Now You See It, Now You Don't. Preliminary Investigation of Age Related Decrements in Peripheral Vision

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Biography
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Abstract
A new testing procedure for peripheral vision that involves the measurement of spatial masking ('crowding') has recently completed the first stage of the validation process. The computer-controlled test determines observers' pattern-recognition capacities in the peripheral visual field by measuring their ability to recognise 'crowded' targets, analogous to the 'real-world' capacity to recognise an individual cyclist at a busy intersection in peripheral vision. The test incorporates proven vision research techniques, and the most appropriate masking (flanking) stimuli. Older adults characteristically perform less well on visual tasks than their younger counterparts. The ultimate aim of the research program is to explore the question of why older people are over represented in crashes at intersections, with the long-term objective of facilitating a reduction in the number of such crashes.
To establish whether age-related decrements exist in peripheral pattern recognition, tasks were administered to thirty older adults aged 70 + and thirty younger adults aged 17 - 37. All participants had their vision assessed by an optometrist prior to participation and met the vision standards for driving in South Australia. Simple patterns were projected onto a screen for 125 milliseconds in either flanked (analogous to a cyclist at a busy intersection) or unflanked (analogous to an individual cyclist) conditions. Older people experienced more difficulty in the peripheral pattern recognition tasks than their younger counterparts, especially when the patterns were flanked.

1. INTRODUCTION

This research addresses global road safety issues that are arising with ageing populations. Crash patterns in Australia are similar to those in Europe and America, namely that older people are over-represented in crashes at intersections (Hakamies-Blomqvist, 2003; The New Jersey Department of Transportation Final Report, 2002; Insurance Institute for Highway Safety, 2001). These studies have concluded first, that a more adequate measure of deterioration in peripheral vision needs to be developed and second, that it should be added to the driver testing procedure. However, Rogé, Pébayle, Kiehn, and Muzet (2002) note that there is no systematic relationship between performance on currently used visual screening tests and accident rates. The reason for this finding may be that the current vision screening techniques for peripheral vision are not adequate "…as standard clinical perimetry seeks to minimize environmental factors typical under everyday conditions" (Ball, Owsley, and Beard, 1990, p.123). Ball et al. (1990) concluded that the nature of the difficulty encountered by older adults occurs in more complex visual scenes that require simultaneous concentration on a primary focal task and a secondary peripheral task that involves distractors. Ball and her colleagues used a test called the Useful Field of View (UFOV) to measure these abilities, and discovered that scores on this test were good predictors of elderly drivers' crash histories (Ball, Owsley, Sloane, Roenker, and Bruni, 1993).

Vision is a complex phenomenon with diverse aspects, including colour, contrast, motion detection, foveal and peripheral acuity. Identification and measurement of these separate skills is difficult. The central visual field is particularly good at segregating complex patterns into their components (analysis), whereas in the peripheral visual field it is more likely that separate shapes will be integrated into their global textures (synthesis) with the consequence that a particular target may get 'lost in the clutter'.

'Crowding' is the inability to discriminate flanked targets that nevertheless can be easily discriminated when presented in isolation. Crowding may occur weakly in central vision but is particularly strong outside central vision (Bouma, 1970). In our experiment the flanked condition produces a 'crowding' phenomenon that is analogous to detecting a cyclist approaching from one side at a busy intersection.

Bouma (1970) found that as the target is presented further from the central fixation point, crowding becomes stronger. Additionally, he found for a symmetrically flanked target in peripheral vision that the 'flank' further from the fovea had the stronger crowding effect and concluded that crowding has a centripetal directional element. In his 1970 publication he failed to find a left or right visual field dominance but in a later paper (Bouma, 1973) he reported finding a weak right field dominance.

Since these earlier studies this phenomenon of crowding has been further investigated and mapped. Toet & Levi (1992) found that the zone within which a flank reduces the ability to see the target is an elliptical shape on radial lines towards the centre of fixation. They mapped these zones of interaction, and obtained markedly different sizes and shapes for different people. Kooi, Toet, Tripathy, and Levy (1994) discovered that the most appropriate flanking stimuli are ones that have pattern specificities identical to those in the target.

Assessment of the vision research and the nature of the crashes in which older adults are involved lead us to agree that crowding in peripheral vision may be playing a significant role, and that the nature of this role needs to be further explored. We hypothesise that crowding will be stronger at greater eccentricities in peripheral vision and that older adults will experience more crowding than younger adults.

The 'Crowding Across the Visual Field' software used in this experiment incorporates the target's pattern specificities into the flank's design thereby maximising the strength of crowding. Our experiment was modelled on the experimental procedures of O'Regan (1983).

2. Method

Sixty-two people agreed to participate but two of these were used only in a pilot study. There were two age groups, Young and Old, each consisting of 30 participants with equal gender splits (see Table 1). A South Australian Driver's licence was held by 53 of the participants, and 51 were currently driving. An optometrist ensured that all participants passed the South Australian vision requirements for the current licensing procedures.

Table 1. Participant's descriptive age statistics in each group split by gender

Group	Gender	n	Driving n	Minimum	Maximum	M	SD
Young	Female	15	12	17	33	21.67	4.58
	Male	15	13	18	37	24.07	5.87
Old	Female	15	12	70	90	76.47	5.77
	Male	15	14	70	84	77.33	4.47

A COMPAQ ARMADA E500 standard issue laptop computer, having 128 MB of RAM, with Microsoft Windows 2000 pro, version SP2 operating system was used to run the 'Crowding Across the Visual Field' software. A Sony Data Projector, model VPL-CX5 resolution of 1024 x 768 dots (horizontal x vertical) projected the display screen onto a vertical flat white wall. The projected display screen size was 186 cm. Stimuli were displayed for 125 ms but as the data projector's refresh rate is 16.66 ms, at times they may have been displayed for up to a maximum of 141.66 ms. The projected target size expressed in terms of visual angle was 0.88° in height and width, and the space between the target and the flank was 0.44°. Even at the maximum display time participants cannot initiate and complete an eye movement (Rayner, 1998) thus ensuring that our measurements reflected their ability to discriminate patterns in peripheral vision.

The software utilises 8 targets (see decision panel in Figure 1) that are presented singly in a randomly generated temporal sequence in the horizontal meridian of the display screen. The horizontal meridian consisted of 17 equally spaced cells and 10 presentations were made in each cell, in each task condition (unflanked and flanked). The first condition presented a target in isolation ('unflanked') and the second condition presented the target with a left and right horizontal mask ('flanked') (see Fig. 1). The highest correct score that a participant could obtain in either task condition (flanked or unflanked) was 170 (10 out of 10 at each of the 17 eccentricities).

Participants were tested binocularly and seated at a distance of 6 m from the full-screen, thus ensuring they used their distance vision. The visual angle subtended at the eye by the screen was 17.5°. Participants were asked to fixate on the screen's centre (fixation circle in Fig. 1) and targets were presented along the horizontal meridian. The task required participants to recognise targets peripherally while gazing at the fixation circle. To become familiar with the experimental procedure participants began with a practice set of stimuli for each task condition; responses from which were not recorded. Participants selected the target seen by clicking the mouse on that target in the decision panel (see Fig 1). The computer program automatically recorded their decisions, and initiated the next presentation after a 500ms delay that enabled participants to re-fixate on the fixation circle. Each participant controlled the onset of each task condition and thereby the overall pace of the experiment. SPSS for Windows version 11.5 was used for data collation, description and analysis.

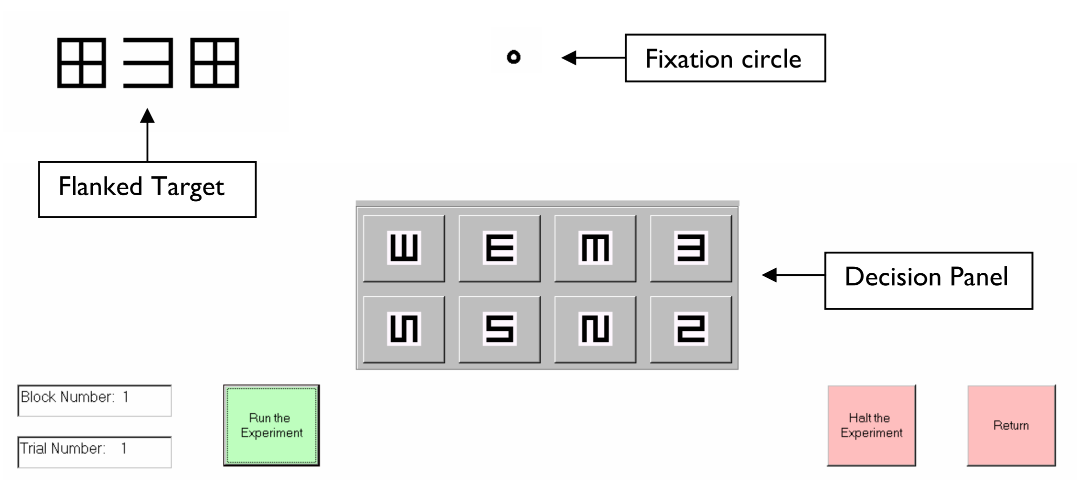

Figure 1. The computer interface used in the experiment to present the stimuli.

3. RESULTS

It can be seen in Figure 2 that task condition (unflanked and flanked) strongly affected the scores obtained. The unflanked target recognition scores are higher and vary little whereas the flanked scores are high only in the foveal region, and decline markedly to the periphery.

There was also an age difference in performance in that younger adults recognised more targets in both task conditions. Eccentricity affected target recognition in both conditions as depicted by the downward sloping lines for targets presented more peripherally. Furthermore, eccentricity appears to have a different pattern of effect in the flanked condition for each age group. The older adults' scores fell more sharply than younger adults' with increasing distance from the fovea. There was no obvious evidence of a left or right visual field advantage. Although not shown in Figure 2, gender had no effect on the results, and this factor was eliminated from further analyses. The interpretation of Figure 2 is supported by a number of statistical analyses.

No pattern of left or right visual field dominance was identified by Paired Samples t-Tests, so the scores for the corresponding left and right field targets were pooled in the following analyses. Target positions were numbered from 1 to 17 starting at the far left of the visual field. Pooling was achieved by combining the scores of the left outermost target (1) and right outermost target (17) creating a total score for eccentricity 8; the scores of the two neighbouring targets (2, 16) were combined creating a total score for eccentricity 7, and so on. The central target (9) had no partner so its score was doubled creating a score for eccentricity 0. The nine eccentricities were classified into 3 groups: foveal (eccentricities 0, 1 subtending visual angles of 0°, 1.1°), parafoveal (eccentricities 2, 3, 4 subtending the visual angles of 2.2°, 3.3°, 4.4°), and peripheral (eccentricities 5, 6, 7, 8 subtending visual angles of 5.5°, 6.6°, 7.7°, 8.8°).

A 2 (gender) x 2(age group) x 2(task condition) x 9(eccentricity) Repeated Measures ANOVA was used to analyse the target recognition scores. All differences apart from gender were significant.

The possible patterns of significance were examined by exploring the effects of eccentricity on target recognition within four subgroups: young/unflanked, young/flanked, old/unflanked, old/flanked. Significant effects of eccentricity were found for each sub-group. For each of the four sets of disaggregated data (2 age groups x 2 tasks) the main effect for eccentricity had a significant linear trend reflecting lower scores further from the fovea, with some contribution from quadratic and higher-order trends.

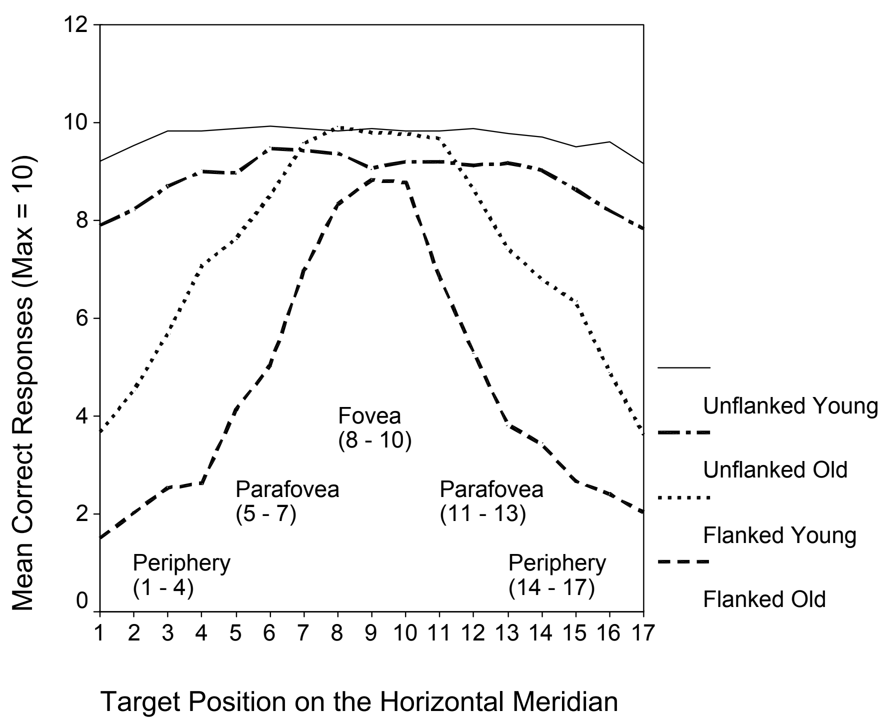

Figure 2. Each group's average score across the horizontal meridian for the flanked and unflanked conditions.

However the patterns shown in Figure 2 indicate that the eccentricity trends were not uniform for different parts for the visual field (i.e. across the fovea, parafovea, and periphery). For example, there was a plateau in the fovea for unflanked targets. We then decided to look for separate eccentricity trends within each of these regions. Within the fovea, parafovea, and periphery, twelve subsets of the scores (2 age groups x 2 task conditions x 3 eccentricity regions) were separately analysed using One Way Repeated Measures ANOVAs. A clear pattern of results was obtained (see Table 2). There were no significant eccentricity trends in the fovea for either age group under either the flanked or unflanked condition. In contrast in the parafovea and periphery there were significant eccentricity trends for both age groups in both task conditions, with the exception that the unflanked condition in the parafovea did not have a significant downward trend for either age group. The trend analysis also detects the presence of non-linear trends. The only such trend found was a weak quadratic component for the young adult flanked condition in the peripheral field.

Table 2. Trend analyses results

Group		Linear Trend analysis *		
Young	Older	Fovea	Parafovea	Peripheral
Unflanked		n.sig.	n.sig.	$F_{(1, 29)} = 19.58$
Flanked		n.sig.	$F_{(1, 29)} = 59.9$	$F_{(1, 29)} = 179.55$
	Unflanked	n.sig.	n.sig.	$F_{(1, 29)} = 29.93$
	Flanked	n.sig.	$F_{(1, 29)} = 110.4$	$F_{(1, 29)} = 39.59$

* indicates that all statistics reported are significant at alpha level $p < .01$

In the parafoveal region the young adults scored only 6.3% better than the older adults when targets were unflanked, but 32% better when targets were flanked. Although significant differences were demonstrated between the age groups, the analyses have not shown how differently the two age groups perform under the different experimental conditions. It can be seen in Figure 2 that the age differences in the parafoveal region are substantial. Median splits were performed on the total parafoveal scores for flanked and unflanked conditions, and the number of older and younger adults that fell above and below the median were recorded (see Table 3). It can be seen that the parafoveal-flanked scores are very good at discriminating between the two age groups, with only 2 misclassified as young, and 2 misclassified as old.

Table 3. Age discriminated by a criterion for parafoveal unflanked and flanked conditions

Parafoveal unflanked			Parafoveal flanked		
	Criterion score			Criterion score	
Age group	Low 58 ≤	High 59 ≥	Age group	Low 44 ≤	High 45 ≥
Young	7	23	Young	2	28
Old	21	9	Old	28	2

4. DISCUSSION

The 'Crowding Across the Visual Field' software measures two types of peripheral vision performance, that are not measured by conventional tests: peripheral acuity and peripheral crowding. The unflanked task condition ensured that participants could identify most targets when presented in isolation across the horizontal meridian, thus eliminating peripheral visual acuity as a potential explanation for performance in the flanked condition (which provides the measure of crowding).

The finding that older adults' performance is more degraded than younger adults' in the flanked task condition suggests that age has a differential effect on crowding (i.e. increases with age). These effects of crowding are not being measured by standard visual assessments.

The crowding effect increases in strength with increasing eccentricity (see the downward trend in Figure 2). Interestingly, the error rate for the foveal flanked task condition for older adults is higher than for the unflanked. This may indicate that crowding is occurring in the foveal region of old adults. There was no corresponding difference between the flanked and unflanked conditions in the fovea for the young adults.

Younger adults outperformed older adults in both task conditions at all eccentricities. The results show that younger adults recognized 6.28% more of the single targets than the older adults. Moreover, this difference in scores between the age groups increased to 32% in the flanked condition.

The flanked task condition did not affect younger adults' target recognition scores until approximately eccentricity 2, then the error rate increased producing a gradual downward linear trend through the parafovea towards the periphery. In contrast, the older adults' flanked target recognition scores were affected at eccentricity 1, and had a steeper rate of descent through the parafoveal region, and a quite noticeable change in the orientation at the beginning and throughout the peripheral region. The correct mean scores for older adults from eccentricity 5 onwards were less than 4 out of 10, and the scores at eccentricity 7 and 8 approximate to chance (for every presentation the probability of guessing the correct answer was 0.125).

Unlike Bouma (1973) we found no evidence for a right visual field advantage, although it was apparent from some individual raw scores that there was a dominant side. The fact that older adults experienced more crowding peripherally than younger adults in the flanked condition is similar to Ball, Owsley, and Beard's (1990) finding that the useful field of view decreases with increasing age.

It is possible that the older adult participants used in this research were high performers in their age range. Some participants of their own volition invoked strategies in an attempt to improve their scores such as crossing their eyes, and trying to predict where the next presentation would appear.

In this particular sample, the total parafoveal flanked condition scores arranged in an ascending order with a median split could predict with 96% accuracy whether the participant was in the older or younger age groups. This implies that the test could be significantly shortened. However, the age groups tested in this experiment were quite distinct. With more empirical data an appropriate age-related criterion could be obtained that could also be useful in a clinical situation as an indicator of a client's current peripheral visual ability relative to their age group.

Crowding affects everyone's visual ability to recognize embedded targets but the sizes of the interaction zones will be unique to the individual. Visual acuity and other aspects of vision also decline at different rates for different individuals. Thus an age-related cut-off for licensing would not be appropriate due to the amount of variation between individuals.

Ball et al. (1993) claimed that the normal battery of vision tests do not relate to predicting crash histories of the elderly but that the measures obtained from the UFOV do. The UFOV test requires a participant to focus on a central task and simultaneously detect a target in peripheral vision. We believe that our test of crowding actually measures the central mechanism that the UFOV uses to determine the participant's useful field of view. Ball et al.

(1993) have stated that UFOV test is the best predictor of elderly with crash histories, and as we believe that we are measuring the underlying essence of the UFOV, our test should also be able to predict with a high degree of accuracy those elderly people with poor crash histories.

5. FURTHER RESEARCH

The development of a screening test of peripheral vision is fast becoming a high priority for driver licensing agencies globally. We have completed the first step in the validation process for the 'Crowding Across the Visual Field' software. The software can measure age-related decrements in peripheral vision. The Crowding Across the Visual Field software has the potential to become part of the vision standard test for drivers and furthermore it can be administered with a typical office computer.

These findings suggest that the crowding phenomenon may be a contributing factor to the over-representation of older adults in crashes at intersections. However the relationship between effects of crowding and 'on road performance' still needs to be evaluated. A study of individual differences as measured by the UFOV and by our test could verify our assumption that we are measuring the underlying central mechanism of the UFOV.

6. CONCLUSION

Software has been developed that measures the strength of 'crowding' - the phenomenon primarily responsible for limiting the pattern-resolving capacities of the peripheral visual system. Pattern-recognition capacities in the peripheral visual field, as measured by an ability to recognise crowded targets, declines with increasing age. Parafoveal and peripheral vision both decline at greater rates with increasing age as reflected by the crowded target recognition scores. Older people may find it more difficult than younger people to react to stimuli amongst a crowded background that are approaching perpendicularly to the vehicle's trajectory as they may not see the stimulus until it moves closer to the foveal region.

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Keywords
Peripheral Vision, Useful Field of View, Elderly Drivers, Screening Tests, Visual Crowding