The Hazard Perception Ability of Older Drivers

Mark S. Horswill, Shelby A. Marrington, Cynthia M. McCullough, Joanne Wood, Nancy A. Pachana, Jenna McWilliam, and Maria K. Raikos

1School of Psychology, University of Queensland, St. Lucia, Brisbane, Australia.
2School of Optometry, Queensland University of Technology, Kelvin Grove, Brisbane, Australia.

We investigated the hazard perception ability of older drivers. A sample of 118 older drivers (65 years and older) completed a video-based hazard perception test and an assessment battery designed to measure aspects of cognitive ability, vision, and simple reaction time. We found that hazard perception response times increased significantly with age but that this age-related increase could be accounted for by measures of contrast sensitivity and useful field of view. We found that contrast sensitivity, useful field of view, and simple reaction time could account for the variance in hazard perception, independent of one another and of individual differences in age.

Key Words: Contrast sensitivity—Hazard perception—Useful field of view.

HAZARD perception ability has been suggested to be an important factor in determining crash risk in older adults (Watzke & Smith, 1994). However, there has been relatively little research examining this skill in older individuals. In the context of driving, hazard perception ability, defined as the ability of individuals to anticipate potentially dangerous situations on the road ahead, has been identified as one of the few measures of driving-specific skills that correlate with crash risk (Horswill & McKenna, 2004). It has typically been assessed by measuring response times to hazardous traffic situations presented on film or video (Deery, 1999; McKenna & Crick, 1991; Pelz & Krupat, 1974; Sagberg & Bjornskau, 2006; Watts & Quimby, 1979). Hazard perception tests have been incorporated into licensing procedures in the United Kingdom and in some states in Australia, and the validity of such tests has been demonstrated by means of correlations with crash risk (Hull & Christie, 1992; McKenna & Horswill, 1999; Pelz & Krupat; Quimby, Maycock, Carter, Dixon, & Wall, 1986; Transport and Road Research Laboratory, 1979), differences between novice and experienced drivers (McKenna & Crick; Quimby & Watts, 1981; Sexton, 2000), and correlations between drivers’ hazard perception video test scores and expert ratings of drivers’ performance on real roads (Mills, Hall, McDonald, & Rolls, 1998).

Theoretically, how would hazard perception ability be expected to vary among older drivers? The multifactorial model for enabling driving safety proposed by Anstey, Wood, Lord, and Walker (2005) provides a framework for making such predictions. The model states that driving behavior is predicted by both a driver’s capacity to drive safely and his or her self-monitoring and beliefs about driving capacity. In turn, a driver’s capacity to drive safely is determined by cognition, vision, and physical function. If hazard perception ability maps onto a driver’s capacity to drive safely, then we propose that it is likely to be determined by elements of cognition and vision. This leads to the prediction that, within the older driver population, hazard perception ability is likely to decline with age because of age-related decreases in cognitive and visual function.

What elements of cognition or vision are likely to account for individual differences in hazard perception in older drivers, and why? Horswill and McKenna (1999) found that novice drivers’ reactions to road hazards were slowed significantly by the presence of a secondary verbal task that did not involve either a visual or motor response component, suggesting that hazard perception requires higher level cognitive resources. Taking this one step further, McKenna and Farrand (1999) found that experienced drivers’ hazard perception reaction times were slowed more than novices’ reaction times when the drivers were required to perform a secondary verbal task. This could indicate that experienced drivers gained their hazard perception advantage over novices by applying cognitive resources to a sophisticated and proactive visual search for hazards—an advantage that was diminished once those cognitive resources were diverted elsewhere.

If this is an appropriate model of hazard perception ability, then we would expect age-related deficits in cognitive functioning to have an impact on this ability. The predominant theories to explain these declines include general cognitive slowing (Salthouse, 1996), inhibitory deficits (Hasher & Zacks, 1988), and task-switching deficits (Mayr & Liescher, 2001), all of which may have consequences for hazard perception. For example, slowing of performance will have a direct impact on hazard perception as it is a dynamic task; inhibitory deficits could be important because hazard perception involves identifying relevant cues from irrelevant cues; and task-switching deficits may create problems as hazard perception often involves attending to multiple sources of information.

Visual performance in a population becomes more variable with advancing age, both through the normal aging process as well as through an increase in the prevalence of ocular disease later in life (Haeagerstrom-Portnoy, Schneck, & Brabyn, 1999). Hazard perception involves the processing of visual stimuli, and so factors such as visual acuity and contrast sensitivity may mediate hazard perception ability in older drivers. Drivers are less likely to be able to anticipate hazards effectively if they have difficulty seeing the cues associated with them.

Only two studies that we are aware of (Olson & Sivak, 1986; Underwood, Phelps, Wright, van Loon, & Galpin, 2005) have specifically investigated hazard perception skills in older...
drivers. Both studies found no significant difference in reaction times to hazards between older and younger drivers, but both studies had low sample sizes (15 and 12 older drivers, respectively). When drivers older than the age of 65 years have been tested in larger numbers, it has been as part of a cross-age sample and the data have indicated that hazard perception ability peaks at age 55 and then declines (Quimby & Watts, 1981). However, the decrease in hazard perception ability shown on aggregate for older drivers in this study could be due to specific pathologies in certain individuals rather than representing a normal age-related decline in all older adults. As most older drivers are highly experienced, and driving experience may compensate for age-related deficits, it is possible that healthy older drivers may be able to maintain their hazard perception performance.

The Current Project

In this article we describe research in which we developed and validated a test of hazard perception response time, which was completed by a sample of older drivers who also completed a battery of cognitive and vision tests. Our aims were (a) to confirm that hazard perception declines with age in a sample of older drivers, (b) to determine whether cognitive ability or vision can account for age-related variance in hazard perception in such a sample, and (c) to determine whether cognitive ability, vision, or simple reaction time can account for individual differences in older drivers’ hazard perception. We favored measuring hazard perception response time by using a video-based test rather than an on-road assessment because hazards are relatively infrequent events; participants would have to drive for many hours to encounter the number of hazards that can be presented in a few minutes on a video, and video-based simulation allows for a much higher degree of experimental control than is possible in the real world.

STUDY 1

One key feature of driving is that the context is highly familiar, especially to experienced drivers. It is therefore possible that although older drivers suffer problems with the novel, unfamiliar stimuli generally presented in both vision and psychological tests, they may have fewer problems with familiar driving scenarios.

We considered it important to develop a hazard perception test that was based on situations and locations that would be familiar to our sample of older drivers. Therefore, our first step was to develop a new video-based hazard perception test using everyday road scenes filmed in the vicinity from which our sample was taken and featuring genuine traffic conflicts. However, it was also important to demonstrate that this new hazard perception test yielded the same properties as previous tests. In order to do this, we used McKenna and Crick’s (1991) strategy of determining whether the test could discriminate between a high crash risk and a lower crash risk group, namely novice and experienced drivers (McKnight & McKnight, 2003). This is not a trivial step: Some hazard perception tests have failed to discriminate between these groups, arguably raising questions as to their validity (Crundall, Chapman, Phelps, & Underwood, 2003; Sagberg & Bjornskau, 2006).

We defined traffic conflicts as situations in which a collision or near collision with another road user (including stationery vehicles, cyclists, or pedestrians) would occur unless the driver took some type of evasive action (slowing, steering, etc).

METHODS

Participants

We recruited 17 experienced drivers (over 10 years of driving experience; 10 women and 7 men) and 16 novice drivers (up to 3 years driving experience; 13 women and 3 men); all drivers were from the university (and received course credit) or were friends of ours (no payment given). The experienced drivers (age, M = 41.94 years, SD = 8.51) were significantly older than the novice drivers (age, M = 19.00 years, SD = 1.86); t(30) = 10.54, p < .001. Note that because age and experience are naturally confounded in this sample (as is the case in most studies in the field), it would be inappropriate to draw conclusions regarding the effect of experience independent of age from these data.

Materials

We filmed the scenes for the hazard perception test from the driver’s perspective during daylight hours and under clear weather conditions (we used a Sony DSR-PDX10P video camera, Sony Corporation, New York, NY). We edited 33 potential traffic conflicts into a 23-minute sequence (1.5 incidents per minute). Because our test was designed as a latency measure, we selected all the traffic conflict situations to become eventually unambiguous in order to minimize missing data. In other words, everyone would be expected to respond by the end of the scenario. We used specially developed software to measure participants’ reaction times to these events.

Procedure

Participants were seated 2.7 m from a screen onto which a 1.12 m × 0.93 m image of the hazard perception test footage was displayed by means of a Sony VPL-CS5 data projector. Participants wore headphones through which they could hear the sound recorded from inside the car. First, participants were shown a preliminary video sequence of traffic conflicts that were not used in the final test. We did this to familiarize participants with the footage as well to allow the use of these data as a control group for a hazard perception training package not analyzed in the present article. Participants then completed the hazard perception test, in which they were instructed to press the response button as quickly as possible whenever they anticipated a potential traffic conflict. Traffic conflicts were defined as “situations in which a collision or near collision with another road user (including stationery vehicles, cyclists, and pedestrians) would occur unless you take some type of evasive action (slowing, steering, etc.).” Participants also completed a questionnaire that included demographic information and driving history.

RESULTS

We replace missing values for reaction times to the traffic conflicts (where participants failed to respond to traffic
conflicts) by the group means for that conflict. There was no significant difference between the number of hazards missed by novices (3.7 out of 33) and experienced drivers (3.3 out of 33); $t(31) = 0.41$, ns. A Kolmogorov–Smirnov test indicated that the distribution of mean reaction times did not differ significantly from a normal distribution; Kolmogorov–Smirnov $z = 0.50$, ns. Cronbach’s alpha for the test was $\alpha = 0.78$. The mean hazard perception reaction time of the experienced drivers (2,745 ms, $SD = 381$) was significantly faster than that of the novices (3,168 ms, $SD = 359$), with $t(31) = 3.28$, $p = .003$, and it constituted a large effect size (Cohen’s $d = 1.14$; see Cohen, 1992); this provided evidence for the validity of our test. The effect size was similar to that found for previous tests (McKenna & Crick, 1991).

**STUDY 2**

In Study 2, we examined three key hypotheses: (a) that hazard perception declines with age; (b) that cognitive ability or vision can account for age-related variance in hazard perception in older drivers; and (c) that cognitive ability and vision and performance on a simple reaction test can account for individual differences in older drivers’ hazard perception. To examine these hypotheses, we asked a sample of drivers aged 65 years or older to complete our hazard perception test, together with a battery of measures of cognition and vision, as well as simple reaction times.

The measures of cognitive ability that we included were designed to cover aspects of cognition that have been found to correlate with driving performance or crash risk in previous studies or were considered important for theoretical reasons. Measures of cognitive functioning, such as the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975), have been found to predict both on-road performance (Fitten et al., 1995; Odenheimer et al., 1994) and crash risk (Owsley, Ball, Sloane, Ronken, & Bruni, 1991; Stutts, Stewart, & Martell, 1998). The Trail-Making Tests (Spreen & Strauss, 1991), considered to measure executive function and visual attention, have been found to correlate with crash risk (Goode et al., 1998; Stutts et al.) as well as on-road driving performance (Odenheimer et al.). Both of these measures could influence hazard perception if it is a task that involves running a proactive mental model of the traffic environment and therefore requires high-level cognitive resources (Horswill & McKenna, 2004). Along the same lines, we might also predict that individual differences in measures of fluid intelligence may influence hazard perception.

Groeger (2000) offered a memory-based theoretical account of hazard perception, in which drivers compare a developing traffic situation with previously encountered situations in order to evaluate the level of danger. Alternatively, hazards could be noticed because they are distinctive events that do not map onto an experienced driver’s vast knowledge of nonhazardous driving. Consistent with these predictions, a test of working memory was found to correlate with performance on a video-based measure of drivers’ decisions as to when to pull out across a stream of oncoming traffic (Guerrier, Manivannan, & Nair, 1999), which could be argued to be a hazard perception judgment. In addition, Odenheimer and colleagues (1994) found substantial correlations between on-road driving assessments and measures of both visual and verbal memory in drivers who were older than 60 years of age. Goode and associates (1998) reported that a measure of visual memory could distinguish between crashers and noncrashers. Finally, given the importance of experience to hazard perception (consistent with the memory-based model), it is also possible that crystallized intelligence could play a role in effective hazard detection.

The Useful Field of View Test, in which participants are required to detect peripherally presented targets while attending to a central task, is considered to measure (among other things) cognitive factors such as visual attention (both divided and selective) and speed of processing. It has been found to correlate with crash risk (De Raedt & Onsjaart-Kristoffersen, 2000; Goode et al., 1998; Owsley et al., 1991; Sims, McGwin, Allman, Ball, & Owsley, 2000), on-road performance (De Raedt & Onsjaart-Kristoffersen), and closed-road performance (Wood, 2002; Wood & Troutbeck, 1995). One could argue that the most plausible causal mechanism is that reductions in the useful field of view result in a situation in which individuals are less likely to detect traffic hazards, leading in turn to unsafe driving behaviors and an inflated crash risk.

We also included measures of vision such as contrast sensitivity, which has been found to correlate with crash risk (Owsley et al., 1991) and both closed-road (Wood, 2002; Wood & Carberry, 2006) and on-road (McKnight & McKnight, 1999) driving performance. In addition, we included a measure of simple reaction time because this has been found to correlate with older driver performance in some on-road studies (McKnight & McKnight; Odenheimer et al., 1994).

**METHODS**

**Participants**

We tested 131 community-dwelling drivers who were 65 years of age or older (and who had a minimum of 10 years of driving experience). We recruited the participants either from an older adult research participant pool or from advertisements. We excluded 13 participants from the analysis because of the insufficient number of viewed hazards: Some participants developed motion sickness, so their tests were terminated early. These participants viewed less than 75% of the hazards. Note that motion sickness in simulators is known to be a particular problem for older individuals (Edwards, Creaser, Caird, Lamsdale, & Chisholm, 2003).

We also stopped the hazard perception test early for three individuals who became motion sick but completed over 75% of the test. For these participants, we included the data but we replaced missing values with overall sample means (rather than group means). The analyzed sample ($n = 118$) included 51 women and 67 men (age = 65–84 years; see Table 1 for mean and standard deviation). In response to a question on overall health, all participants rated themselves as at least “fair,” with 88% indicating that their health was either “good,” “very good,” or “excellent.” All participants scored at least 75 out of
100 on the Modified Mini-Mental State Examination (3MS; Teng & Chui, 1987).

Materials

Hazard perception test.—We selected the scenes from the hazard perception test that best discriminated between experienced and novice drivers. We included 17 of the original 33 scenes and filmed 14 new traffic conflicts in an attempt to improve the test stimuli further (31 incidents in total). We used some of the scenes that failed to discriminate between experienced and novice drivers in Study 1 as a 1.5-minute practice. The overall reaction time measure was the mean of all hazards. The 31 hazards were replaced by sample means (3.8 out of 21 hazards were missed on average). There were also 38 missing values (0.01%) in the data set, which were either due to equipment problems or to the 3 participants who terminated the test session (though always in the same location). We recorded participants’ reaction times in milliseconds; we excluded responses more than 2 SD from an individual’s mean over the 16 trials as outliers. The overall reaction time measure was the mean of all the responses not excluded as outliers.

Simple reaction time measure.—We devised a test of simple reaction time, in which participants were required to press a response button as quickly as possible whenever a blue circle appeared in the center of the video screen. There were 16 trials over 1.5 minutes and the circle appeared at random intervals.
test early because of motion sickness but completed over 75% of the test. These missing values were also replaced by sample means (note that we carried out all analyses by excluding all participants with any such missing values, and it made little difference to the pattern of correlations). The raw scores for all variables are found in Table 1. Cronbach’s alpha for the hazard perception test was \( \alpha = 0.85 \).

We transformed the variables to maximize normality where necessary (which, given the sample size, we checked by inspecting histograms) by using either an inverse, square root, or logarithmic transformation. To aid interpretation, we reflected any scales that were reversed by the transformations back to their original orientation.

**Does Hazard Perception Decrease With Age in Older Drivers?**

We found a correlation between age and hazard perception response time, indicating that older drivers were slower at responding to traffic conflicts (Table 1). This correlation was significant (\( p < .05 \)) after we controlled for 30 multiple comparisons (corresponding to the first two columns of correlations in Table 1, i.e., all correlations involving hazard perception, age, and the other variables) with a Bonferroni correction (\( \alpha = 0.05 \), one-tailed tests).

To determine whether the variance between hazard perception and age could be accounted for by our other measures, we performed a hierarchical regression, in which any variable that correlated significantly with both age and hazard perception (after we applied a Bonferroni correction for 30 multiple comparisons) was entered in Block 1, and age was added in Block 2. Two variables, that is, useful field of view with no distracters and contrast sensitivity, fulfilled these criteria. Assumptions required for multiple regression were satisfied. We found that age could not account for unique variance in hazard perception ability once individual differences in useful field of view (no distracters) and contrast sensitivity had been accounted for (Table 2). That is, the declines in hazard perception with age could be accounted for by individual differences in measures reflecting both cognitive ability and vision.

**What Accounts for Individual Differences in Hazard Perception Ability in Older Drivers?**

Applying a Bonferroni correction for 15 comparisons (the number of correlations between all variables and hazard perception; see Table 1), we found that the variables that correlated with hazard perception were contrast sensitivity, useful field of view (no distracters), simple reaction time, and visual acuity (\( \alpha = 0.05 \), one-tailed). It is worth noting that the correlations between hazard perception and the 3MS, Trail-Making Test B, Digit Span and Digit–Symbol subtests, and Useful Field of View Test (full distracters) would also have been significant without the Bonferroni correction for multiple comparisons (many studies in the literature do not appear to apply this correction). This indicates that it may be worth following up the relationship between hazard perception and these variables in a more powerful study (either by using a greater sample size or by limiting the number of comparisons). Note that although the useful field of view measure with distracters appeared to correlate less with hazard perception than the measure without distracters, the difference between the correlation coefficients was not statistically significant, \( t(117) = -1.63 \), \( ns \).

To determine whether the relationship between hazard perception and its significant correlates, that is, contrast sensitivity, useful field of view (no distracters), simple reaction time, and visual acuity, could be accounted for by individual differences in either age or each other, we performed a direct entry regression by using hazard perception score as the dependent variable and age, visual acuity, contrast sensitivity, useful field of view (no distracters), and simple reaction time as independent variables. Assumptions required for multiple regression were satisfied. We found that contrast sensitivity, useful field of view (no distracters), and simple reaction time could account for variance in hazard perception once individual differences in age and all other variables were adjusted for (see Table 3). This is consistent with our proposal that individual differences in hazard perception in older drivers are due to cognitive and vision processes; it also indicates the importance of simple reaction time in this age group. Note that the overlapping 95% confidence intervals for the magnitude of the standardized regression weights of these three variables (Table 3) suggest that there were no significant differences between the sizes of their independent relationship with hazard perception. That is, we cannot conclude that any one of these three predictors had a greater effect on hazard perception than any of the others in the present study.

**General Discussion**

We found that hazard perception ability declines with increasing age, even in a sample of older adults who considered themselves relatively healthy, and that a significant proportion

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<th>Model 1</th>
<th>Model 2</th>
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<td><strong>Standardized Coefficients</strong></td>
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<tr>
<td>( \beta )</td>
<td>( p )</td>
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<tr>
<td>Age</td>
<td>-0.369</td>
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<tr>
<td>Contrast sensitivity</td>
<td>-0.212</td>
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Note: CI = confidence interval; UFOV = Useful Field of View Test. For hazard perception, lower values are better. For contrast sensitivity and the UFOV Test, a higher score is better. The significance of \( R^2 \) change from the null model to Model 1 is <.001; the significance of \( R^2 \) change from Model 1 to Model 2 is .376. For the overall model, the Model 1 \( R^2 \) value is .218; the Model 2 value is .224.
of individual differences in hazard perception in this sample can be attributed to cognitive and vision factors.

One of the variables that had a significant impact on hazard perception performance, independent of other measures, was contrast sensitivity. This finding has implications for a number of issues. These include the timing of cataract removal operations, because a major effect of cataracts is loss of contrast sensitivity and many individuals with cataracts drive for months before having surgery whereas others may elect not to have surgery at all. The finding is also relevant to driver screening, as there have been calls for a minimum level of contrast sensitivity to be required for driving. Finally, there could be road-design implications, because it is possible that creating high-contrast driving environments may improve hazard detection for those with poor contrast sensitivity. For example, Horberry, Anderson, and Regan (2006) reported evidence that higher visibility road markings (which would increase image contrast) improved the driving performance of older adults at night. It could be the case that such marking may have a differentially greater benefit for drivers with poor contrast sensitivity (see McGregor & Chaparro, 2005, for other design improvements that could aid older drivers).

We also found evidence that the useful field of view is important for hazard perception. This provides a mechanism to explain the strong relationship found between crash risk and performance on the Useful Field of View Test (De Raedt & Ponjaert-Kristoffersen, 2000; Goode et al., 1998; Owsey et al., 1991, 1998; Sims et al., 2000), in which a reduction in the useful field of view makes traffic conflicts harder to detect, which in turn impacts crash risk.

As with any simulator study, it is possible to argue that the relationships found between our hazard perception test score and the other measures are an artifact of our testing procedures and may not generalize to hazard perception on the real road, despite the strong evidence for the validity of video-based hazard perception tests. However, we have already outlined the problems involved with the real-world measurement of hazard perception, which we believe makes our approach more appropriate.

If poor hazard perception is a problem for some older adults, then what can be done about it? One possibility is to exploit the hazard perception test as a screening tool to assess fitness to drive in older adults. At the moment, this assessment is often performed by the use of intuitive judgments by medical practitioners. In contrast, the hazard perception test, by using task-specific and realistic stimuli, provides an objective assessment of drivers’ ability to perceive and respond to genuine traffic conflicts. If older drivers are found to perform poorly on hazard perception tests, then it may be possible to develop training interventions specifically aimed at improving their hazard perception skill. Hazard perception ability has been found to be modifiable by both on-road and video-based training (McKenna & Crick, 1997; McKenna, Horswill, & Alexander, 2006; Mills et al., 1998) in novice and more experienced age groups, though to date no one has attempted this with older adults. Such training typically involves having participants watch filmed traffic situations while an expert instructor describes strategies for anticipating hazards; it is possible that such training might benefit older drivers even though they have considerable driving experience. In addition, there is evidence that speed of processing training for older adults can successfully improve performance on a useful field of view test (Ball, Edwards, & Ross, 2007), which may in turn improve hazard perception ability and allow individuals to continue driving without compromising road safety.

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**Correspondence**

Address correspondence to Dr. Mark S. Horswill, School of Psychology, University of Queensland, St. Lucia, Brisbane, QLD 4072, Australia. E-mail: m.horswill@psy.uq.edu.au

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