click event was verified manually after the experiment using the audio recording from the verbal responses. If the mouse click was followed by a correct verbal description of the immediate hazard (e.g., "pedestrian crossing from the left" in Fig. 1) the reaction time for the hazard was calculated as the time period in milliseconds from the start of the critical period to the time when the mouse click event occurred. Mouse click events that were not followed by a correct verbal identification of the hazard were discarded. For each trial, the first dependent variable was the number of detected and correctly identified hazards and for each of those hazards, the second dependent variable was the corresponding reaction time. If a participant missed a hazard, the average reaction time of the group the participant belonged to (experienced, young or control group) was used instead.

There are other approaches to dealing with missing reaction time data. For example, some researchers argued that such values should be replaced with the maximum possible reaction time, to account for the fact that the participant missed the hazard (Sagberg and Bjørnskau, 2006). However, in the current study, the young drivers detected fewer hazards than the experience drivers. Therefore, replacing the missing data with the maximum possible reaction time (some of which were up to 40 s) would skew the data in favour of the experienced drivers. An alternative approach would be to only analyse the reaction times for correctly identified hazards. However, in this study there was no consistency in the hazards which participants missed, and by using this approach we would effectively be ignoring the missed hazards. Thus, this approach would have favoured the participants who missed many hazards (mostly young drivers during baseline trials) as their lack of a response would not have been accounted for. Consequently, we decided to replace the missing data with the group mean. This also has its limitations, in particular it may minimise differences between the reaction times of those who detected many hazards compared to those who detected few. However, overall we felt this was the most balanced approach to take and would result in data that most accurately reflected the performance of the participants.

The video-based traffic simulations were between 15 and 78 s long and were selected as individual video clip files from a pool of 100 clips, which were produced for the interactive driver training product 'a^{2}om-mind' of the a^{2}om driving academy in the UK. Fig. 1 shows a sample screen shot of such a driving simulation including a virtual dashboard with animated speedometer and indicators (steering wheel was static) and three rear view mirrors. Any text components that related to the interactive functionality of a^{2}om-mind have been removed. The front view was filmed on high-definition video format providing traffic information to the participants for up to 200 m (656 feet) ahead. The three other videos

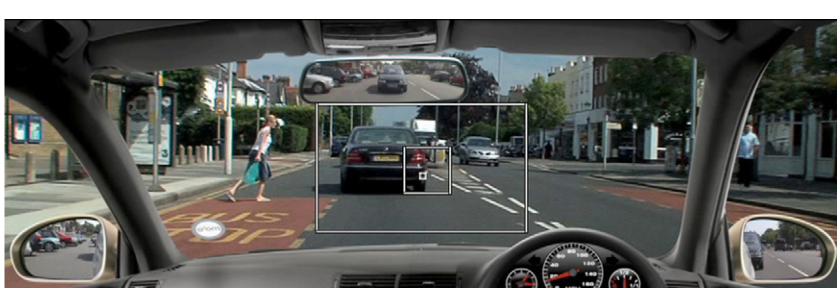

Fig. 1. Sample screen shot of a video-based traffic simulation for the hazard perception dual task, including the computer generated dashboard and the three rear view mirrors with composited video images providing a near 360° vision around the virtual car. The central tracking task including the rectangle, user controlled square and the (moving) target in the square is also visible in the centre of the traffic scenario.

were synchronised with the front view video and composited in the three rear view mirrors and provided a near 360° vision around the virtual car (see Fig. 1).

For the hazard perception dual task, nine traffic simulations were selected. One simulation served as a practice trial, four scenarios containing a total of 20 hazards were used for the baseline trials and four scenarios with a total of 23 hazards were used for four post-training trials. Each scenario contained between 2 and 14 immediate hazards. In some cases, several immediate hazards were visible simultaneously. All immediate hazards displayed in the traffic simulations were filmed as they were naturally occurring (not staged) over a period of approximately 40 h driving in rural, semi-rural and urban traffic in or in the vicinity of London (UK).

The secondary task required the participants to carry out a central tracking task, simulating the steering in real driving while identifying the hazards. As can be seen in Fig. 1, the central tracking task consisted of a stationary rectangle (130 × 80 mm) that was digitally superimposed in the central lower area of the driving scenario on to the video-based traffic simulation, approximately at the location of the road ahead. The participants were required to keep a moving target dot (5 mm, speed approximately 10 mm/s) within a square (30 × 30 mm), whose position was controlled by the participants via the computer 'mouse' device. The square was contained within a larger stationary rectangle, bouncing off its sides like a ball would on a billiard table. Each time the target dot was miss-tracked by the participants and moved out of the square, a low pitched 'peep' sound was produced and the frame around the simulation temporarily changed colour from blue to red for 500 ms, alerting the participants to the tracking error. These occasions were recorded as the dependent variable 'number of tracking errors' for each trial. A second dependent variable 'miss-tracked time' was also derived from the amount of time that the target spent outside the square for each trial. However, this variable strongly correlated with the 'number of tracking errors' and was therefore not further analysed.

The road commentary training trials used another 12 video-based traffic simulations which were selected from the same pool of simulation clips as the hazard perception dual task. They were displayed on the computer monitor in the same way as the simulations for the hazard perception dual task, but without the secondary tracking task.

The participants who received the video-based road commentary training were instructed that instead of the primary and secondary task of the hazard perception dual task they were required to provide a running verbal commentary about any hazards they detected including potential as well as immediate hazards. A potential hazard was defined as a hazard that may develop to an immediate hazard over time.

During the commentary training trials, there were about 150 immediate and potential hazards visible. All the participants' commentaries were audio-taped. The dependent variable analysed from this was the total number of hazards that were pointed out verbally by the participants during their road commentaries.

There were also two control conditions. For the first control condition, the participants watched the same 12 trials of video-based traffic simulations as the participants who received the road commentary training, but they did not provide the running commentary. The participants for the second control condition watched a series of mute TV commercial video clips, which were not related to driving, for the same length of time that the road commentary training would have taken. The commercial clips were randomly recorded from New Zealand television.

2.3. Procedure

The participants were firstly briefed on how to perform the hazard perception dual task and had the opportunity to run the practice trial several times until they clearly understood and performed the dual task correctly. The participants then completed the four baseline trials of the hazard perception dual task. The trials were shown to all participants in the same order and after each trial there was a break and the participants decided when they were ready for the next trial by clicking on the 'click here to continue' field. After the baseline trials, the 24 young drivers in the sample were then randomly assigned to one of three groups with driving experience being fairly well balanced across the groups; a road commentary training group (Young-Training; $n = 8$; three full license, four restricted license, one learner license) or one of two control groups (Young-Control 1; $n = 8$; five full, one restricted, two learner and Young-Control 2; $n = 8$; five full, two restricted, one learner). The experienced drivers were all assigned to a second road commentary training group (Experienced-Training, $n = 8$).

An initial analysis was conducted to determine if the driving experience of the young drivers as indicated by license type altered their baseline performance in the hazard perception dual task. The group of 24 young drivers (all 18 or 19 years old) was divided into those with a full NZ license ($n = 13$) and those with either a learner or restricted license ($n = 11$; eight restricted, three learner license holders). Inferential statistics revealed no differences between these two groups in any of the baseline performance measures of the hazard perception dual task, all $ps > 0.5$ and therefore combining them in one group was warranted.

The participants of the two training groups took part in road commentary training, while two control groups completed their particular control condition. After having completed the road commentary training trials or one of the two control conditions, each participant took part in four post-training trials of the hazard detection dual task, using the same procedure as for the four baseline trials.

3. Results

We used univariate one-way analyses of variance (ANOVAs) with alpha levels of 0.05 and 0.01 to determine statistical significance. Partial eta squared (η_p^2) were used as an indication of effect size. Traditionally, η_p^2 values of 0.01, 0.06 and 0.14 represent small, medium and large effect sizes (Cohen, 1988).

3.1.1. Performance on the hazard perception dual task

The performance of the young ($n = 24$) and experienced drivers ($n = 8$) across the four baseline trials of the hazard perception dual task is shown in Fig. 2. The figure shows the mean percentage of detected and correctly identified hazards (primary task) and the mean number of tracking errors in the secondary tracking task. Visual inspection of the figure reveals that the young drivers detected and identified a smaller percentage of the hazards ($M = 75.2$, SD = 9.3) compared to the experienced drivers ($M = 87.5$, SD = 9.3), but at the same time made a smaller number of tracking errors ($M = 9.7$, SD = 5.3) than the experienced drivers ($M = 16.1$, SD = 7.2).

Inferential statistics confirmed that the young drives were performing significantly worse than the experienced drivers in regards to the percentage of hazards detected and identified, $F(1, 30) = 10.56$, $p < 0.01$, $\eta_p^2 = 0.26$, and had a significantly smaller number of tracking errors, $F(1, 30) = 7.11$, $p < .05$, $\eta_p^2 = 0.19$, compared to the experienced drivers. In regards to the hazard perception reaction times (see method section for the strategy we used to deal with missing values), it took the young drivers significantly longer to detect the hazards with an overall mean reaction time of 5.95 s (SD = 0.54) compared to the experienced drivers with a mean reaction time of 5.42 s (SD = 0.54), $F(1, 30) = 6.42$, $p < 0.05$, $\eta_p^2 = 0.18$.

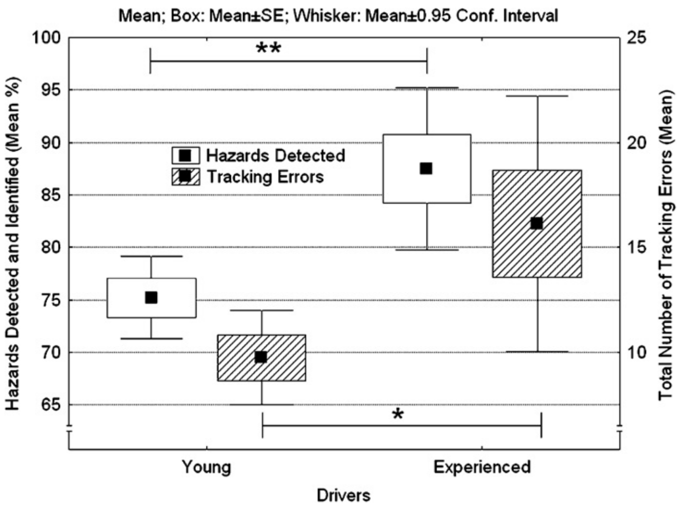

Fig. 2. Mean percentage of hazards detected and identified (left *y*-axis) and mean total number of tracking errors (right *y*-axis) including variability measures for the young drivers ($n = 24$) and the older, more experienced drivers ($n = 8$), $^{*}p < 0.05$, $^{**}p < 0.01$.

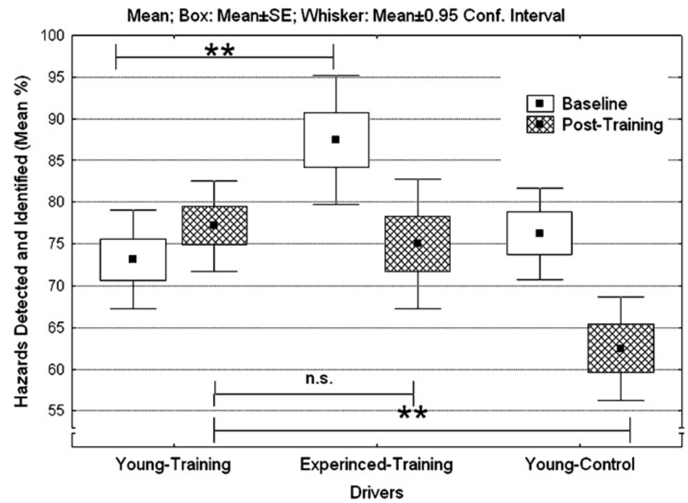

Fig. 3. Mean percentage of hazards detected and identified before (baseline trials, left) and after the road commentary training (post-training trials, right) for the young ($n = 8$) and older, more experienced drivers ($n = 8$) in the two training groups (Young-Training and Experienced-Training), as well as for the young driver control group ($n = 16$, Young-Control). The graph includes several variability measures (see key on top of the graph), $^{**}p < 0.01$, n.s.: not significant.

3.1.2. *Effect of road commentary training*

The second part of the study examined the effect of road commentary training on the performance of the participants in the hazard perception dual task. There was no significant difference between the performance of the control group who watched traffic simulations (Young-Control 1) and the control group who watched commercials (Young-Control 2) on either the baseline or the post-training trials for any of the dependent variables (all $ps > 0.05$) of the hazard perception dual task. The two control groups were therefore pooled to a larger single control group (Young-Control, $n = 16$).

Across the 12 trials of road commentary training which contained a total of 150 immediate hazards, the results revealed that there was no significant difference between the mean number of hazards (potential and immediate) the young drivers (Novice-Training) had commented on ($M = 115.1$, $SD = 31.6$) compared to the experienced drivers (Experienced-Training: $M = 110.5$, $SD = 39.1$), $F(1, 14) = .260$. $p = 0.80$, $\eta_p^2 = 0.005$.

Fig. 3 shows the performance of the drivers in the two training groups (Young-Training and Experienced-Training) over the four trials of the hazard perception dual task before (baseline) and after they received the road commentary training (post-training). The figure shows that the trained young drivers were able to increase the percentage of hazards detected slightly from the baseline trials ($M = 73.1$, $SD = 7.0$) to the post-training trials ($M = 77.2$, $SD = 6.5$), while there was a substantial decrease in that measure in the trained experienced drivers (baseline trials $M = 87.5$, $SD = 9.3$ vs post-training trials $M = 75.0$, $SD = 9.2$). This indicates that the hazards in the four post-training trials were considerably more difficult to detect and to identify than the hazards in the four baseline trials assuming that road commentary training could not have had any negative effects on the hazard perception performance in the experienced drivers.

The mean total number of tracking errors in the secondary task decreased slightly for the trained young drivers from the baseline trials ($M = 9.0$, $SD = 3.4$) to the post-training trials ($M = 7.0$, $SD = 4.3$), and for the trained experienced drivers (baseline trials $M = 16.1$, $SD = 7.28$ vs post-training trials $M = 15.3$, $SD = 6.9$).

Inferential statistics confirmed that for the baseline trials, the Young-Training group detected and identified significantly fewer hazards, $F(1, 14) = 12.2$, $p < 0.01$, $\eta_p^2 = 0.46$ and made significantly fewer tracking errors, $F(1, 14) = 6.31$, $p < 0.05$, $\eta_p^2 = 0.31$ than the Experienced-Training group.

After the road commentary training in the post-training trials, there was no significant difference between the two groups regarding the mean percentage of detected and identified hazards, $F(1, 14) = 0.298$, $p = 0.59$, $\eta_p^2 = 0.02$, but the young drivers still made fewer tracking errors than the experienced drivers, $F(1, 14) = 8.15$, $p < 0.05$, $\eta_p^2 = 0.37$. These results indicate that the road commentary training improved the hazard detection and identification skills of the young drivers to the level of the experienced drivers but did not affect the performance of the drivers in the secondary central tracking task.

Regarding the hazard perception reaction times, the Young-Training group were significantly slower ($M = 6.01$ s, $SD = 0.67$) than the Experienced-Training group ($M = 5.43$ s, $SD = 0.36$) in the baseline trials, $F(1, 14) = 4.63$, $p < 0.05$, $\eta_p^2 = 0.25$ and a difference was still apparent in the post-training trials (Young-Training $M = 7.66$ s, $SD = 0.89$; Experienced-Training $M = 6.76$ s, $SD = 1.04$) but it did not reach statistical significance, $F(1, 14) = 3.23$, $p = 0.09$, $\eta_p^2 = 0.18$). Fig. 3 also compares the performance of the young drivers ($n = 8$) in the Young-Training group with performance of the young drivers ($n = 16$) in the control group (Young-Control) in the four baseline trials and the four post-training trials of the hazard perception dual task. Visual inspection of the figures reveal that while the two groups performed almost equally regarding the percentage of hazards detected and identified in the baseline trials (Young-Training $M = 73.1$, $SD = 7.0$; Young-Control $M = 76.3$, $SD = 10.25$), after the road commentary training (post-training trials) the Young-Training group detected and identified substantially more hazards ($M = 77.2$, $SD = 6.5$) than the Young-Control group ($M = 62.5$, $SD = 11.6$). The mean total number of tracking errors in the secondary task remained similar for both groups, for the Young-Training group from the baseline trials ($M = 9.00$, $SD = 3.38$) to the post-training trials ($M = 7.00$, $SD = 4.34$), and for Young-Control group from the baseline trials ($M = 10.13$, $SD = 6.17$) to the post-training trials ($M = 8.25$, $SD = 5.34$).

Inferential statistics confirmed that for the baseline trials, the drivers in the Young-Training group detected and identified a similar percentage of hazards as the Young-Control group, $F(1, 22) = 0.60$, $p = 0.45$, $\eta_p^2 = 0.03$ and made a similar number of tracking errors, $F(1, 22) = 0.23$, $p = 0.64$, $\eta_p^2 = 0.01$. However, after the road commentary training in the post-training trials, the Young-Training group detected and identified a significantly greater percentage of hazards compared to the Young-Control group, $F(1, 22) = 10.84$, $p < 0.01$, $\eta_p^2 = 0.33$. There was still no difference regarding the number of tracking errors in the secondary task, $F(1, 22) = 0.33$, $p = 0.57$, $\eta_p^2 = 0.02$.

In summary, compared to a control group who did not receive any road commentary training, the trained young drivers substantially improved their hazard perception skills but the training did not affect their performance in the secondary central tracking task. Regarding the hazard perception reaction times, there was no difference between the Young-Training group ($M = 6.01$ s, SD = 0.67) and the Young-Control group ($M = 5.92$ s, SD = 0.48) in the baseline trials, $F(1, 22) = 0.14$, $p = 0.71$, $\eta_p^2 = 0.01$, however, during the post-training trials, the Young-Training group reacted faster to the hazards ($M = 6.83$ s, SD = 0.67) than the Young-Control group ($M = 7.65$ s, SD = 0.89), $F(1, 22) = 6.31$, $p < 0.05$, $\eta_p^2 = 0.22$.

4. Discussion

In summary, the results of this study showed that during baseline trials, the young drivers detected and identified considerably fewer immediate hazards and had longer hazard perception reaction times in the primary task of the hazard perception dual task than the experienced drivers. However, the young drivers performed significantly better in the secondary central tracking task than the experienced drivers. These results are in line with much research indicating that young drivers have poorer hazard perception abilities than experienced drivers (e.g., Horswill and McKenna, 2004). The better performance of the young drivers in the secondary task could be due to the fact that they assigned fewer attentional resources to the primary task of hazard perception compared to the experienced drivers. That is, the two groups of participants may have prioritised their workload differently in the hazard perception dual task. While the young drivers seemingly put more priority on performing well on the secondary tracking task the experienced drivers may have focused more on the primary task of detecting and identifying hazards. The secondary task gave immediate and strong audio and visual feedback for every tracking error, while there was no feedback given on any hazards they may have missed. This could have signalled to the young drivers that the secondary task required more urgent attention than the primary task, while the same feedback had less impact on the experienced drivers.

Translated into a real driving situation and assuming that our hazard perception dual task contains reasonable ecological validity, this could explain why beginner drivers are clearly anxious to avoid making a steering error, a mistake which could result in an immediate crash. Consequently, this may lead them to focus their visual search predominantly on areas which provide crucial visual information relevant to the steering task, but at the same time reducing their ability to detect hazards further down the road. Indeed, Mourant and Rockwell (1972) and Underwood (2007) found that young drivers fixated closer to the front of the car, scanned less widely in the vertical plane, and their visual search remained very much the same regardless of road type (Crundall and Underwood, 1998). Alternatively, a different explanation for young drivers' poor visual search and hazard perception in real driving has been proposed. It could be that the steering task uses most of the free cognitive resources in young drivers and that there is simply no extra attentional capacity left for 'reading the road' and engaging in effortful situation awareness. This might be true particularly in the very early stages of driving when much attentional capacity is directed towards vehicle control activities including gear changes, lane positioning and speed control. However, these activities become largely automated within quite a short time frame with relatively little driving practice (e.g., Hall and West, 1996). In addition, Crundall and Underwood (1998) found that when novice drivers were released from the steering task and were required to respond to hazards only by watching video-based traffic simulation, their visual search behaviour was still significantly less efficient than that of the experienced drivers, indicating that their poor search behaviour could not have been caused solely by a lack of available cognitive resources when focusing on the steering task. At the same time, the fact that releasing them from the steering task did not improve their visual search could mean that they were either not able to redirect their attentional resources to the visual search task or simply did not have the skills to engage in efficient visual search behaviour. Crundall and Underwood (1998) used novice drivers with very limited driving experienced (0.2 years) while our young drivers had an average of 1.5 years of driving experience and therefore were not only likely to have their steering skills fully automated but also had more opportunities to develop visual search skills. When our young drivers were released from the steering task during the road commentary training they were able to comment on the same number of hazards as our experienced drivers, implying that they were able to engage in efficient visual search behaviour.

The crash risk of young drivers is clearly age related, at least until they reach the age of 25 years (Mayhew et al., 2003), which seems to be the time when the prefrontal cortex of the frontal lobes of the brain, responsible for executive functions, fully matures (Lenroot and Giedd, 2006; Sowell et al., 2002). Recent studies by Sim (2008) and Isler et al. (2008) found that executive functions were significantly predictive of risk taking behaviour in young drivers which in turn may be somewhat related to their hazard perception ability. Indeed, McKenna et al. (2006) found evidence that lack of hazard perception skills could lead to ignorance-based risk taking behaviour. Once the hazard perceptions skills of the young drivers were improved with hazard anticipation training, video-based risk-taking driving behaviour (such as speed choice, close following and overtaking) improved as well. The dramatic reduction of crash risk in young drivers shortly after licensing can however, only be attributed to an interaction between age and accumulated driving experience factors (Mayhew et al., 2003). This may include the acquisition of hazard perception skills; although Sagberg and Bjørnskau (2006) concluded that hazard perception might be only a minor factor when it comes to explaining the initial risk decrease in young drivers after they are licensed. Clearly more research is needed to help partial out the relative contributions of age and driving experience in the hazard perception related abilities of young drivers.

There is no doubt that once the driving steering task becomes automated, considerable cognitive resources are freed up and advanced novice young drivers are able to re-invest these resources. Kuiken and Twisk (2001) suggested that this could be the time when these young drivers may miscalibrate by creating an imbalance between their perception of the driver task demand and their capabilities (Brown and Groeger, 1988; Horswill et al., 2004; Katila et al., 2004; McKenna et al., 1991). This also coincides with the point of time when they become licensed solo drivers and experience considerable crash risk. Being aware of their improved car handling skills in addition to the sense of achievement experienced after having passed the driver licensing test, young drivers may have inflated confidence in their driving skills, leading them to underestimate the complexity of the driving task. As a result they might be tempted to re-invest their free cognitive resources into unsafe, but for young drivers often more rewarding driving behaviour (e.g., speeding, close following, showing off, drink-driving) rather than into safe driving behaviour (e.g., hazard perception) whose goals may appear less rewarding (see also Kuiken and Twisk, 2001).

Assisting young drivers to direct these freed cognitive resources toward higher level driving skills, rather than risk taking should be a priority. Findings from the current study suggest that training can be used to direct young drivers' attentional resources, as evidenced by the remarkable effects of the road commentary intervention on their hazard perception skills. It seems that it prompted them to redirect their attentional priority from the secondary tracking task to the primary task of hazard perception, without affecting their performance in the secondary task. After the road commentary trials, they were able to perform the primary hazard perception task at the same level as the experienced drivers, and significantly better than the control group, who did not receive any road commentary training. Nevertheless, they still had significantly fewer tracking errors than the experienced drivers on the secondary tracking task and on this measure performed at a similar level to the control group. These results offer little support for the idea that the young drivers performed poorly on the primary hazard perception task in the baseline trials because they 'used up' all their cognitive resources in performing well on the secondary tracking task. The secondary task seemed to have required only limited cognitive resources as all participants showed 'ceiling' performance of no tracking errors in the practice trials when they performed this secondary task without the hazard perception task. It seems much more likely that the young drivers deliberately focused more on the secondary task that gave them strong and immediate feedback on their performance, and it was only after the road commentary training that they were then made more aware of the importance of the hazard perception task. This supports the findings of Cnossen et al. (2004) who demonstrated that drivers can indeed prioritise their goals in dual tasks in relation on how important they perceive these tasks to be.

In the baseline trials of the current study, the young drivers had significantly slower hazard perception reaction times than the experienced drivers, while after the road commentary training no significant difference in reaction times between the two groups was detectible. This indicates that road commentary training may have encouraged the young drivers to report hazards more willingly and faster. This supports recent research by Wallis and Horswill (2007), which also used a road commentary training intervention and found, using fuzzy signal detection theory, that it lowered young driver's threshold of danger, and therefore were more likely to label situations as hazardous.

Overall, taking the results of this study and previous research findings together, a rather compelling picture of the effectiveness of road commentary training emerges. Firstly, road commentary training seems to be effective, regardless of whether it is performed by the driver on the road or by watching video-based traffic simulations, or whether the drivers provide the commentary themselves as in the current study, or whether it is given by a driver instructor while the drivers just listen (e.g., Wallis and Horswill, 2007). Secondly, commentary in combination with hazard anticipation and visual search training improved visual search behaviour of young drivers and produced clearly detectible differences in their eye movement patterns on the road and during video-based traffic simulations; some of the changes, at least in the laboratory task, were still measurable three to six months later (Chapman et al., 2002).

In addition, it has been shown that road commentary training cannot only improve the hazard anticipation of young drivers, but also decrease their risk taking behaviour (McKenna et al., 2006). The current study showed that road commentary can help young drivers shift some of their attentional priority from a secondary central tracking task to the primary hazard perception task. It also added some support to the research finding of Wallis and Horswill (2007), which showed that road commentary training influences the hazard perception response bias of young drivers helping them to respond faster and more frequently to hazards.

The effects of road commentary training in improving hazard perception skills in young drivers could have substantial road safety implications as hazard perception has been found to be directly related to their crash involvement (Horswill and McKenna, 2004). Furthermore, the '100-car naturalistic' study by Klauer et al. (2006) clearly emphasised the importance of addressing visual search and attention related crashes in young drivers, especially in New Zealand where young drivers are particularly vulnerable being eligible to become solo drivers at 15½ years having had limited supervised driving experience. It would be interesting to use gender and level of driving experience of young drivers as independent variables in a follow-up study in order to examine further which drivers at what level of their licensing process would benefit most of a road commentary training intervention.

In any case, road commentary training would be a cost-effective and evidence-based intervention which could help remedy the 'failed to look at the right place at the right time' type of crashes. Additionally, this training could be conducted in vehicle or even more safely and without the steering task as a distraction, via video-based traffic simulations.

Acknowledgements

We would like to thank Andrew Malcolm for programming the dual task and the a^{2}om academy (UK) for allowing us to use some of their video-based traffic simulations. We also like to thank two anonymous reviewers for their thoughtful comments.

References

Brown, I.D., Groeger, J.A., 1988. Risk perception and decision taking during the transition between novice and experienced driver status. Ergonomics 31 (4), 585–597 (Special Issue: Risky decision-making in transport operations).

Chapman, P., Underwood, G., Roberts, K., 2002. Visual search patterns in trained and untrained novice drivers. Transportation Research, Part F: Psychology and Behaviour 5, 157–167.

Cnossen, F., Meijman, T., Rothengatter, T., 2004. Adaptive strategies changes as a function of task demands: a study of car drivers. Ergonomics 47 (2), 218–236.

Cohen, J., 1988. Statistical Power Analyses for Behavioural Sciences. Lawrence Erlbaum Associates, New York.

Crundall, D., Underwood, G., 1998. The effects of experience and processing demands on visual information processing acquisition in drivers. Ergonomics 41, 448–458.

Crick, J., McKenna, F.P., 1991. Hazard Perception: can it be trained? In: Grayson, G.B. (Ed.), Behavioural Research in Road Safety II. Proceedings of a Seminar at Manchester University 17–18 September, 1991. Crowthorne, Berkshire: Transport Research Laboratory, pp. 100–107.

Dahl, R.E., Spear, L.P., 2004. Adolescent brain development: vulnerabilities and opportunities. Annals of the New York Academy of Sciences 1021, 1–22.

Deery, H.A., 1999. Hazard and risk perception among young novice drivers. Journal of Safety Research 30 (4), 225–236.

Endsley, M., 1995. Measurement of situation awareness in dynamic systems. Human Factors 37, 65–84.

Engström, I., Gregersen, N.P., Hernetkoski, K., Keskinen, E., Nyberg, A., 2003. Young novice drivers, driver education and training—Literature Review (No. 491A). University of Turku, Finland.

Farrand, P., McKenna, F.P., 2001. Risk perception in novice drivers: the relationship between questionnaire measures and response latency. Transportation Research, Part F 4, 201–212.

Fisher, D.L., Pollatsek, A., Pradhan, A., 2006. Can novice drivers be trained to scan for information that will reduce their likelihood of a crash? Injury Prevention 12 (Suppl. 1), 125–129.

Hall, J., West, R., 1996. The role of formal instruction and informal practice in learning to drive. Ergonomics 39, 693–706.

Horswill, M.S., McKenna, F.P., 2004. Drivers' hazard perception ability: situation awareness on the road. In: Banbury, S., Tremblay, S. (Eds.), A Cognitive Approach to Situation Awareness. Asgate, Aldershot, UK, pp. 155–175.

Horswill, M.S., Waylen, A.E., Tofield, M.I., 2004. Drivers' ratings of different components of their own driving skill: a greater illusion of superiority for skills that relate to accident involvement. Journal of Applied Social Psychology 34, 177–195.

Isler, R.B., Starkey, N.J., Drew, M., Sheppard, P., 2008. The 'frontal lobe' project: a double blind, randomized controlled study of the effectiveness of higher level driving skills training to improve frontal lobe (executive) function related driving performance in young drivers. Report with unpublished data to the Accident Compensation Corporation and the Road Safety Trust, New Zealand.

Katila, A., Keskinen, E., Hatakka, M., Laapotti, S., 2004. Does increased confidence among novice drivers imply a decrease in safety? The effects of skid training on slippery road accidents. Accident Analysis & Prevention 36 (4), 543–550.

Keating, D.P., 2007. Understanding adolescent development: Implications for driving safety. Journal of Safety Research 38 (2), 147–157.

Klauer, S.G., Dingus, T.A., Neale, V.L., Sudweeks, J.D., Ramsey, D.J., 2006. The Impact of Driver Inattention on Near Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data. National Highway Traffic Safety Administration, Washington, DC.
Klein, C., Foerster, F., Harnegg, K., Fischer, B., 2005. Lifespan development of pro- and anti-saccades: multiple regression models for point estimates. Developmental Brain Research 160, 113–123.
Kuiken, M.J., Twisk, D.A.M., 2001. Safe driving and the training of calibration: a literature review. Report R2001-29. Institute of Road Safety Research, Leidschendam.
Land, M.F., Lee, D.N., 1994. Where we look when we steer. Nature 369, 742–743.
Laya, O., 1991. Eye movements in actual and simulated curve negotiation tasks. IATSS Research 16 (1), 13–26.
Lenroot, R.K., Giedd, J.N., 2006. Brain development in children and adolescents: insights from anatomical magnetic resonance imaging. Neuroscience & Biobehavioral Reviews 30 (6), 718–729.
Lewis-Evans, B., Lukkien, C., 2007. Crash Profile of New Zealand Novice Drivers Strategy and Sustainability. Ministry of Transport, Wellington, New Zealand.
Mayhew, D.R., Simpson, H.M., Pak, A., 2003. Changes in collision rates among novice drivers during the first months of driving. Accident Analysis & Prevention 35 (5), 683–691.
Mourant, R.R., Rockwell, T.H., 1972. Strategies of visual search by novice and experienced drivers. Human Factors 14, 323–335.
Munoz, D.P., Broughton, J.R., Goldring, J.E., Armstrong, I.T., 1998. Age-related performance of human subjects on saccadic eye movement tasks. Experimental Brain Research 121 (4), 391–400.
McKenna, F.P., Farrand, P., 1999. The role of automaticity in driving. In: Grayson, G.B. (Ed.), Behavioural Research in Road Safety IX. Transport Research Laboratory, Crowthorne, UK.
McKenna, F.P., Horswill, M.S., Alexander, J.L., 2006. Does anticipation training affect drivers' risk taking? Journal of Experimental Psychology: Applied 12 (1), 1–10.
McKenna, F.P., Stanier, R.A., Lewis, C., 1991. Factors underlying illusory self-assessment of driving skill in males and females. Accident Analysis & Prevention 23 (1), 45–52.
Mills, K.L., Rolls, G.W.P., Hall, R.D., McDonald, M., 1998. The effects of hazard perception training on the development of novice driver skills. Road Safety Research Report No. 4. Department of the Environment, Transport & the Regions, London, UK.
Sagberg, F., Bjørnskau, T., 2006. Hazard perception and driving experience among novice drivers. Accidents Analysis and Prevention 38, 407–414.
Senserrick, T.M., 2006. Reducing young driver road trauma: guidance and optimism for the future. Injury Prevention 12, i56–i60.
Sim, C., 2008. Individual differences in risk taking during adolescence. Unpublished Master of Arts thesis, University of Otago, Dunedin, New Zealand.
Sowell, E.R., Trauner, D.A., Gamst, A., Jernigan, T.L., 2002. Development of cortical and subcortical brain structures in childhood and adolescence: A structural MRI study. Developmental Medicine & Child Neurology 44 (21), 4–16.
Underwood, G., 2007. Visual attention and the transition from novice to advanced driver. Ergonomics 50 (8), 1235–1249.
Wallis, S.A., Horswill, M.S., 2007. Using fuzzy signal detection theory to determine why experienced and trained drivers respond faster than novice drivers in a hazard perception test. Accident Analysis and Prevention 39, 1177–1185.