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Driving experience and situation awareness in hazard detection

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ABSTRACT

How does driving experience help in the development of situation awareness? A comparison of detection rates of roadway hazards that involved other road users by inexperienced and experienced car drivers and experienced motorcycle riders with car driving experience was conducted under laboratory conditions. Motorcycle rider-drivers, due to their greater breadth of road experiences, were predicted to have an advantage over other road users in the detection of hazards. Two types of hazards abrupt-onset events and gradual-onset hazards were examined. Abrupt-onset events capture attention by virtue of sudden movement and risk of impending collision, as when a pedestrian runs into the roadway for example. It was expected that these hazards would be detected regardless of experience or situation awareness. Gradual-onset hazards require the anticipation of unfolding events as recognition of the danger from children playing on the footpath, and as such are a test of advanced situation awareness. The results showed no inexperienced–experienced driver differences in the detection of either type of hazard, eliminating hazard-type as an explanation of previous inconsistencies. However, motorcycle rider-drivers detected gradual-onset hazards faster than car drivers and they also perceived more hazards in relatively safe sections of roadway, that is, they showed a higher level of situation awareness.

1. Introduction

There is cause for increasing concern over motorcycle rider safety. In the USA, roadway fatalities have been decreasing in recent years (a 22% reduction between 2005 and 2009), but motorcycle fatalities are increasing (National Highway Traffic Safety Administration, 2010). An overall reduction of 9.7% in the year 2007–2008 was accompanied by an increase of 2.2% in motorcycle fatalities. While there is a low prevalence of motorcycle riders (less than 4% of licenced vehicles in the UK) they have a disproportionately high involvement in road crashes and account for more than 20% of fatalities. A crash, however, often includes other road users and so understanding both driver and rider behaviour is important. It is now accepted that the off-road assessment of the road users' skills in assessing the dangers of a roadway scene is clearly desirable, and hazard perception testing has been suggested as an important component of the driver licencing process (Quimby and Watts, 1981; Sexton, 2000).

1.1. Gaining situation awareness

The more varied roadway experiences of motorcycle riders who also drive cars might be expected to provide them with an enhanced situation awareness as well as increased levels of safety compared to other road users. While experienced rider-drivers may have a more developed awareness of the events around them, their crash involvement does not suggest that situation awareness invariably leads to safety. It might be expected that the rider-drivers' awareness of their own vulnerability would provide them with a developed awareness of the behaviour of other road users and of the manoeuvering capabilities of a greater range of vehicles, but this alone is insufficient to ensure their safety. If situation awareness in the roadway context, is taken to be perception of the salient elements of the environment (other road users, the roadway configuration) and the projection of their status in the immediate future (see Endsley, 1995; Stanton et al., 2001; Underwood, 2007), then an experienced rider-driver would be expected to have good anticipation of roadway events that develop into hazardous situations. The present laboratory study compares rider-drivers and drivers using hazard perception videos that present unfolding events that can be anticipated if the road user has a developed sense of situation awareness, and sudden events that abruptly capture the attention of all road users.

1.2. Developing situation awareness

Driving experience does result in safer driving – fewer crashes – and we have previously related this development of skill to the extent of roadway scanning (Crundall and Underwood, 1998;

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Underwood et al., 2002, 2003). Inexperienced drivers search the roadway to a lesser extent than more experienced drivers, possibly as a function of their under-developed situation awareness. On safer, uneventful roads the scanning of the two groups of drivers has been shown to be similar, but on an urban motorway with other road users merging from both directions, the experienced drivers demonstrate their situation awareness by searching the roadway around them more extensively. As drivers' interactions with other road users increase over time and they negotiate a greater range of events, their situation awareness develops and they learn when they need to be especially attentive and increase their scanning. Accordingly, road users with more extensive and varied experience should develop greater situation awareness, and motorcycle riders with car driving experience should be one such a group of road users, as they will have encountered traffic situations from a greater range of perspectives. Using a motorcycle simulator in which both dynamic and static hazards were presented, Hosking et al. (2010) reported that more experienced motorcycle riders do indeed change their visual search behaviour more than inexperienced riders when a hazard is present. Experience was also associated with faster responses to the hazards. These differences in laboratory behaviour are reflected in results of crash analyses. Magazzù et al.'s (2006) analysis of 742 crashes found that car drivers holding a motorcycle licence tended to be less responsible for car-motorcycle crashes than drivers who were not motorcycle riders. Riders were more aware of the manoeuvering capabilities of motorcycles but there may also be an effect of a personal interest in motorcycles resulting in a greater awareness of their presence. Drivers are more likely to be involved in car-motorcycle crashes than are car drivers who are also riders, suggesting the two groups are differentially aware of roadway dangers.

1.3. Testing situation awareness

In the Hosking et al. (2010) study testing took place while volunteers rode a motorcycle simulator. Although this is more realistic than the traditional procedure for assessing hazard perception, and goes someway to answering criticisms of ecological validity, it may have caused some measure of distraction from the detection task. More traditional tests of hazard perception characteristically require the viewer to watch a video filmed from a vehicle travelling along a roadway, and in which other road users move towards a pathway that would result in a collision if avoiding action is not taken. The viewer signals the required action, such as braking or steering away from the other road user, by pressing a response button, or alternatively moving a lever on a sliding scale marked "safe" to "unsafe". While differences between inexperienced and experienced drivers have been reported, the pattern of such differences is not consistent. One purpose of the present study is to distinguish between two types of hazards in an attempt to account for this inconsistency. A second purpose is to include in the comparison a group of experienced motorcycle rider-drivers, as road users who are sometimes described as being exceptionally skilled and who would be expected to perform particularly well relative to car-only road users.

Early studies suggested a relationship between performance on a laboratory test of hazard perception and performance on the road. Pelz and Krupat (1974), for example, found that individual drivers who either self-reported as having been crash-involved or who had received a traffic violation citation during the previous year, behaved less cautiously in a hazard perception test. Safer drivers responded sooner to the onset of a hazardous situation, and they maintained a more cautious setting on a sliding scale that required continuous adjustment according to the danger inherent in the situation. Other studies reviewed by Horswill and McKenna (2004) have found a similar relationship between crash involvement and responses to hazard perception videos, giving validity to this off-road assessment of driving ability.

Not all studies have found a relationship between accident liability and hazard detection, however, and this perhaps explains why hazard perception testing has not been adopted widely. Comparisons of individuals with varying experience should report an advantage for experienced drivers over newly qualified drivers, but this is not always the case. While some studies have found faster response times to hazards for experienced drivers (e.g. Quimby and Watts, 1981; McKenna and Crick, 1991; McKenna et al., 2006; Wallis and Horswill, 2007; Smith et al., 2009) other studies have failed to replicate this result (e.g., Chapman and Underwood, 1998; Crundall et al., 2003; Sagberg and Bjørnskau, 2006; Borowsky et al., 2010). The question arises, then, as to why this result is difficult to replicate. One possibility involves the types of hazards used in the videos, and the present study investigates differences between abrupt hazards that capture attention, and gradually developing hazards that involve anticipation of what might happen as events unfold. Abrupt hazards capture attention effortlessly and immediately, whereas the recognition of gradual-onset hazards is sensitive to situation awareness. The question of failed replications is important because if we can discriminate between inexperienced drivers who are at greater risk in comparison with those who are likely to be safer drivers, then we will have an instrument for inclusion in the driver testing and licencing process.

The videos used in our early studies had a mixture of hazard types, having been filmed in preparation for inclusion in the revised UK driving test (1999). As well as the range of roads reported by Chapman and Underwood (1998), with country roads eliciting slower responses than urban roads (a result confirmed by Hosking et al., 2010), the videos varied in the extent to which they required the viewer to anticipate upcoming events. McKenna et al. (2006) placed emphasis on anticipation in the detection of hazards, but many of the movie clips used in the Chapman and Underwood (1998) study did not require any anticipation. These hazards can be described as involving the abrupt capture of attention by an exogenous event. Such hazards involved another road user appearing suddenly – a pedestrian stepping from behind a parked vehicle, or a car door opening, or a previously off-camera cyclist moving rapidly into the path of the camera car (see Fig. 1b). Hazards such as these were under consideration for inclusion in the UK driving test and so they were included in our earlier evaluation, but they are tests more of the viewer's speed of reaction than of their ability to assess a scenario and to predict how the situation will develop. Other videos showed unfolding events involving, for example, one car braking as a second car entered the road from a side-road, with both cars being visible for several seconds before braking occurred, or the appearance of another car heading towards the camera car on a narrowing road. The example shown in Fig. 1a gives the viewer sight of a pedestrian getting into a parked car in the distance, and the car then indicating that it is about to enter the road ahead of the camera car. In these cases the need to brake or steer away from another road user is predictable, and the only decision concerns when the action should be necessary. These hazards may be characterised as being sensitive to high-order situation awareness (see Horswill and McKenna, 2004; Underwood, 2007) in that they require the driver to predict alternative future scenarios emerging from the current interaction between road users and to consider preparations for evasive action. By including some hazards that required anticipation and others that captured attention as they appeared, our earlier study inevitably increased the variance in the distributions of hazard response times, and this may have masked differences between groups of drivers. One of the purposes of the present comparison is to separate responses to these different categories of hazards.

Fig. 1. Examples of frames taken from gradual and abrupt onset hazard videos. In the gradual onset movie here (frame a) the nearest parked car on the left has previously been seen to have a passenger entering, and it is now signalling that it intends to enter the roadway. It proceeds to do so, ahead of the camera car. In this case the interval between the passenger being seen to get into the car, and the car entering the roadway, is approximately 7 s. In the abrupt onset movie (frame b) the cyclist on the left appears from the side the building, and enters the roadway ahead of the camera car, without pausing. The interval between the cyclist being first visible on the screen, and the cyclist entering the roadway, is approximately 2 s. In both cases the camera car must brake.

Videos showing abrupt-onset hazards were compared with those showing gradual-onset hazards, to assess differences between inexperienced and experienced drivers. Experienced drivers have been found to make faster responses to hazards in some studies (for a recent example, see Wetton et al., 2010), and we predicted an advantage for experienced drivers but with gradual-onset hazards only. A third group of road-users was introduced, to extend the range of abilities tested. Motorcycle rider-drivers have sometimes been claimed to have better hazard judgement than car drivers, and have sometimes been shown to perform better than experienced drivers in laboratory tests. Underwood and Chapman (1998) found that motorcyclists with 15 years of riding/driving experience responded to hazards half a second faster than car drivers with similar experience, a result confirmed by Horswill and Helman (2003) and by Hosking et al. (2010). Riders are regularly heard to claim, informally, that they have better roadway awareness than car drivers, and we therefore predicted faster hazard detections by experienced riders in the present study, and again predicted that this difference would be apparent only with the gradual-onset hazards.

2. Method

2.1. Design

This study used a mixed-model experimental design with one between – groups factor of road users with three levels (inexperienced drivers; experienced drivers; rider-drivers) and one within-groups factor of type of hazard with two levels (abrupt onset; gradual onset).

2.2. Participants

Drivers and riders were recruited from a range of sources, including the University population, driving schools in Nottingham, and local motorcycle associations. Participants were all paid an inconvenience allowance. The road users were allocated to one of three groups: 25 inexperienced car drivers aged 18–24 years and who had completed their preliminary training but who had a maximum of two years of post-licence driving (mean of 1.25 years of post-licence driving); 38 experienced car drivers aged 19–75 years and with at least two years of driving (mean of 11.41 years driving), and 30 motorcycle riders aged 20–66 years who had at least two years of riding (mean of 14.30 years of riding). None of the drivers had motorcycling experience, whilst all of the motorcyclists also held a car driving licence (at least two years of car driving).

2.3. Materials and procedure

The hazard perception videos were filmed from the driver's perspective in a car travelling along different road types (e.g. rural scenarios, residential areas) and were sampled from the library of videos previously used by Chapman and Underwood (1998), (Crundall et al., 1999), and Underwood et al. (2003, 2005). The movie clips each lasted between 20 and 95 s, with an average of 50 s, and included at least one potentially hazardous situation (with a maximum of three hazardous events per clip). The definition of a hazard was presented as 'anything that would cause you to consider taking action (e.g. braking or steering) to prevent a possible danger'. Participants were not informed about the number of hazardous events in each clip, and as the clip lengths varied, they were not able to predict the possible hazards without paying attention to the videos. Twenty videos contained at least one abrupt hazard, and 20 contained at least one gradual onset hazard, and some of the clips contained both types of hazards. Examples of still frames taken from these videos are shown in Fig. 1. A further five videos, containing both abrupt and gradual onset hazards, were used for practice before the experiment started. The hazards all involved other road users – another vehicle that pulled out into the path of the camera-car, or a pedestrian that stepped onto a marked road crossing, or a cyclist that prompted a change of direction by pulling into the car's path. The hazards were classified according to how long the other road user was in view before an action became necessary. For example, children that run into the roadway in front of the camera car could be an abrupt hazard if they appear suddenly from behind a parked bus, or they could be a gradual onset hazard if they have been stood at a pedestrian crossing for a while as the camera-car approaches. The start time for both hazards was the first appearance on the screen of the hazardous object, for example another car or a child. Road users (such as a child pedestrian) who were visible for less than 3 s before becoming hazardous and requiring action were classified as having an abrupt onset (mean time on screen before action would be necessary was 1.88 s, SD = 0.73), and those that were visible for at least 5 s were classified as having a gradual onset (mean of 8.0 s, SD = 3.34).

The hazard videos were presented from an Apple iMAC G5 with a 17-inch monitor and were played through a purpose-written program. The program showed the videos and recorded button press responses. The participant was seated approximately 60 cm from the computer screen. The task required participants to respond to any potential hazards by tapping the spacebar on the computer keyboard, as soon as they were detected. The time of each button press was recorded relative to the start of the onset of each hazard. No feedback was given and each movie clip continued for its full course, regardless of how many button press responses were made. The 5 practice clips were shown, participants' questions answered, and then the 40 test clips shown in a new random order for each participant. All of the hazard movies were shown to all participants.

3. Results

A series of 3 × 2 ANOVAs were conducted, with road users and type of hazard as the independent variables. The principal dependent measures were the response latency to the first appearance of each hazard and the percentage of hazards detected, for each group of road users. These data are shown in Figs. 2 and 3. A hazard was declared as being correctly detected if the response was made while the hazard was visible on the screen – while a pedestrian was still in sight or when the brake lights of a leading car were still illuminated. This hazard window varied in duration for each hazard.

The three measures of response time, percentage of hazards detected, and hazard detection difference ratio were submitted to separate analyses of variance, each with one between-groups factor (road users) and one within-group factor (type of hazard). For response times, there were differences between road users ($F(2,90) = 4.49$, $MSE = 4.44$, $p < .05$), and between hazard types ($F(1,90) = 487.15$, $MSE = 191.86$, $p < .001$). There was also an interaction between these factors ($F(2,90) = 4.23$, $MSE = 1.67$, $p < .05$). Pairwise t-tests indicated that motorcycle riders made faster responses to hazard onsets than both the inexperienced drivers ($p < .05$) and the experienced drivers ($p < .01$). Abrupt onset hazards gained faster responses than gradual onset hazards, and the interaction was first inspected with an analysis of simple main effects. There was no difference between the three groups of road users in their responses to abrupt onset hazards ($F < 1$), but there was a substantial difference in the responses to gradual onset hazards ($F(2,180) = 8.50$, $MSE = 5.88$, $p < .001$). With gradual onset hazards only, pairwise tests found faster responses for rider-drivers relative to both inexperienced drivers ($p < .01$) and experienced drivers ($p < .01$). The difference between inexperienced and experienced drivers was not statistically reliable.

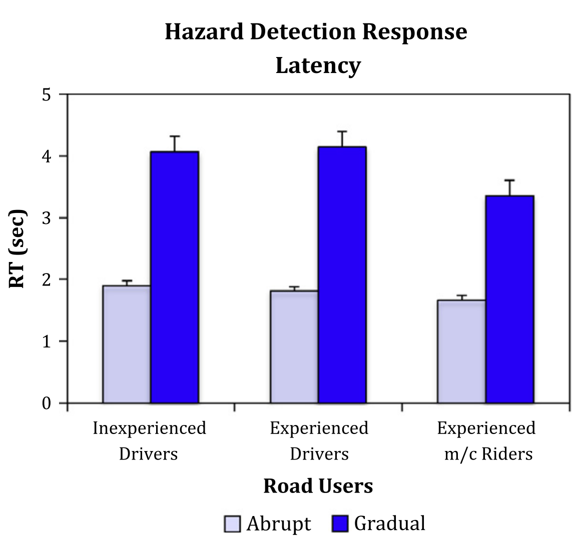

Fig. 2. Response times (means and standard errors) to the first appearance of a hazard, for three groups of road users and for two types of hazards.

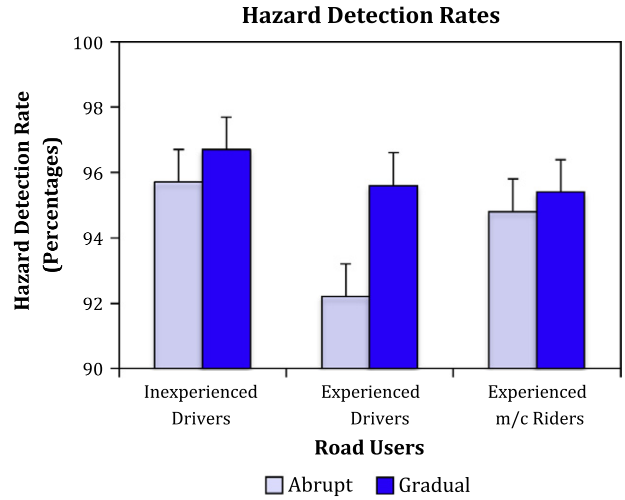

Fig. 3. Percentages (means and standard errors) of abrupt-onset and gradual-onset hazards detected by three groups of road users.

The ANOVA applied to the percentage of hazards correctly detected again found a difference between abrupt and gradual onset hazards ($F(1,90) = 6.21$, $MSE = 0.012$, $p < .05$), with more gradual onset hazards being detected, but no effect of road user ($F(2,90) = 2.59$, $MSE = 0.008$), and no interaction ($F(2,90) = 1.72$, $MSE = 0.003$).

We also recorded the number of button presses ("hazard" detections) made when there was no designated hazard present (Fig. 4). This is a measure of the sensitivity of the road user to the dangers associated with driving or riding, with someone who is highly aware of potential dangers from other road users expected to generate high numbers of button presses out of the designated hazard window. A one factor ANOVA was used to analyse these rates, finding a marginal effect of road user ($F(2,90) = 2.77$, $MSE = 10.17$, $p = .067$). This effect is a product of the motorcycle rider-drivers making more button press responses than the other two groups. Using this measure of false alarms and the successful hazard detection rates we derived a difference ratio to indicate the sensitivity of the participants to the presence of actual hazards. The ratio was designed to emphasise correct detections relative to the number of false alarms, and took the form:

$$[\text{False Alarms} - \text{Hits}]/[\text{False Alarms} + \text{Hits}] = D$$

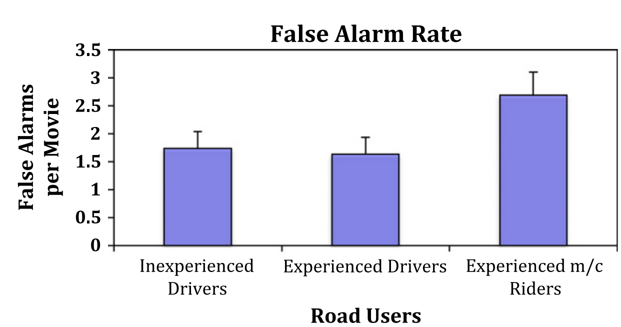

Fig. 4. False alarm rates (means and standard errors) by three groups of road users, for all videos. These are button presses (hazard detections) when no designated hazard was shown.

A high value of D for an individual road user would be indicative of a relatively large number of false alarms for each correct hazard detection, with a value approaching +1 if there were very few hits and a large number of false alarms. The highest values from individual participants here were $D = 0.839$ (abrupt hazards) and $D = 0.855$ (gradual hazards). A low value of D would be obtained by an individual making very few false alarms, which would render a value of D that approached -1. The lowest values observed were $D = -0.769$ (abrupt hazards) and $D = -0.754$ (gradual hazards). A D value approaching 0 would be obtained by making approximately the same number of false alarms as correct detections.

These difference ratios are shown in Fig. 5, and are an alternative to the more traditional measure of sensitivity generated by the application of signal detection theory, whose assumptions are not met by the present data. As has been pointed out by Parasuraman et al. (2000) and by Wallis and Horswill (2007), correct hits (a button press during a hazard) and false alarms (button presses at other times) are readily identifiable only when they form non-over-lapping distributions whereas driving situations regularly present degrees of danger. The calculation of a false alarm rate is straightforward only in that the number of false alarms per movie can be found (the means ranged from 0.15 to 5.97 per movie), but assigning these values to either abrupt or gradual onset hazards is not possible, given that some clips contained both types of hazard. Incorrect misses can be identified simply enough (no button press during a designated hazard window), but a correct rejection also presents a difficulty because it corresponds to the continued absence of a button press when no hazard is being shown, and is therefore not a discrete, measurable event. Correct rejections can be classified on the basis of the opinions of expert drivers, but even then calculation is not straightforward. For example, if the camera car is travelling along an empty country road, with good sight of the road ahead, and no walls or hedges to occlude the possible entry of other road users into the car's path, then it may be reasonable to declare that there are no potential hazards, and so no events to reject. On the other hand, if the car is filming along a busy urban street with cars parked on both sides of the road, and pedestrians walking along both footpaths, then it may be reasonable to declare that there is a huge number of potential hazards that should be rejected. The number of correct rejections will vary from scenario to scenario, and from moment to moment in each scenario depending on the potential for a hazard to develop. For these reasons we opted not to use the measures provided by the fuzzy signal detection theory suggested by Parasuraman et al. (2000) and by Wallis and Horswill (2007), and to rely instead on the ratio of hits to false alarms. The difference ratio D used here makes no assumptions about the hazard-like characteristics of segments of the videos, and records a value between -1 and +1 according to the ratio of hazard detections to other button presses.

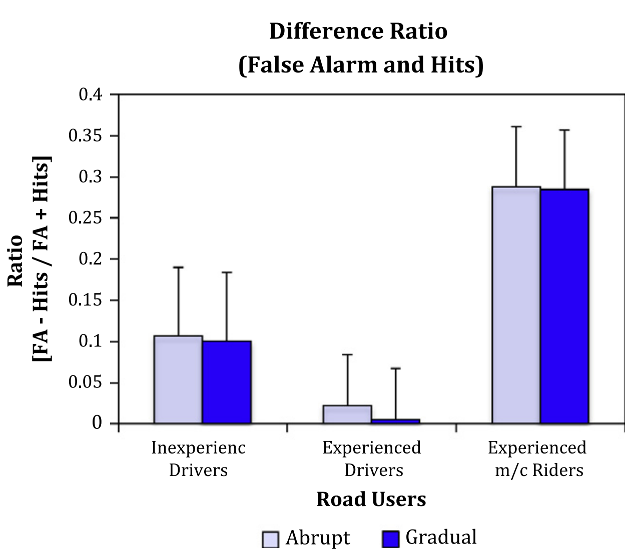

Fig. 5. Difference ratios (means and standard errors) for three groups of road users and for two types of hazards. This ratio takes account of the mean number of button presses made outside of the hazard window, and ranges between +1 and -1, with higher ratios representing larger number of non-hazard button presses relative to the detection of pre-defined hazards.

The difference ratios (D) summarised in Fig. 5 were also submitted to a two-factor ANOVA, which found a main effect of road users ($F(2,90) = 3.40$, $MSE = 1.20$, $p < .05$), with pairwise tests indicating that experienced drivers showed greater selectivity (lower D ratio) than the riders ($p < .01$). There were no other pairwise differences. There was also a main effect of hazard type ($F(1,90) = 8.34$, $MSE = 0.003$, $p < .01$), with abrupt hazards having higher difference ratios than gradual hazards. There was no interaction ($F(2,90) = 2.37$, $MSE = 0.001$) between the two factors.

4. Discussion

We predicted that the road users with more extensive and more varied experience would have an advantage with hazards that tested their anticipation of unfolding events when the precursors of a hazard were visible for a few seconds before evasive action became necessary. There were differences between the road users in their responses to hazards in the roadway videos shown in the experiment, but not the differences that were expected.

The motorcycle riders did not respond to the hazard videos in the same way as either group of car-only drivers. They responded faster to the onset of anticipation hazards than both inexperienced drivers and experienced drivers, confirming an advantage for riders reported previously (Underwood and Chapman, 1998; Horswill and Helman, 2003; Hosking et al., 2010). This difference was only apparent with gradual-onset hazards; abrupt onset hazards did not differentiate between road users, confirming their attention-capturing status. Riders detected as many of the hazards as the other road users, but they tended to make more button-press responses (false alarms) overall, and there was an interesting comparison with the difference ratio D. As can be seen in Fig. 5, riders have higher D scores than the experienced drivers, who did not differ from the inexperienced drivers. The rider-drivers made a larger number of responses during the relatively safer sequences of the videos (Fig. 4), indicating a greater inclination to declare any given situation as being more hazardous than did the drivers. Overall these rider-drivers both responded faster and more often than the other road users, suggesting both greater caution generally and faster detection of actual hazardous situations.

Motorcycle riders are much more likely than car drivers to be involved in a fatal road crash, even though they cover less distance travelled (e.g., National Highway Traffic Safety Administration, 2006; European Transport Safety Council, 2007; Department for Transport, 2010). They are over-represented in the crash statistics, and when they do crash the consequences are more serious for them than for car drivers. As well as needing to be aware of other road users that are generally of greater mass, they also need to be more aware of discontinuities in the road surface than do car drivers. Perhaps it is this vulnerability that results in a cautious viewing of road scenes, with more hazards being perceived by riders than by equally experienced drivers. Following the Pelz and Krupat (1974) analysis we would conclude that the high number of false alarms relative to correct hazard detections indicates that riders are more aware of roadway dangers than other road users. Awareness of their own vulnerability requires riders to have enhanced situation awareness. Shahar et al. (2010, Expt. 1) found a similar result by asking riders and drivers to rate written vignettes that described roadway events. Riders rated the scenes as being more dangerous than did the drivers. There is an apparent inconsistency here, because if this analysis is correct, with the roadway as being perceived as dangerous more by riders than by drivers, then a question is raised by the observations reported by Horswill and Helman (2003). As well as reporting faster hazard detection responses by riders, they also found that riders had more risky attitudes towards high speeds, and had greater tolerance of small gaps when pulling into a line of traffic and when overtaking using a video-presented judgement task. In their on-road observations Horswill and Helman also recorded motorcycles travelling at higher speeds than cars. Acceptance of high riding speed is experience-dependent however, and using a motorcycle simulator, Liu et al. (2009) found more cautious behaviour in more experienced riders. They approached hazards more slowly than inexperienced riders, and crashed at hazards less often. Riders appear to perceive the roadway as being more dangerous and yet their attitudes and behaviours indicate a greater tolerance of risk.

The higher *D* ratios shown by the motorcycle riders here indicates that they were perceiving the roadway as being more hazardous generally than the car drivers, and this is consistent with the report from the motorcycle simulator study by Shahar et al. (2010, Expt. 2), in which riders were judged to be safer as well as more skilful than a matched group of car drivers. The experiences of riders may have resulted in these road users being more sensitive to potential danger. A study of decision-making with photographs of roadway scenes also demonstrates that riders are more cautious than drivers when judging whether it would be safe to enter a main road at a t-junction (Underwood et al., 2011).

One concern of the experiment was to establish whether differences between hazard types had introduced so much variance in previous investigations that inexperienced–experienced driver differences had been lost through a Type 2 error, and we will now focus on differences between the two groups of car drivers. Chapman and Underwood (1998), Crundall et al. (2003), and Sagberg and Bjørnskau (2006) have reported failures to find any difference in the reaction time made in response to the onset of a hazard, whereas other studies have found an advantage for experienced drivers (e.g., Quimby and Watts, 1981; McKenna and Crick, 1991; McKenna et al., 2006; Wallis and Horswill, 2007; Smith et al., 2009). The possibility investigated here is that only gradual-onset hazards that require anticipation would reveal individual driver differences, and that abrupt, attention-capturing hazards would attract similarly fast responses for all road users. The abrupt-onset hazards here certainly attracted faster responses (mean of 1.79 s) than the gradual-onset hazards (3.87 s), and for all drivers the variance estimates were smaller (as indicated by the standard error bars in Fig. 2), but the predicted difference between inexperienced and experienced drivers still did not emerge with either type of hazard.

The second measure of performance was the number of hazards detected (hits), and again there was no difference between inexperienced and experienced drivers. The derived measure *D*, a difference ratio that takes into account the relative numbers of false alarms and correct detections, was intended to identify participants who made large numbers of "hazard" detections. This is related to a pattern reported by Pelz and Krupat (1974), who found that accident- and violation-involved drivers tended to regard all periods of the videos as being safer than did non-involved drivers. On this basis we would expect safer, more experienced drivers to make more button-press responses than the inexperienced drivers, but this pattern was not seen here. It was the motorcycle riders who made high numbers of hazard detections during the safer sections of the videos. Values of *D* were similar for both groups of car drivers, suggesting that they were adopting similar criteria for reporting a hazard. The pattern of inconsistency in reports of hazard detection performance continues then, and we cannot reject the possibility that drivers do not differ in the speed of their responses to hazards of all types. This conclusion lends support to Groeger's (2000) suggestion that hazard perception testing has poor face validity, but it does not explain why some studies have successfully differentiated between inexperienced and experienced drivers on the basis of their responses to hazard videos.

Why should there be an inconsistency in the appearance of the inexperienced–experienced driver effect in the detection of hazards while watching roadway videos? It is important to resolve this problem, given the use of hazard perception elements in national and state driving tests and given that other bodies have the use of hazard perception under review. We need to know whether the detection of hazards does discriminate on the basis of experience and ability, or whether it is an artifact of some other individual difference. It should be noted that the inconsistency in the appearance of the effect is not due to differences in the definition of inexperience, with perhaps only very young or very inexperienced drivers showing impairment. A failure to find a difference has been found in previous studies of drivers with less than a year of experience (Chapman and Underwood, 1998; Sagberg and Bjørnskau, 2006; Borowsky et al., 2010) but other studies have found differences when drivers with up to 3 years of experience were tested (Wallis and Horswill, 2007; Smith et al., 2009; Wetton et al., 2010). The inexperienced drivers tested here had a maximum of 2 years of driving but showed no disadvantage for the detection of either type of hazard, ruling out the experience of inexperienced drivers as the reason that we failed to find the effect. A second possible source of the inconsistency in the inexperienced–experienced driver effect in hazard perception may be associated with differences in visual scanning. There are now a number of reports of inexperienced drivers demonstrating reduced scanning of the roadway and of reduced scanning of videos showing roadway scenes (Crundall and Underwood, 1998; Falkmer and Gregersen, 2001; Underwood et al., 2002, 2003; Borowsky et al., 2010). So if hazard perception videos differ in the *location* of the emergent hazard does this account for inexperienced drivers detecting some hazards more slowly than experienced drivers. If a hazard occurs in the central field – the lead car braking, for example – then there may be a smaller difference between types of drivers compared to the situation when a peripheral hazard such as a pedestrian steps from behind a parked car. As inexperienced drivers scan the roadway less than experienced drivers it is to be expected that they would be slower at detecting hazards approaching from the side of the visual field. Experienced drivers scan the roadway more extensively – while driving and while watching videos – and so they should detect potentially hazardous road users more quickly and more often, Thus if successful reports of a driver difference in the literature have used peripheral hazards and unsuccessful reports have used centrally placed hazards, then this would be one possible explanation of the inconsistency. This possibility requires future investigation.

One final variable may be relevant for future investigations. In a study of young pedestrians Underwood et al. (2007) found no overall difference in male and female recognition of risk in road scenes, although males in the age group under investigation were far more likely to be involved in road accidents. However, they did find a difference in the focus of attention, with males focusing on physical environmental factors while the females centred their attention on people when assessing risk. This difference occurred across age groups, suggesting that gender may be another reason for discrepancies between studies of hazardous risk.

The two kinds of hazards used here successfully differentiated between road users. Abrupt-onset hazards captured attention promptly, with both drivers and rider-drivers responding as quickly and as accurately as each other. The gradual-onset hazards required the anticipation of unfolding events, and were regarded as a test of advanced situation awareness. Motorcycle rider-drivers had an advantage over both groups of drivers in the detection of these hazards, and they also perceived more hazards in relatively safe sections of roadway suggesting that their riding experiences have resulted in an enhanced awareness of roadway dangers.

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