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# The Effect of Simulated Cataracts on Drivers' Hazard Perception Ability

Cataract extraction is one of the most common surgical procedures accounting for 12% of the entire US Medicare budget.[1] Research shows that the number of people in the US who have undergone cataract surgery has increased by 478% over the last 25 years[2]. Likewise, cataract surgery in Australia has increased over 300% in the last ten years.[3] Importantly, many people live with cataracts for extended periods of time before their operations,[1] and may continue to drive even if their vision does not meet the visual standards for driving. Twenty three per cent of an Australian sample of patients about to undergo cataract extraction surgery were found to be driving illegally due to poor vision.[3]

These findings have implications for road safety as there is growing evidence that older drivers with cataracts are less safe to drive than those without cataracts. US drivers with cataracts were found to have a two and a half times greater at-fault crash rate of an age-matched control group over a five year period[1], even if cataracts were only present in one eye. This is despite individuals with cataracts reporting that they drive less frequently and more slowly than controls.[1] Drivers with cataracts also report experiencing greater difficulty with challenging driving situations.[1] Crash rates for a group of US drivers who underwent cataract extraction surgery were half those of a group of drivers with cataracts who did not elect to have surgery.[4]

While cataracts are known to result in a number of visual changes, including decreased contrast sensitivity, susceptibility to glare, and decreased visual acuity,[1] only contrast sensitivity has been found to be directly associated with increased crash rates.[5] This is consistent with findings that improvements in driving performance following cataract surgery can be predicted by changes in contrast sensitivity.[6, 7] Crash-involved US drivers[5] have been shown to be eight times more likely to have poor contrast sensitivity (Pelli-Robson score of 1.25 or less) in their worse eye than crash-free controls. In fact, static visual acuity (upon which the legal visual standards for driving are almost exclusively based) is a poor measure of loss of visual function due to cataract[8, 9] leading many researchers[8, 10] to call for tests of contrast sensitivity to be used when assessing fitness to drive.

Importantly, the mechanisms underpinning this relationship have received little attention despite the finding that the presence of cataracts and associated reduction in contrast sensitivity increases crash risk in older drivers. One hypothesis is that contrast sensitivity might affect hazard perception ability, which in turns affects crash risk.

Drivers' hazard perception, their ability to anticipate potentially dangerous situations, is the only driving-specific skill that has been found to predict crash involvement across a number of published studies.[11-15] There is a long history of research using hazard perception tests for evaluating driving skill.[12] Such tests usually involve measuring drivers' reaction times to potential dangers presented in filmed road scenes, such as traffic conflicts in which drivers must brake or take evasive action to avoid a collision with another road user.

Hazard perception response times slow after 55 years of age.[16] One possible explanation for this is due to worsening ocular health (for example, a significant proportion of people develop lens opacities and cataracts as well as other eye diseases).[17] Horswill *et al*[18] reported a correlation of -0.42 between contrast sensitivity and hazard perception for a sample of drivers aged over 65 years (lower contrast sensitivity was associated with slower hazard response times) and this relationship could not be completely mediated by other variables such as age, simple reaction time, and the Useful Field of View. However, as this study was correlational, it is possible that the relationship could be a result of unmeasured mediating variables. That is, we cannot conclude that there is a direct causal link between reduced contrast sensitivity and slower hazard perception.

In the present study, we used an experimental design to test for a causal link between reduced contrast sensitivity (as induced by simulated cataracts) and slower hazard perception.

While it has long been known that target visibility affects response times,[19-21] it is not necessarily a foregone conclusion that reduced contrast sensitivity will affect drivers' hazard perception because this skill is known to comprise more than just perceptual ability. There is also a substantial strategic cognitive component. Unlike the abstract stimuli typically presented in laboratory detection tasks, hazard perception involves the anticipation of often predictable targets in a context with which even novice drivers will be highly familiar. For example, it is possible that any slowing in response time due to problems in perceptual object detection could be compensated for by the participant applying more cognitive resources to a pre-emptive search for hazards. This would be consistent with the finding that hazard perception scores are affected by cognitive load.[22]

If we do find that individuals wearing simulated cataract goggles respond slower to hazards than individuals without simulated cataract goggles then it raises the question of precisely why hazard perception is affected by this condition. There is more than one possible candidate mechanism. Hazard perception involves drivers first detecting the presence of potential hazards, such as other road users, and then determining the speed and trajectory of these road users relative to the driver to allow a decision as to whether there is a possibility of a collision. Cataracts could affect this process through both object detection and speed perception. For example, Horswill and Plooy[23] found that a fog effect, which reduced image contrast in a video-based driving simulation, made vehicle speeds appear both slower and harder to discriminate. That is, the reason that drivers with poor contrast sensitivity have slower response times to hazards could be a result of drivers misjudging their own and others' speeds rather than failing to detect other road users in the first place.

We wanted to investigate whether the ability to detect the presence of other road users is affected by the presence of simulated mild and moderate cataracts (independent of speed perception and other factors that might affect their overall ability to anticipate potential traffic hazards). In our experimental design we tested younger drivers rather than older drivers in order to maximize homogeneity in vision status and hence make the experimental groups as equivalent as possible. We employed both a standard hazard perception task as well as a change detection task involving photographs of traffic scenes. The latter task uses a flicker paradigm[24], which has been used previously to investigate object detection in driving[25], participants must locate a single difference between two alternately-presented static images, where the difference is the presence or absence of a road user that represents a potential hazard. Hoffman *et al*[26] developed a similar task, which included safety-relevant changes such as traffic light colours, road users, and traffic signs. They argued that the ability to detect these changes reflected visual attention in driving. Using a sample of drivers aged over 63 years, they found that their change detection task correlated significantly with performance on a driving simulator ($r$ = .41) and visual impairment ($r$ = .23). Such a test allows measurement of a participant's ability to detect the presence of hazard independent of speed perception and other factors that might affect hazard perception scores, such as drivers' response criteria (the level of evidence required by an individual to classify an incident as a hazard).

## Method

### ***Participants***

The sample comprised of 186 participants, with 121 females and 65 males, with an age range of 17-59 years (though note that 83.9% were under age 25). Participants were first year psychology students who received course credit. All participants had normal or corrected-to-normal vision (minimum distance visual acuity was 0.00 logMAR and the minimum Pelli-Robson contrast sensitivity score was 1.85 log units) and all participants reported themselves to be free from eye disease. All participants held a current Australian driver's license, had passed their driving test on average 3.93 years previously (*SD* = 5.08), and reported as a group having driven 10803 km per year (*SD* = 9835) averaged over the previous three years. Participants were randomly assigned into one of three experimental groups: 56 participants completed the experiment wearing goggles without lenses (control group), 60 wore mild cataract simulation goggles, and 70 wore moderate cataract simulation goggles. The unequal group sizes were due to goggle availability (for example, there were more First-Lite goggles than VisTech goggles available to us and so when multiple participants were being tested simultaneously, we were able to test more people in the moderate condition than in the mild condition). Note that because this was a between-subjects design, having unequal group numbers is not a concern. The experiment was approved by the Human Research Ethics Committee of The University of Queensland.

### ***Materials and Apparatus***

*Cataract Simulation Goggles:* The mild cataract simulation goggles were obtained from VisTech Consultants Inc. (Dayton, Ohio, USA) and the moderate cataract simulation goggles were produced by Good-Lite (www.good-lite.com). The goggles were worn over participants' own distance spectacles where necessary. The VisTech goggles have been found to replicate the effect of real cataracts in previous work, in that they possessed a "similar angular distribution of light scatter as real cataract on clinical (visual acuity, contrast sensitivity, and disability glare) and real world vision (face recognition, reading speed, and mobility orientation)" (Elliott *et al.*, 1996, p. 799).[27] Similar data does not exist for the Good-Lite goggles, so we assessed contrast sensitivity in three participants with normal vision. Contrast sensitivity functions for both sets of goggles and for no goggles can be seen in Figure 1. The Good-Lite goggles resulted in a larger reduction in contrast sensitivity than the Vistech goggles but the pattern of results was similar, with both sets of simulated cataract goggles reducing contrast sensitivity at low and intermediate frequencies as well as at high spatial frequencies as has been shown for participants with real cataracts.[28, 29] The effect of the goggles on visual function was estimated using the Pelli-Robson Letter Sensitivity chart[30] and the logMAR distance acuity chart (NVRI, Melbourne, Australia). Six individuals from the same population as the main sample were tested with the control goggles and the mild cataract goggles. Another five similar individuals were tested with the control goggles and the moderate cataract goggles. Table 1 shows the effects of the goggles on both visual acuity and contrast sensitivity.

*Simple spatial reaction time control measure:* We devised a test of simple spatial reaction time to check that there were no significant between-group differences in computer mouse accuracy. Participants were required to click on black squares of differing sizes that appeared at random intervals and locations on the screen using the computer mouse. This task was designed to be analogous to the two hazard tasks but without the traffic stimuli. There were 36 trials over 2.5 minutes. The overall reaction time measure was the mean of all the responses (excluding any missing values).

*Hazard Perception Test:* The Hazard Perception Test was 17 minutes in duration and contained 55 measured hazards. Drivers viewed unstaged Queensland road scenes filmed from the driver's perspective and were required to use a computer mouse to click on any road users who represented a potential traffic conflict. A traffic conflict was defined as any situation in which the camera car had to brake or take evasion action to avoid a collision with another road user (for example, a pedestrian crossing the road). The validity of this test has been demonstrated through its ability to discriminate between novice and experienced drivers[31] and the test's reliability (Cronbach's alpha) was found to be .90[31]. The luminance and root mean square contrast of the display was estimated by dividing the screen into a 5 x 7 grid and taking a luminance reading from each of the 35 cells every 20th frame using a Konica Minolta LS 110 luminance meter. The mean luminance was estimated to be 21.11 cd $m^{-2}$ and the root mean squared contrast was 26.57 cd $m^{-2}$.

In order to gain a sense of how our stimuli compared with actual driving, the luminance of a range of real world road scenes was also measured. For 13 scenes in bright daylight, the mean luminance was found to be 2379.84 cd $m^{-2}$ and the root mean square contrast was 2107.84 cd $m^{-2}$. However, for 13 low light evening scenes, the mean luminance was found to be 1.10 cd $m^{-2}$ and the root mean square contrast was 0.86 cd $m^{-2}$. That is, while the computer monitor, not surprisingly, could not achieve the levels of brightness and contrast observed in naturalistic scenes in bright daylight, the readings from our video stimuli are nonetheless within the range that might be encountered during real driving if one takes into account lower light conditions.

*Hazard Change Detection Task:* We devised a hazard change detection task to measure the ability to detect the presence of hazards independent of speed and other factors such as individual differences in what was considered to represent a hazard. The task involved participants viewing pairs of alternating images of traffic scenes, in which one image in each pair contained a hazard while in the other image the hazard had been removed. Participants were instructed to detect the difference between each pair of images. They were informed that only one hazard would be removed per image pair (either a car, pedestrian, cyclist, bus, or an open car door). Each image was presented for 250ms and was followed by a 80ms grey mask. Participants were asked to click on the single difference between the two images as soon as they detected it. The images were alternated repeatedly until a response was made or until 32 seconds had elapsed. Five practice trials were used to acquaint the participants with the procedure and the test itself consisted of 59 trials. The dependent variable was the time taken for participants to find the difference between the images. The luminance and root mean square contrast of the display were estimated using a similar technique to the hazard perception test (35 readings per frame were taken from the image with the hazard from every third trial). The mean luminance was 26.57 cd $m^{-2}$ and the root mean squared contrast was 20.34 cd $m^{-2}$.

### *Procedure*

Between 1 and 6 people were tested at a time. Binocular static visual acuity was tested using the logMAR distance acuity chart (NVRI, Melbourne Australia) at a viewing distance of 3.8 meters and contrast sensitivity was determined using the Pelli-Robson Letter Sensitivity Chart (1 meter viewing distance) and scored on a letter by letter basis[30]. Participants were first allowed to familiarize themselves with the computer mouse (they were asked to click through an array of numbers). Then they completed the simple spatial reaction time task (without goggles).

The hazard perception test and the hazard change detection task were completed wearing goggles (either no cataract, mild cataract, or moderate cataract). Half the participants in each group completed the hazard perception test followed by the hazard change detection task and the other half completed the tests in the reverse order.

## Results

There were no significant differences between the three experimental groups for time since they passed the driving test, the number of kilometers driven per year (previous 3 years), visual acuity, contrast sensitivity, and simple spatial reaction time (non-parametric tests were used as the variables were skewed).

For hazard perception test responses, missing values for each scene were replaced with overall means (not group means) for that particular scene. This was a conservative strategy, favoring the null hypothesis. Note that we also tried replacing misses with group means (a less conservative strategy) and found that this did not affect the pattern of results. There were no significant between-group differences in the number of misses.

For hazard change detection responses, missing values were replaced with the maximum value for the scene (32 seconds). This strategy was used because in the change detection task it was considered unambiguous that a missing response indicated a failure to detect the hazard (in contrast to the hazard perception test, where a missing response could indicate that participants saw the hazard but did not consider it sufficiently hazardous to warrant a response). Note that we tried replacing misses with means in the change detection task and it made no difference to the pattern of results. There was no significant difference in number of misses between the control and mild cataract simulated cataract groups on the change detection task but a significant difference was found between the control and moderate simulated cataract groups, $t(77.24) = -7.508$, $p < .001$, which is discussed below.

The reliabilities (Cronbach's Alpha) of the simple spatial reaction time test, the hazard perception test, and the hazard change detection task were .95, .90, and .88 respectively. An alpha level of .05 was used for all inferential statistics.

An inverse transform was used on the hazard change detection response time to minimize skew and the transformed scale was then reflected back to its original orientation. In order to provide some evidence of the validity of our hazard change detection task, we carried out a partial correlation with the previously-validated hazard perception test, controlling for simple spatial reaction time. We found that change detection response times correlated with hazard perception response times, $r(183) = .303$, $p < .001$ (note that, in this calculation, simple spatial reaction time was inverse transformed to minimize skew).

The hypotheses were tested using planned comparisons (effect sizes are expressed as *Cohen's d,* which is the difference between the means in units of the within-population standard deviation).[32] For the hazard perception test, there was no significant difference between the no simulated cataract and the mild simulated cataract condition, $t(114) = -1.33$, $p = .19$, *Cohen's d* = 0.24, but those with moderate simulated cataracts were significantly slower than the no simulated cataracts group, $t(98.50) = -3.71$, $p < .001$, *Cohen's d* = 0.69 (see Figure 2). For the hazard change detection task, those without cataract lenses were significantly faster than both those with mild simulated cataracts, $t(114) = -4.04$, $p < .001$, *Cohen's d* = 0.75, and those with moderate simulated cataracts, $t(124) = -13.86$, $p < .001$, *Cohen's d* = 2.49 (see Figure 3). Note that where fractional degrees of freedom are reported, this is because a Levene's test indicated that group variances were unequal, and hence a Welch's *t* test was used instead.

## Discussion

In this study we found that both mild and moderate simulated cataracts significantly slowed hazard detection response times as assessed using a change detection task, while moderate though not mild simulated cataracts slowed participants' ability to anticipate hazardous situations in a validated video-based hazard perception test. This provides evidence for a direct causal effect of simulated cataracts on drivers' hazard perception response latencies and suggests that the ability to detect safety-relevant objects in a traffic scene, independent of object motion, is a key component underlying this relationship.

We also found some evidence to support the validity of our new hazard change detection task in the form of a correlation between change detection responses and hazard perception scores, controlling for response mode (where the hazard perception test has been previously validated). This is consistent with previous findings that traffic-based change detection performance correlated with performance in a driving simulator.[26] We also found a significant increase in misses for the hazard change detection task between the no simulated cataract and the moderate simulated cataract. This indicates that, for some trials, a higher proportion of participants wearing moderate cataract goggles were unable to detect the hazard within 32 seconds, which maps onto the response time results.

Our previous finding,[18] that hazard perception correlates with contrast sensitivity in a sample of older drivers, provides some evidence that the effects found in the present study are likely to generalize to genuine, long-term variations in contrast sensitivity in older drivers. That is, while the findings of both studies have limitations (correlational study of older adults with long-term contrast sensitivity decrements versus experimental study on younger drivers wearing temporary filters), both sets of results point to the same conclusion: that reduced contrast sensitivity (both long term and temporary) affects drivers' hazard perception, an ability known to correlate with crash risk.

The findings from the present study raise some important questions. First, why did the change detection task appear to be more affected by simulated cataracts than the hazard perception task, given that the former was conceptualized as a component of the latter? There are a number of possible explanations. It is likely that a wider range of factors determine performance in the hazard perception task, some of which are less likely to be affected by contrast sensitivity (hence resulting in a greater amount of between-subject variance not associated with reduced contrast sensitivity), such as individual differences in response bias (the threshold at which an incident is classified as a hazard and hence warrants a response: see Wallis and Horswill[33] for a discussion of response bias and hazard perception). In addition, the hazard perception task involved moving stimuli and therefore the motion itself might have provided additional cues to aid hazard detection that were not available in the change detection task.

A further, related, question is why we did not find an effect on hazard perception for mild simulated cataracts, when Horswill *et al*[18] found a significant relationship between hazard perception and contrast sensitivity for a sample with a mean Pelli-Robson score of

1.71 (*SD* 0.1). This indicated that participants, overall, had minimal impairment (substantially less than that introduced by even our mild cataract goggles). The discrepancy between the findings of the two studies could be a result of mediating variables affecting the hazard perception/contrast sensitivity relationship in the correlational study or a result of the younger sample used in the present experiment (it could be that there is an age/simulated cataract interaction, whereby even simulated cataracts affect older drivers with normal vision more than younger drivers with the same level of vision). Also, unlike real cataracts, which develop over a long time period, the simulated cataract goggles resulted in an immediate change in contrast sensitivity. That is, the smaller hazard perception effect size we found for younger drivers with temporary reductions in contrast sensitivity compared with older drivers with long term contrast sensitivity suggests that the present study may be underestimating the true effect of cataract on hazard perception.

While our stimuli were realistic in the sense of using video-based or photographic footage of genuine driving incidents, they were not perceptually identical to the equivalent real world scene. For example, the video stimuli were displayed with lower levels of luminance and image resolution than would be experienced in bright daylight in the real world (despite depicting daytime scenes). Also our display mode does not exactly replicate the real world effects of glare. However, as demonstrated, the mean luminance and contrast of our display is within the range that might be encountered in real driving if one takes into account lower light conditions. Of course, it could be that in some real life situations dynamic ranges would be greater than in our stimuli and this would affect how easily the hazards might be detected. That is, the effect sizes found in our present study may only generalize to real life situations with dynamic ranges similar to those found in our stimuli (that is, lower light conditions).

It is also important to note that the hazard perception test does have demonstrated validity (the scores on the test we used reflect novice/experienced driver differences and previous similar tests have been found to correlate with real life crash risk[11, 13] and driving instructors' rating during driving in real traffic[12]). Nonetheless, the issue of realism is shared with any simulator-based approach and hence our estimates of the magnitudes of the effects should be regarded as an approximation.

It should be noted that running an equivalent experiment under real world driving conditions would be extremely difficult. Implementing a hazard perception test in real traffic would involve deliberately exposing participants to dangerous situations. In addition, the video-based testing approach allows a high frequency of traffic hazards to be presented (we estimate that drivers would have to travel for about 50 hours to experience a similar number of traffic hazards as are present in our twenty minute test and, even then, these hazards would not be controlled across participants). Also it could be argued that the more abstract stimuli used in standard vision and neuropsychological tests, which are commonly used to judge fitness to drive, are even further removed from real driving.

In future studies, it would be desirable to measure the effect of the goggles for every participant, rather than estimate the aggregate effects, as the goggles could plausibly have different effects for different people. This would allow for more accurate measurement of effect sizes.

Notwithstanding these limitations, we found that moderate levels of simulated cataract, which resulted in vision that satisfied the visual acuity requirements for legal driving, significantly slowed hazard perception. Of course, a significant effect does not necessarily mean that the effect size was large enough to be important in a road safety context. To gain a sense of the importance of the effect sizes found in the present experiment, we referred to our finding that moderate simulated cataracts slowed drivers' hazard perception response times by 351 milliseconds. This was calculated to be equivalent to 5.85 meters of travel for a driver travelling at 60 kilometers per hour, which plausibly maps onto the difference between having and not having a collision (note that a similar calculation relating to the change detection task would be inappropriate as these response times were not in the context of a dynamic stimulus).

Our findings have a number of implications. First, they raise the possibility that drivers who may meet the current legal standards for driving (based on visual acuity), may be at increased crash risk due to impairments in their ability to detect traffic hazards (especially if one also takes into account the correlation between hazard perception and crash involvement[13], the correlation between contrast sensitivity and crash involvement,[1] and the correlation between contrast sensitivity and hazard perception).[18] This supports the call by some researchers to introduce minimum vision standards for driving based on contrast sensitivity[8, 10]. Second, it is known that many individuals with cataracts continue to drive for months before having cataract surgery (and others may decide not to have surgery at all). Our data suggests that the link between cataracts and elevated crash risk may be due in part to impairments in hazard perception ability. This highlights the importance of performing cataract operations as soon as possible if individuals wish to continue driving. There are also possible consequences for road design (it is possible that creating high contrast driving environments may improve hazard detection for those with poor contrast sensitivity). It is also possible that drivers could be given anticipation training of the type developed by McKenna *et al*[34] where they could be taught to compensate for their reduced contrast sensitivity by predicting where hazards are likely to occur.

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## References

**1.** Owsley C, Stalvey B, Wells J, Sloane ME. Older drivers and cataract: Driving habits and crash risk. *Journals of Gerontology Series A: Biological Sciences and Medical Sciences.* Apr 1999;54(4):M203-M211.

**2.** Erie JC, Baratz KH, Hodge DO, Schleck CD, Burke JP. Incidence of cataract surgery from 1980 through 2004: 25-year population-based study. *Journal of Cataract and Refractive Surgery.* Jul 2007;33(7):1273-1277.

**3.** Pager CK, McCluskey PJ, Retsas C. Cataract surgery in Australia: a profile of patient-centred outcomes. *Clinical and Experimental Ophthalmology.* Aug 2004;32(4):388-392.

**4.** Owsley C, McGwin G, Sloane M, Wells J, Stalvey BT, Gauthreaux S. Impact of cataract surgery on motor vehicle crash involvement by older adults. *Journal of the American Medical Association.* Aug 21 2002;288(7):841-849.

**5.** Owsley C, Stalvey BT, Wells J, Sloane ME, McGwin G. Visual risk factors for crash involvement in older drivers with cataract. *Archives of Ophthalmology.* Jun 2001;119(6):881-887.

**6.** Wood JM, Mallon K. Comparison of driving performance of young and old drivers (with and without visual impairment) measured during in-traffic conditions. *Optometry and Vision Science.* May 2001;78(5):343-349.

**7.** Wood JM, Carberry TP. Older drivers and cataracts: Measures of driving performance before and after cataract surgery. *Transportation Research Record.* 2004;1865:7-13.

**8.** Wood JM. Age and visual impairment decrease driving performance as measured on a closed-road circuit. *Human Factors.* Fal 2002;44(3):482-494.

**9.** Wood JM, Troutbeck R. Elderly Drivers and Simulated Visual Impairment. *Optometry and Vision Science.* Feb 1995;72(2):115-124.

**10.** McCarty CA, Keeffe JE, Taylor HR. The need for cataract surgery: projections based on lens opacity, visual acuity, and personal concern. *British Journal of Ophthalmology.* Jan 1999;83(1):62-65.

**11.** Quimby AR, Maycock G, Carter ID, Dixon R, Wall JG. *Perceptual abilities of accident involved drivers.* Crowthorne, UK: Transport and Road Research Laboratory; 1986.

**12.** Horswill MS, McKenna FP. Drivers' hazard perception ability: Situation awareness on the road. In: Banbury S, Tremblay S, eds. *A cognitive approach to situation awareness: Theory and Application*. Aldershot, UK: Ashgate; 2004:155-175.

**13.** McKenna FP, Horswill MS. Hazard perception and its relevance for driver licensing. *Journal of the International Association of Traffic and Safety Sciences.* 1999;23(1):26-41.

**14.** Hull M, Christie R. Hazard perception test: The Geelong trial and future development. Paper presented at: National Road Safety Seminar, 1992; Wellington, New Zealand.

**15.** Drummond AE. Paradigm lost! Paradigm gained? An Australian's perspective on the novice driver problem. Paper presented at: Novice Driver Conference; 1-2 June, 2000; Bristol.

**16.** Quimby AR, Watts GR. *Human factors and driving performance.* Crowthorne, UK: Transport and Road Research Laboratory; 1981.

**17.** Haegerstrom-Portnoy G, Schneck ME, Brabyn JA. Seeing into old age: Vision function beyond acuity. *Optometry & Vision Science.* 1999;76:141-158.

**18.** Horswill MS, Marrington SA, McCullough CM, et al. The hazard perception ability of older drivers. *The Journal of Gerontology: Psychological Science.* In press.

**19.** Breitmeyer BG. Simple reaction time as a measure of temporal response properties of transcient and sustained channels. *Vision Research.* 1975;15(12):1411-1412.

**20.** Harwerth RS, Levi DM. Reaction time as a measure of suprathreshold grating detection. *Vision Research.* 1978;18(11):1579-1586.

**21.** Plainis S, Murray IJ. Reaction times as an index of visual conspicuity when driving at night. *Ophthalmic and Physiological Optics.* Sep 2002;22(5):409-415.

**22.** Horswill MS, McKenna FP. The effect of interference on dynamic risk-taking judgments. *British Journal of Psychology.* 1999;90(5):189-199.

**23.** Horswill MS, Plooy AM. Reducing contrast makes speeds in a video-based driving simulator harder to discriminate as well making them appear slower. *Perception.* In press.

**24.** Rensink RA, Oregan JK, Clark JJ. To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science.* Sep 1997;8(5):368-373.

**25.** Wallis G, Bulthoff H. What's scene and not seen: Influences of movement and task upon what we see. *Visual Cognition.* Jan-Mar 2000;7(1-3):175-190.

**26.** Hoffman L, McDowd JM, Atchley P, Dubinsky R. The role of visual attention in predicting driving impairment in older adults. *Psychology and Aging.* Dec 2005;20(4):610-622.

**27.** Elliott DB, Bullimore MA, Patla AE, Whitaker D. Effect of a cataract simulation on clinical and real world vision. *British Journal of Ophthalmology.* Sep 1996;80(9):799-804.

**28.** Hess R, Woo G. Vision Through Cataracts. *Investigative Ophthalmology & Visual Science.* 1978;17(5):428-435.

**29.** Elliott DB. Evaluating Visual Function In Cataract. *Optometry and Vision Science.* Nov 1993;70(11):896-902.

**30.** Pelli DG, Robson JG, Wilkins AJ. The Design of a New Letter Chart for Measuring Contrast Sensitivity. *Clinical Vision Sciences.* 1988;2(3):187.

**31.** Smith SS, Horswill MS, Chambers B, Wetton M. The effect of sleepiness on young novice and older experienced drivers’ hazard perception. *Sleep.* Under review.

**32.** Cohen J. A power primer. *Psychological Bulletin.* 1992;112(1):155-159.

**33.** Wallis TSA, Horswill MS. Using fuzzy signal detection theory to determine why experienced and trained drivers respond faster than novices in a hazard perception test. *Accident Analysis and Prevention.* Nov 2007;39(6):1177-1185.

**34.** McKenna FP, Horswill MS, Alexander JL. Does anticipation training affect drivers' risk taking? *Journal of Experimental Psychology-Applied.* Mar 2006;12(1):1.

## Figure Legends

Figure 1

*Contrast sensitivity functions for no simulated cataract, VisTech mild simulated cataract goggles, and First-Lite moderate simulated cataract goggles.*

Figure 2

*Group differences (no/mild/moderate simulated cataract) in mean response latency on the hazard perception test (error bars are standard errors of the mean)*

Figure 3

*Group differences (no/mild/moderate simulated cataract) in mean response latency on the hazard change detection test (error bars are standard errors of the mean). Note that untransformed values are presented to aid interpretation (note that the same pattern of results was found with and without the inverse transformation).*

Table 1

*Estimation of the mean effect of the cataract simulation goggles on visual acuity and contrast sensitivity (SD in brackets)*

| | Mild cataract goggles (*n* = 6): | | Moderate cataract goggles (*n* = 5): | |
|---|---|---|---|---|
| | Without goggles | With goggles | Without goggles | With goggles |
| logMAR acuity score | -.07 (.05) | -.02 (.06) *ns* | -.09 (.02) | .09 (.02)* |
| Contrast sensitivity (log units) | 1.88 (.05) | 1.53 (.07)* | 1.87 (.05) | 1.18 (.06)* |

*ns* Without goggles/with goggles difference not significant (paired t-test), *p* > .05

* Without goggles/with goggles difference significant (paired t-test), *p* < .001