Increasing Senior Driver Safety through Vision Tests and Education - A Community Based Program.

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AIMS
This paper reports on the correlation between driver's opinions of their driving ability generally as well as in vision based driving situations with clinical test responses for vision. This paper will also explore the relationship between visual sensitivity and driving behaviours such as the numbers of days per week spent driving to see if drivers adapt to be safer.

CONTENT
The paper reports on the outcome from a detailed visual assessment, which is one segment of a community based Senior Driver Education Program supported by three Shire Councils in NSW and facilitated by a Driver & Work Safety Consultant. At the initial session, each driver undertook a vision assessment and responded to a questionnaire about preferred driving situations and a personal opinion of their driving skills. The vision assessment included basic tests that screen to determine whether the licensing standard has been met (central acuity, peripheral vision and detection of double vision) and tests that investigated a greater range of vision skills (contrast sensitivity, depth perception and the impact of reduced light on vision performance). The outcomes were correlated with the response from the questionnaire.

RESULTS
The results show that whilst the response for screening tests remained at a pass standard, there was a decrease in vision sensitivity in the senior drivers and that this was related to decreased comfort in some driving circumstances, such as driving in heavy traffic and speeds over 60 kilometres per hour. Anecdotal responses indicated that some senior drivers who had decreased visual sensitivity, modified their driving pattern to avoid driving in those circumstances. Senior drivers were pleased to know that their vision could be contributing to the problem and accepted the recommendation that they modify their driving pattern.

CONCLUSION
The physical vision response changes with age and has been found to be associated with driver reported difficulties in some driving situations. Senior drivers, who are informed of their vision status can be supported to manage their driving behaviour to support safe driving practice.

INTRODUCTION

In drivers over the age of 70 years there is a general increase in the incidence of accidents [1, 2]. As a consequence there is concern about the safety of senior drivers and a need to decrease the accident rate. Whilst the factors associated with accidents are complex, including an increase in the level of urban driving, physical frailty, and for a small proportion, reduced fitness to drive, when figures are adjusted to take into account the number of accidents over the amount of distance travelled then older drivers appear to be over-involved in serious injury and fatal crashes.[3]

Research has reported a link between crash frequency and decreased responses for visual acuity and more subtle vision responses such as night vision, contrast sensitivity, stereopsis (level of depth perception), visual field sensitivity and colour discrimination [4, 5]. Packer reported that as people age there is a normal physiologic decline in contrast sensitivity and functional vision. This decline may cause problems in complex traffic situations resulting in crashes [6]. What is not known is the relationship between current vision standards for drivers, actual vision skills across a wider range of clinical responses, age related changes in vision, and driver performance on-road.

The vision standards in Australia require a set level of visual acuity of 6/12, peripheral vision of 120 degrees across and 10 degrees above and below the horizontal meridian of the test plot and no double vision[7]. Drivers of any age who hold a license must have a minimum acuity standard of 6/12 and are screened at first application, at regular intervals, or at age-related intervals by many Australian licensing authorities to ensure this standard is present. Peripheral vision and double vision are detected as part of a regular medical test, especially in the presence of systemic diseases, and drivers with defects are excluded from driving. If all vision defects are detected clinically, then traffic accidents reported should not be related to vision problems, unless the problems are in some way subtle and have an impact on the drivers' performance.

Outside Australia, some vision standards include other more sensitive tests of visual function. Countries such as Belgium have a minimum driving standard for twilight (mesopic) vision[8]. Research has demonstrated that tests such as contrast sensitivity, Useful Field of View (which assesses visual attention and higher order attention skills), and cognitive status assessments show that older drivers who have a decreased response in the detection of stimuli are linked to an increased accident rate[9].

An additional issue is the actual skill as self-reported by the driver. During conventional clinical practice, senior drivers report that their vision is not at a high level, particularly at dusk, in the wet and at night. When the clinical responses indicate that they are within the required standard they drive, but with potentially less confidence. The relationship between the subjective reports of vision skills and tests that examine more sensitive vision functions could establish a link between decreased vision and self-reported decreased driving confidence. Drivers with decreased skills can be supported to modify their driving behaviours to ensure they drive at times when their vision is operating at the best level and support safe driving practice. Safe driving practice can include driving at times of the day when vision is optimal by avoidance of dusk or dawn and avoidance of certain situations such as undercover car parks.

The aim of this study is to investigate a link between early changes in vision function and driver self-reported identification of decreased confidence and reduced driving comfort. Particular emphasis will be given to the assessment of subtle vision skills such as contrast sensitivity, vision in reduced light levels (mesopic vision), stereopsis (level of depth perception) and colour vision.

METHODS

The study was conducted in NSW and drivers 60 years and older were invited to participate in a driver education program provided by a Shire Council in NSW, and designed and facilitated by a Driver and Work Safety Consultant. The program extended over three days in consecutive weeks. Day 1 included self evaluation of driving skills, answering a questionnaire, testing vision and hearing, knowledge of rules of the road and on road driver performance. Day 2 provided education and information for the participants for driving behaviour change assisting with concrete measurable guidelines. Day 3 included re-assessment of on road driving performance and evaluation of driving behaviour change.

Participants were provided with an information sheet and signed a consent form. They completed a questionnaire which explored their opinion about various vision based scenarios that occurred in the driving situation. A summary of the questions is shown in Table 1. Participants were asked to identify their response to the questionnaire by circling the appropriate answer on a four point Likert scale (N/A; never; sometimes; mostly or always). Participants were also asked to self-rate their driving ability between 1 and 5, where 1 equals poor driving skills and 5 equals excellent driving skills.

Table 1 Questionnaire Content

Question	Sub Questions (with Likert scale)
1. How often do you drive:	Less than 1 day/week; 1 day/week; 2-3 days/week; 3-7 days/week; everyday (no Likert scale for this question)
2. I have difficulties driving in the following conditions	Busy roads/heavy traffic; particularly sunny days; Poor light; Rain; Night; speed limits over 60 km/h.
3. I am confident driving in the following conditions	Busy roads/heavy traffic; particularly sunny days; Poor light; Rain; Night; speed limits over 60 km/h.
4. When driving in the day time I have difficulty:	Reading the license plates of cars in front of me; Reading road signs; identifying road markings; noticing traffic lights.
5. When driving on a particularly sunny day I:	Find the glare bothersome; find reflections off other cars distracting; screw up my eyes; shut an eye; drive slower.
6. When driving during the day I find:	Brake lights of the cars in front of me are not bright enough; Traffic lights are not bright enough; vehicle traffic indicators are difficult to see.
7. When driving during the day	I am unaware of vehicles approaching from the side; I am unaware of pedestrians approaching from the side; I am aware that at intersections I scan more fully in both directions than I used to.
8. During night driving I find	The head lights of oncoming traffic bothersome; the instrument panel is not bright enough; headlights in the rear view mirror are bothersome.

The vision assessment was undertaken on the first day of the course using conventional clinical tests in standard room illumination to provide a baseline of vision results, and some tests were repeated in reduced light levels which in this study were identified as mesopic test procedures. The visual assessment included six stages:

1. Visual acuity was first tested at 6 metres monocularly to detect vision defects and determine whether the licensing standard had been met. Secondly, it was tested binocularly to parallel the vision level used in the on-road situation.
2. Visual acuity was tested at 3 metres binocularly to test the acuity level at the same distance at which the contrast sensitivity test is conducted, and also to explore the participant's ability to detect information just outside the vehicle e.g. road markings. This test was performed in standard light (photopic) and reduced light (mesopic).
3. Near vision was tested binocularly at 3 metres to assess the level of vision needed for reading the instrument panel.
4. Contrast sensitivity was tested binocularly in standard (photopic) and reduced (mesopic) light. Contrast sensitivity measures the ability to discriminate different sized objects within a competitive background and is a visual function test that parallels daily life experiences. The test presents plates at different frequencies or stimulus sizes: row A, with a low frequency, represents a large stimulus and row E, with a high frequency, represents a small stimulus. The contrast level for each row varies from level 1, which is a high black on white differentiation, to level 8, which is a low grey on grey differentiation.
5. Ocular posture, eye movements and stereopsis (the level of depth perception) were assessed, to ensure the licensing requirement of no double vision was met.
6. Peripheral vision was assessed by confrontation to reveal the presence of any gross defects. Confrontation visual field is a simple test where the person being examined covers one eye and stares at the examiner sitting opposite. The examiner brings their fingers in from the periphery and waits for a response from the person who indicates when it is first seen, a comparison is made to the examiners visual field to assess if it is normal and full or abnormal.

Mesopic testing conditions require 1 lux to be reflected from an optotype (a standardised symbol for testing visual function). This was achieved by placing a 15 watt light globe four meters from the optotype[8]. For the purpose of this study the optotypes included a reduced 3 metres Snellen's chart and the VISTEC contrast sensitivity chart, which was tested at 3 metres as stated by the manufacturer.

The on-road test was undertaken in a suburban environment (including suburban streets with speed of 50 km/h, small shopping centres and multilane roads), with qualified driving instructors who gave an overall score of the driving safety performance based on their ability to travel safely, independently and to interact with the driving public, and recommendations were made for driver remediation. The score was on a scale of 0 to 5 where 0 equals a hazardous driver and 5 equals perfect driving. All participants were licensed drivers, indicating that, at the last renewal of their license, they met the National Licensing authority vision standard of reading 6/12.

RESULTS

1. Participants
Forty seven drivers volunteered to participate. There were 24 females (51%) and 23 males (49%). The ages ranged between 61 and 87 (mean age 76 years).

2. Drivers Opinions
Most drivers self ranked their own driving skills with an 'average' ranking at level 3 of its 5 point scale (n= 17, 37%) or 'above average' ranking at level 4 (n= 15, 33%). The participants' responses to the questionnaire revealed that they had reduced confidence when driving at night (55%), in reduced light (36%) rain (38%), and on particularly sunny days (22%). Participants also responded that they had difficulty driving at night (20%), in reduced light (28%), rain (15%) and on particularly sunny days (5%).

3. Vision Results
In this group of participants the response to peripheral field assessment was normal. Colour vision was normal for 98% of the participants. Two demonstrated minor defects (plate 7/8) Ocular motility results revealed one participant had an eye turn (strabismus) at near viewing only, otherwise full binocularity was present. All participants showed a full and accurate range of ocular movements.

Snellen's visual acuity results were converted to a degree equivalent, to enable a better comparison with other results. Snellen's 6/3 equated to 0.04167 degrees, 6/6 to 0.08333 degrees, and 6/60 to 0.8333 degrees with the results in ratio. The mean visual acuity binocularly in photopic conditions at six metres $(6/7.5_{+3})$ was slightly better than at three meters $(6/7.5_{-4})$ (see Table 2). In mesopic conditions it was reduced (6/18) binocularly. Mean visual acuity for the subjects was $(6/9_{-1})$ for the right and left eyes. Near vision was normal (N5) to slightly reduced (N8). These standards are within the licensing requirements but are less than the normal level of 6/6.

Table 2 Summary of visual assessments

Test	Mean or Median	Standard Deviation	Range
Visual Acuity at 6 metres binocularly :	$6/7.5_{+3}$	.03	$6/5$ to $6/12_{+2}$
Photopic Visual Acuity at 3 metres binocularly:	$6/7.5_{-4}$ equivalent	.03	$6/5_{-3}$ to $6/12_{-2}$
Mesopic Visual Acuity at 3 metres binocularly:	$6/18_{+2}$ equivalent	.07	$6/7.5_{-1}$ to $6/24_{-1}$
Near Vision binocularly:	N5-N8		5 to 8
Confrontation Peripheral Visual Fields binocularly:	100% with no abnormalities detected		
Deviation: Distance-	100% heterophoria (straight eyes);		
Near-	96% heterophoria (straight eyes), 4% strabismic		
Stereopsis (level of depth perception):	240" (Median)	1234" of arc	15 to 3000 or nil stereopsis
Ocular Movements:	100% normal range of movement		
Contrast Sensitivity	Refer to Figure 1		

The mean results of the contrast sensitivity tests for the test population in full and reduced light are plotted in Figure 1. The mean result for each frequency has been joined to form a contrast sensitivity curve. The outcome shows that the curve is at the lower edge of the normal grey scale as defined by the VISTEC group. The results for the Low spatial frequencies (1.5 and 3 cycles per degree) were within the normal range. The mid spatial frequency (6 cycles per degree) was outside the normal range and higher spatial frequencies (1.2 to 1.8 cycles per degree) were on the lower border of the normal range. When the test surround light levels were reduced to mesopic levels, the responses decreased further and were below the normal grey scale range.

Figure 1 Mean responses of forty-seven subjects for contrast sensitivity, in full light and mesopic viewing conditions. The grey band represents the range of normal contrast sensitivity.
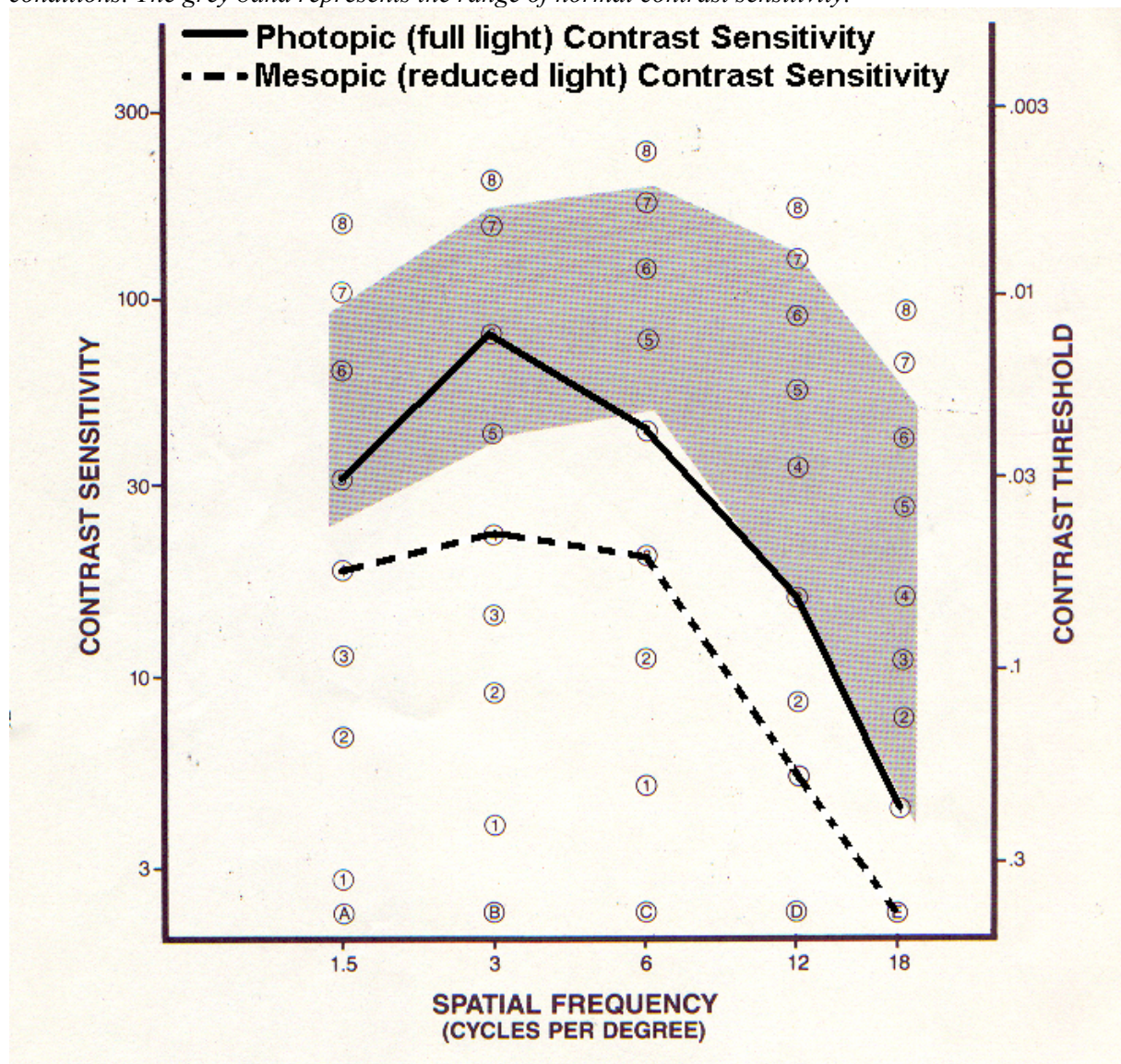
Of the 45 participants who were tested for stereopsis (level of depth perception), 24% achieved a high level response (15 to 60 seconds of arc), 47 % achieved a mid range response (120 - 480 seconds of arc) and 29% achieved a poor or no response. Three participants who failed to appreciate any level of depth perception had 6/60 acuity in one eye (2 people), and one had an eye turn (strabismus).
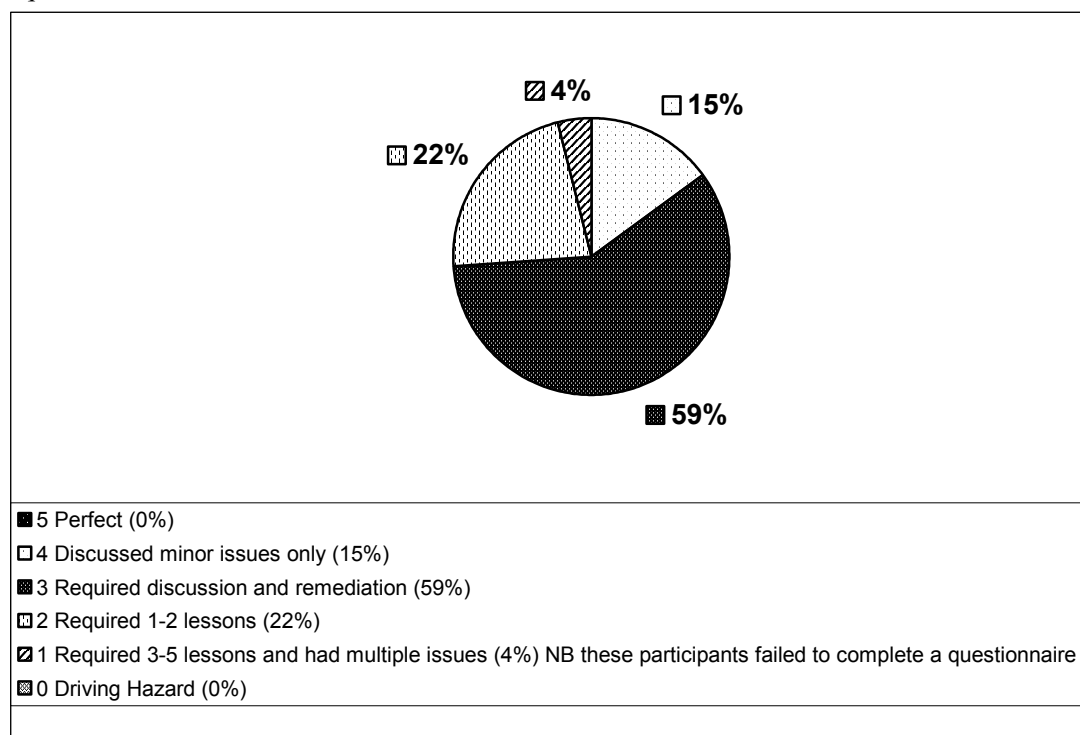
4. Driving Results

The participants reported varied patterns of driving. Twenty percent reported that they drove 1 to 3 days per week; 42% reported that they drove 3 to 7 days per week; and 38% reported that they drove every day. This therefore indicates that there is regular use of a car by this age group. There was no link between the pattern of driving and all of the vision test responses including visual acuity at near, 6 metres, 3 metres, contrast sensitivity, confrontation peripheral vision, stereopsis and ocular movements.

Figure 2 shows the results for the driver assessment as scored by the driving instructor. No participants scored 0 (driving hazard) or 5 (perfect). The majority of drivers (59%) required discussion and remediation. A small percentage of participants (15%) required a discussion about minor errors that were made. Twenty-six percent were referred for between 1 to 5 lessons to improve their driving performance. The recommended driving lessons were undertaken at the personal choice of the driver.

There was a repeat driver assessment which one participant failed due to a driver instructor report that the driver was unable to follow instructions, apart from that all participants improved by at least one level.

There was a weak statistically significant link between on-road driver performance and some of the opinions on the questionnaire including difficulties driving at night ($r_s = -.388$ p<0.05) and particularly sunny days ($r_s = .326$ p<0.05). There was a weak correlation between reduced on-road driver performance and a lower level of stereopsis achieved (level of depth perception) ($r_s = -.339$ p< 0.05).

Figure 2 On-road Driver Assessment with outcomes ranked from minimum (5) to maximum (0) support required

Legend:
- ■ 5 Perfect (0%)
- □ 4 Discussed minor issues only (15%)
- ▦ 3 Required discussion and remediation (59%)
- ▤ 2 Required 1-2 lessons (22%)
- ▨ 1 Required 3-5 lessons and had multiple issues (4%) NB these participants failed to complete a questionnaire
- ▩ 0 Driving Hazard (0%)

5. Comparison of results from questionnaire with clinical tests

Of the twenty three scenarios presented in the questionnaire, eight were found to have a significant correlation with measured contrast sensitivity and are presented in Table 3. A further five scenarios were found to have a weaker correlation with contrast sensitivity and visual acuity at three meters. There was no correlation with any other clinical result.

Table 3 suggests three main conclusions:

Reduced contrast sensitivity for row A (low spatial frequency or the ability to see large objects with reduced light) under photopic and mesopic conditions correlated with problems with busy roads, heavy traffic, speeds over 60kms/h, driving on particularly sunny days, reflections off cars on sunny days, driving in poor light and at night.

- ▪ Reduced contrast sensitivity for row D (moderate to high spatial frequency) under photopic conditions correlated with problems with reading licence plates during the day time.
- ▪ Reduced contrast sensitivity for row E (high spatial frequency or the ability to see small objects with reduced light) under photopic conditions correlated with problems with speeds over 60 km/h.

The five additional scenarios for which there was a statistical significant weaker correlation to the 0.05 level, with clinical responses included being unaware of pedestrians approaching from the side, oncoming headlights, headlights in rear view mirror, shutting an eye on particularly sunny days and driving in the rain.

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The clinical responses that did correlate included visual acuity at 3 metres, and contrast sensitivity results across all rows. As these relationships are weak, their values are not reported here.

Table 3 Correlations and p values between measured contrast sensitivity and drivers' opinions from the questionnaire

Scenario from questionnaire	Contrast plate A		Contrast plate D	Contrast plate E
	photopic	mesopic	Photopic	photopic
Busy roads / heavy traffic	-.467 difficulty p <.003 .470 lack confidence p<.001	.418 p<.006		
Speeds over 60 km/h	.400 p<.008	.436 p<004		.529 P< .000
Reading license plates during day time			-.410 p< .008	
On particularly sunny days	.429 p<.005			
Reflection of cars are distracting on a particularly sunny day		-.411 p< .008		
Poor light	.414 p<.006			
At night	-.475 p< .002			

6. Age related factors
No link was found between age, self opinion of driving skills, driving performance and response to the questionnaire. There was a moderate correlation between age and photopic visual acuity at 6 metres (r_s = .634, p<.001) and two contrast plates with responses including photopic D (r_s = .403 p<000) and mesopic A (r_s = -.387 p<.009)

DISCUSSION

Participants from this study came from a population of fully licensed drivers who volunteered to participate in an educational program to increase their knowledge and driver performance and could be said to represent a highly motivated part of the population. All drivers met the vision standard that is required to hold a driver's license and only one participant failed the driving test which was for cognitive reasons. This outcome suggests that all these drivers should have no problems with vision based skills when driving.

Outcomes from the questionnaire demonstrated that in spite of meeting the vision standard requirements the participants considered they had difficulty and reduced confidence with a range of driving tasks. These responses correlated with reduced contrast sensitivity in both photopic and mesopic test conditions and these correlations mostly clustered around plate A which assesses low frequency and slightly decreased contrast sensitivity. In the driving situation this represents decreased awareness of large objects as the surrounding light starts to fade. Decreased awareness suggests potential safety problems. Therefore, the assessment of contrast sensitivity could possibly be an effective tool in identifying on road situations where feedback from vision is decreased and may contribute to reduced driver confidence. Conversely, if a driver expresses concern about driving in congested traffic it may prompt the practitioner to test contrast sensitivity levels. Although there are many other reasons for lowering of confidence whilst driving, with regards to this study which concentrated on visual impacts and driver confidence, there were several correlations found between reduced contrast sensitivity levels and reduced driver confidence.

Light related problems, for instance with glare or low light, in the driving situation appear to be mostly linked to contrast results in the low spatial frequency level. Poor detail appreciation and a lack of comfort with glare was linked to a decreased response for high spatial frequencies.

This conclusion should prompt practitioners to recommend strategies for drivers with reduced contrast in these areas. For instance in the presence of poor low spatial frequency results, strategies to help drivers with issues with bright light include the use of sunglasses during day time driving, avoiding hours at sunset, drive only in well lit areas so glare from headlights is reduced and using the night setting of the rear view mirror. In the presence of poor high spatial frequency results and difficulties with detail discrimination, strategies include where possible driving in a well lit environment, pulling to the side of the road to read detailed signs and planning the route in advance so that sign reading is not required.

The mesopic visual acuity responses at 3 metres correlated with difficulty when driving in the rain, a need to shut an eye on particularly sunny days and visual acuity at 3 metres. It is interesting that visual acuity at 3 metres is the only acuity link to problems identified in the questionnaire which suggests that mid range acuity (3 metres) is more sensitive in disclosing problems in the driving situation than the acuity response at 6 metres. If acuity is to be used as a predictor of driver comfort then it should be performed at 3 metres under photopic and mesopic conditions.

The vision results whilst passing licensing standards, was lower than normal for visual acuity (6/7.5 when normal is 6/6) for contrast sensitivity and stereopsis which raises a potential for vision based problems when driving. Drivers identified particular problem situations via their response to the questionnaire, these certain situations were particularly linked to decreased contrast sensitivity. The on-road test response showed a need for improvement but there was only a weak link between driver performance and vision results. The combination of change in the specialised vision clinical responses and driver opinions that identify problems when driving, suggests that vision changes do impact on driving but there is little evidence of this through a conventional driver assessment. This raises a need to identify minor vision problems, test for them on road in a more appropriate way for example if you take into consideration driving skills at night, and support the affected drivers to modify their driving behaviours. It also raises the possibility of modifying driver tests to detect driver skills in a range of situations including night driving.

There is no evidence in this study of a link between clinical responses, vision responses and driving patterns. This study has focused on clinical outcomes and has highlighted a need to specifically ask participants what they have done to modify their driving pattern to meet their individual skills and ensure safety. It must be acknowledged that participants in this study were personally motivated to improve their driver performance and as such the results may not echo the outcome of the total population.

The original stimulus for this study, that senior drivers in the community commented that they do not see well in spite of adequate clinical responses has been demonstrated via more extensive clinical vision tests. It is still not clear why senior drivers are involved in more motor vehicle accidents; perhaps the vision changes identified in this study and the linked reported problems in the driving situation explain one aspect of the cause of accidents. The outcome supports the recommendation that drivers be tested to reveal a full range of vision skills and where responses are decreased that drivers be encouraged to make adaptations to help them to see at the best possible level.

REFERENCES:

1.   Kreisfeld R, Harrison J. Injury Death, Australia 1999. Injury Research and Statistics 2005;Series Number 24. (AIHW cat. no. INJCAT 67). Adelaide: AIHW
2.   Hole G. How risky are older drivers. The University of Sussex, 2003; v. 2003.
3.   Langford J. Improving the Infrastructure for Older Road Users. Mobility and Safety of Older People. C. PRS. Melbourne, Parliament of Victoria: 51-62, 2002.
4.   Ball K, Owsley C, Sloane ME, et al. Visual attention problems as a predictor of vehicle crashes in older drivers. Investigative Ophthalmology & Visual Science. 1993;34(11):3110-23.
5.   Lachenmayr B, Berger J, Buser A, Keller O. [Reduced visual capacity increases the risk of accidents in street traffic]. [German]. Ophthalmologe 1998;95(1):44-50.
6.   Packer MMD. Contrast Sensitivity in Healthy Subjects 20 to 69 Years Old. In: Stephenson M, ed. ASCRS•ASOA Symposium & Congress. San Francisco: EyeWorld, 2003.

7.   Assessing Fitness to Drive commercial and Private Vehicle Drivers Third Edition ed: National Road Transport Commission and Austroads Inc., September 2003.
8.   Uvijls A, Baets R, Leroy BP, Kestelyn P. Mesopic visual acuity requirements for driving licences in the European Union - Research Report. Bulletin of the Belgian Societies of Ophthalmology 2001;282:71-7.
9.   Owsley C. Vision and driving in the elderly. Optometry & Vision Science. 1994;71(12):727-35.