COMPARISON OF VELOCITY DETECTION IN YOUNG AND OLDER OBSERVERS IN A SIMULATED NIGHT DRIVING SITUATION

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Abstract

Thresholds for detection of angular velocity were determined in young and older observers for a target simulating the motion-in-depth of a motor vehicle at night. Thresholds were determined for a range of target sizes and for central and peripheral viewing conditions. We found significant differences in thresholds between these groups with the older subject group performing worse. Angular velocity thresholds increased with target angular size and with peripheral viewing.

Introduction

It is commonly estimated that over 90% of the information input to the driver is visual information (Hills, 1980). Despite this, studies attempting to relate drivers' vision and accident history have shown only very weak correlations and usually only for older drivers (see Davison (1985) and Hills (1980) for reviews of previous studies in this area). Typically however the visual functions investigated in these studies have been basic visual functions such as visual acuity, colour vision and stereopsis.

While adequate vision is necessary for driving there is no particular reason for strong correlations to exist between these specific basic visual functions and driver behaviour and performance (including accident history). Indeed driving is the result of a complex set of sensory and motor skills and recent evidence indicates that accidents are more related to failures in higher order visual functions (see Hills (1980) for a review).

While it has been recognised that higher order visual functions are important in driving there is little information about human functional capabilities in this area (see Harvey and Michon, 1974). In addition there appears to be little reported regarding the functional visual characteristics of the aged which are important for mobility (including mobility in vehicles) in the environment.

There is some evidence to suggest that elderly drivers may have difficulty in speed judgements. Hills (1980) reports that young and elderly subjects who were asked to judge the speed of approaching cars under-estimated the speed of fast moving cars and overestimated the speed of slowly moving cars. The older drivers, however, gave lower speed estimates than did their younger counterparts and also showed poorer sensitivity to vehicle speed. Hills (1975) also demonstrated reduced sensitivity to detection of angular movement (of two spots of light) for older subjects.

Planek (1973) reviewed several studies related to the ageing driver and concluded that they have higher accident rates than drivers in their middle years and are responsible for more accidents than their experience warrants. Elderly drivers are overrepresented in other accident statistics. Faulkner (1975) found that older drivers are at greater risk when crossing or joining major rural roads, as well as at urban junctions. Scialfa et al (1987) found that older drivers considered it to be safer than young drivers to enter or cross the lane of an approaching vehicle. Andreassen (1985) considered that some accident types indicate a skill decrement for older drivers and found a larger representation of older drivers in intersection accidents.

Sivak et al (1981) demonstrated that older drivers perform substantially worse than younger subjects in a night-time legibility task using a wide range of sign materials. They concluded that the older driver at night has less time available to act on the information contained in highway signs. Planek (1973) reviewed previous studies to conclude that older persons have a reduction in their ability in visual search and in processing information. This is consistent with the finding that older persons have a reduced capacity to process multiple sources of information (Hoyer and Plude (1982).

It has long been recognised that in daylight conditions there is a rich array of visual cues providing information about distance and depth (see Graham 1965). Indeed contemporary psychophysical and neuro-physiological research suggests there are a number of neural mechanisms interpreting information from these cues (see Nakayama, 1985). It seems likely that considerable redundancy is built into the visual system to support judgements of distance and motion over a range of photopic (i.e. daytime) ambient conditions.

At night however the visual environment is reduced and there are fewer cues for the judgement of distance and velocity. On rural roads at night where there is an absence of significant environmental cues, a driver will judge the behaviour of other vehicles largely on information provided by headlights and tail-lights. The change in angular separation between these lights is the main source of information for the judgement of velocity and change of distance. When the separation between two vehicles changes the visual information appears as a change in the visual angle subtended by the head-lights or tail-lights of the other vehicle.

A number of studies have investigated detection of motion or change of headway in daytime or simulated daytime conditions (for reviews see Hoffman, 1968; Olson, 1971; Evans and Rothery, 1972). There are however few such studies which have investigated these factors in the night driving situation with its conditions of deficient visual cues. Using night driving simulations, velocity thresholds were determined by Todosiev and Fenton (1966) and Hills (1975) for smaller vehicle separations relevant mainly in close car-following. Only Harvey and Michon (1974) appear to have provided velocity thresholds in night simulations for a wide range of vehicle separations and viewing times.

Because there is evidence of increased accident rates at night and for older drivers (Davison, 1985; Faulkner, 1975; Hills, 1980) we simulated the night driving environment and compared the performance of young and older observers. Investigations in this area are important in the design of the road-vehicle environment since the numbers of elderly in the driving population will increase markedly in the next 20-30 years as the general population ages (Australian Bureau of Statistics, 1980). People who have used automobiles all their lives for transportation will expect to continue to use them.

In this study we investigated a higher order visual function directly relevant to the driving situation. Specifically we investigated the ability of observers in a movement detection task where subjects were required to detect the movement of a target simulating the motion-in-depth of a motor vehicle at night. The experiments described were designed to measure thresholds for detection of angular velocity in young and older observers. We determined these thresholds for both central and peripheral vision. The project also sought to make a contribution to the understanding of visual function in older persons.

Methods

Eleven young and eleven older subjects with unaided or corrected visual acuity of 6/6 or better participated in this experiment. The subjects were recruited from the student and staff population and the Optometry Clinic at the Queensland University of Technology. The older subjects (age range 55-69; mean 61 years) and the young subjects (age range 20-29, mean 25 years) were free from ocular pathology and significant media opacities.

Thresholds for detection of motion were determined by presenting a target (two horizontally separated spots of light) on the face of an oscilloscope screen. The spots were positioned symmetrically about the centre of the oscilloscope screen and were moved together or apart at the same speed. A range of target angular subtenses from 2° to 0.5° was used corresponding to an automobile with tail-light separation of 1.4 m at viewing distances of 40 m to 160 m respectively. A range of retinal eccentricities between 0° and 5° was investigated. See Table 1.

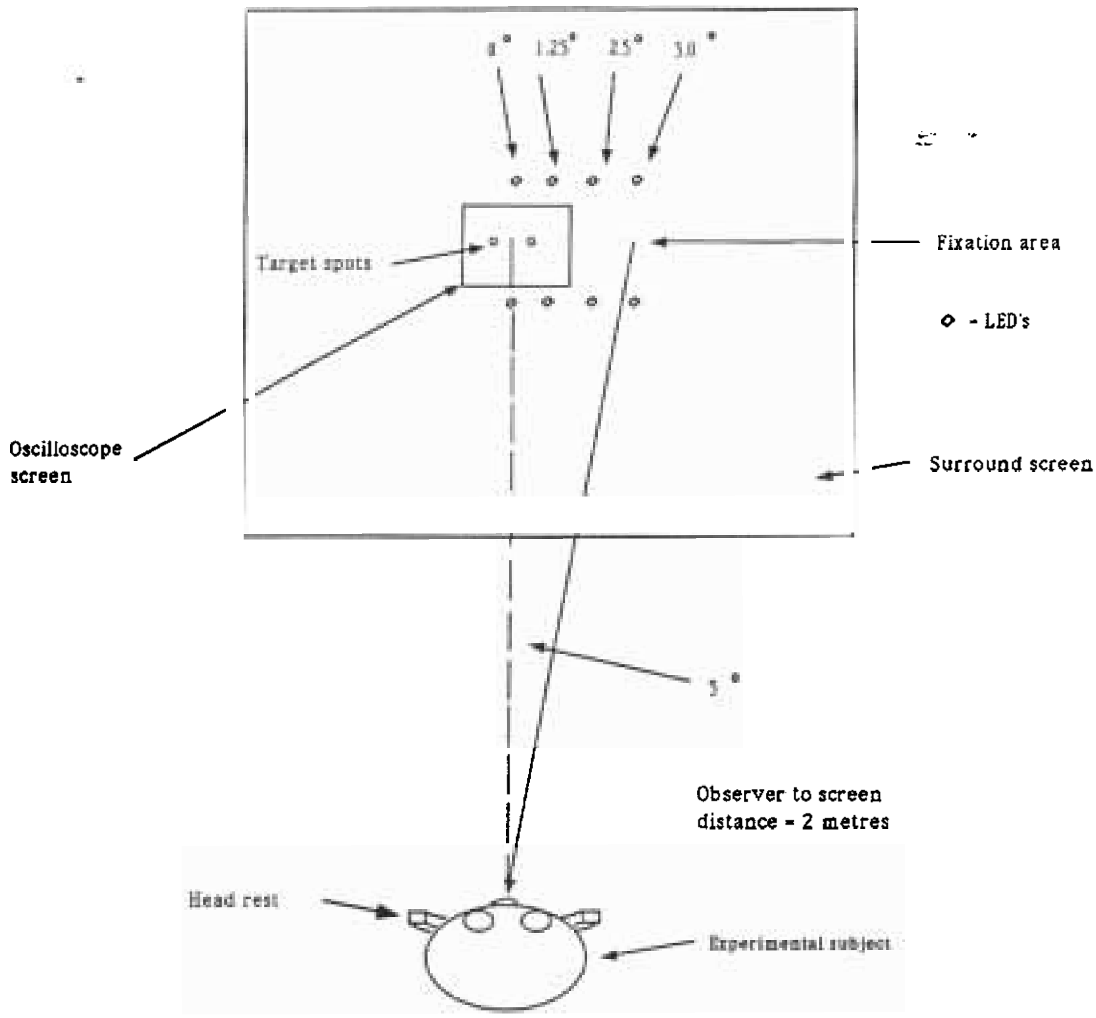

Figure 1. Schematic representation of the experiment. The figure shows the 5° eccentric fixation case.

TABLE 1

Experimental conditions for determining the velocity detection thresholds

Spot Separation (degrees)	Simulated Vehicle Distance (metres)	Retinal Eccentricity (degrees)
2	40	0 and 5
1	80	0 and 2.50
0.5	160	0 and 1.25

The experimental situation simulated that condition in which the driver of a vehicle is required to detect whether he/she is approaching or receding from another vehicle travelling in the same direction. He/she is required to do so when directly viewing the car in front (i.e. central vision) and when viewing another vehicle travelling in an adjacent lane (i.e. peripheral vision) in the same or a different direction. The centre to centre separation of the vehicles in each of the three simulated peripheral conditions was 3.5m.

The experimental task was performed under scotopic conditions with ambient illuminance levels of approximately 0.05 lux. The oscilloscope screen (Tektronix Model 620 with P31 short persistence phosphor) was dark, except for the spots which each subtended 1 minute of arc and had a luminance of approximately 60 cd/m^2, and was centred in an extended black surround which was darker than the screen itself.

This method of stimulus presentation simulated the night-time condition with its paucity of visual spatial information.

The spots appeared, already moving, and were presented for randomly determined times between 400 ms and 600 ms so that distance travelled by the spots could not be used as a cue to their velocities. Approximately 3s elapsed between each stimulus presentation although this was controlled by the speed of the subject's response. During this time subjects continued to view the fixation area. The horizontal separation of the spot pairs, stimulus presentation times, spot velocity and interstimulus interval were controlled via digital and digital-to-analogue systems from an IBM compatible micro-computer.

Subjects' fixation was varied by having them fixate mid-way between two vertically separated faint red light emitting diodes placed centrally about and also eccentric to the display screen (for those conditions requiring peripheral retinal stimulation). Subjects viewed the targets monocularly with the right eye from a distance of 2m. Natural pupils were used and also a distance spectacle correction if required. (See Figure 1).

Subjects were shown the pairs of spots moving towards or away from one another at one of nine possible relative velocities (i.e. 4 approaching and 4 separating velocities and one stationary pair). At each stimulus presentation the subject was required to respond by indicating whether the two spots were moving 'together' or 'apart'. Responses were made by button presses which were recorded by the computer. Ten responses were collected for each of the nine relative velocities. At the end of 90 randomly ordered presentations the data were stored on disk and the threshold velocity in each direction calculated by Probit analysis.

The threshold for detection of angular velocity was determined by plotting the percentage of 'apart' responses against each of the nine angular velocities. At the extremes of the range of velocities subjects respond correctly and at the centre of the range they respond at chance (50%) levels. Probit analysis of this data (% 'apart' responses vs. angular velocity of spots) allows determination of velocity threshold (Finney, 1947). Threshold velocity corresponded to half the difference between the 75% and 25% levels (i.e. half the interquartile range).

The nature of the experimental task was explained to each subject. Prior to testing subjects were shown a range of spot separations and speeds and were given a trial run to familiarise them with the experimental procedure and to reduce contamination of responses by learning effects.

Threshold angular velocities were determined for each of the 11 young and 11 older subjects for each of the three separations and two eccentricities using the above procedure. These angular velocity thresholds were transformed to natural logarithms to normalise their distribution and analysed by Analysis of Variance (ANOVA).

Results

There were significant differences between the thresholds for young and older subjects ($p = 0.0130$) with the older subjects performing worse. Thresholds increased with increasing angular separation of the target ($p = 0.0003$) but there was no interaction between age and angular separation.

Angular velocity detection thresholds also increased with retinal eccentricity (i.e. with peripheral viewing) ($p = 0.0001$) but there was no interaction between age and eccentricity.

Figures 2, 3 and 4 show the increasing thresholds with increasing target angular separation and with increasing retinal eccentricity for the young and older subject groups. Although the analysis of variance did not indicate an interaction between age and retinal eccentricity inspection of Figures 1, 2 and 3 suggests that the older subject group has a greater increase in mean threshold between central and peripheral viewing conditions than does the young group. Further analysis of the data indicated that there was no significant difference between the means of the young and older groups for the 0.5 degree and 2 degree targets in the peripheral viewing conditions. There was however a significant difference ($p<0.02$) in the case of the 1.0 degree target in the peripheral viewing conditions.

It appears therefore that there may be tendency for the older subjects to perform more poorly in the peripheral viewing conditions. There is greater variation in the responses of the older subjects group in the peripheral viewing conditions as evidenced by the size of the standard errors compared to those of the younger group.

Discussion

We have found that older subjects have reduced sensitivity to the detection of target motion compared to their younger counterparts. This suggests that older subjects may be less able to detect the movement of vehicles, at night, toward or away from them, for both central and near-peripheral viewing conditions. It may also be that the movement detection performance of older subjects, compared to their younger counterparts, becomes progressively worse with targets presented to the peripheral retina.

Hills (1975) also found reduced performance in a similar movement detection task for older subjects. Hills, however, used only one target angular subtense (viz. 3°45', which represented a one second, or 19.4m, vehicle separation at 70 km/hr). Our study has extended this to include a range of simulated vehicle separations from 40m to 160m and included peripheral viewing conditions important in the road environment where fixation is not always able to be maintained on a vehicle directly in front of the observer.

Interpretation of these results needs to be tempered by the fact that we have investigated a limited range of simulated conditions because of the demands on the concentration of experimental subjects made by the experimental procedure.

Table 2 shows the angular velocity threshold values of Figures 2, 3 and 4 converted to kilometres/hour for a vehicle whose simulated movement is towards the observer. It is obvious that while angular velocity thresholds increase with increasing angular subtense of the target the threshold

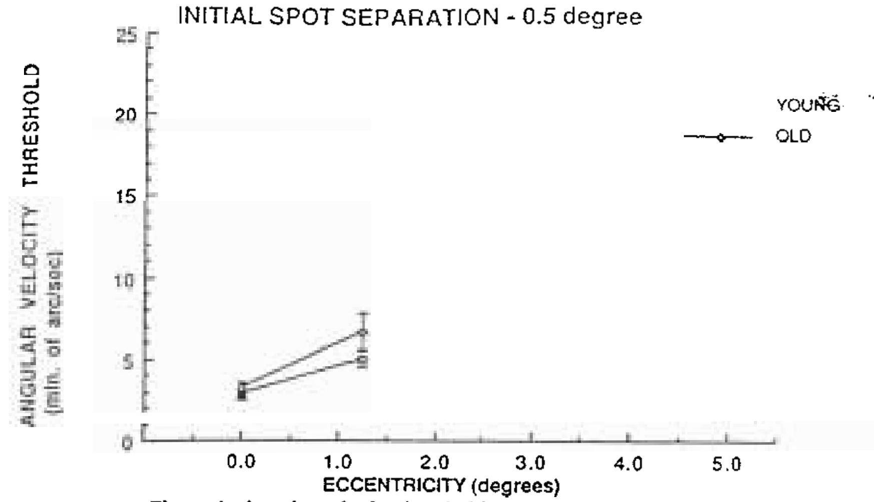

Figure 1. Angular velocity threshold as a function of target eccentricity for an initial spot separation of 0.5 degree. Error bars are standard errors.

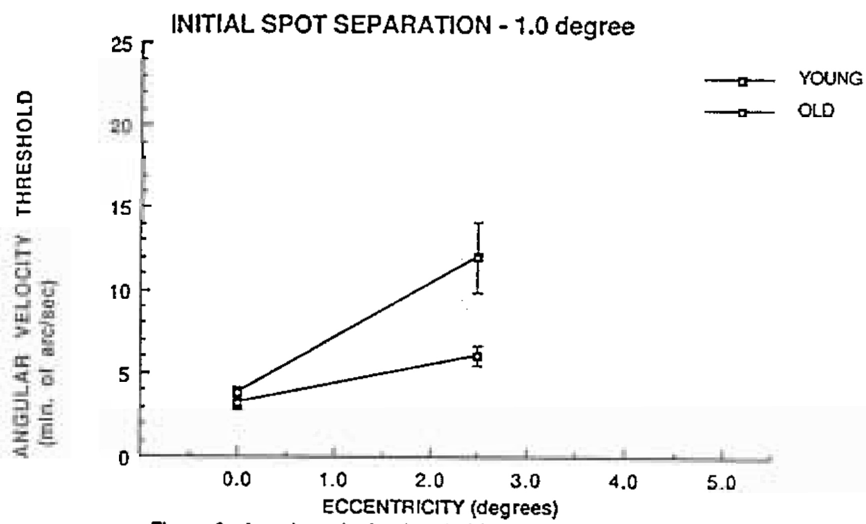

Figure 2. Angular velocity threshold as a function of target eccentricity for an initial spot separation of 1.0 degree. Error bars are standard errors.

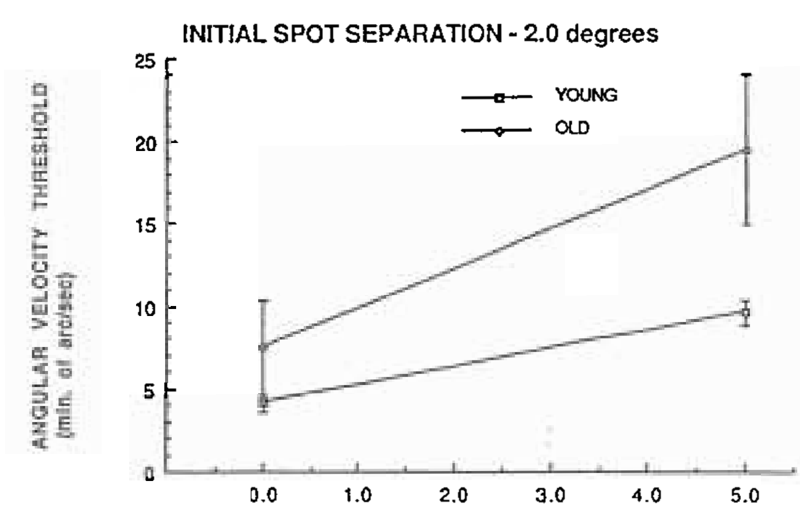

Figure 3. Angular velocity threshold as a function of target eccentricity for an initial spot separation of 2.0 degrees. Error bars are standard errors.

TABLE 2

Threshold relative velocities (in kilometres/hour) for detection of the relative motion of a simulated vehicle in an adjacent traffic lane as a function of viewing distance for young (Y) and older (O) subjects for central and peripheral viewing conditions. The centre to centre separation of the vehicles in each of the three simulated peripheral conditions was 3.5m. Simulated movement is toward the observer.

Viewing Condition	Viewing Distance (Metres)					
	40m		80m		160m	
	Y	O	Y	O	Y	O
Central	2.1	4.0	6.8	8.0	26.1	29.3
Peripheral	5.1	10.5	13.0	25.4	44.0	57.6

values in kilometres/hour reduce with larger target size. This demonstrates the large effect of the viewing distance on the threshold in kilometres/hour. The values in Table 2 are for the 0.5 second viewing duration used in this study. The effect on velocity detection thresholds, of varying viewing duration, has been demonstrated by Harvey and Michon (1974). Different threshold values could therefore be expected for other viewing durations.

It can be seen from Table 2 that, at each distance, the younger observers have lower relative velocity detection thresholds than their older counterparts. Thresholds are also higher for peripheral than for central viewing for both young and older observers at all simulated distances. Table 2 suggests that the visual system is more sensitive in detecting the relative movement between vehicles with central fixation than with even the near-peripheral viewing conditions (viz. 1.25°, 2.5° and 5°) investigated in this study.

Our concern in this present study was to investigate age-related changes on angular velocity detection. We have demonstrated that there is a difference in performance between young and older subjects. Our elderly subjects were selected on the basis of normal visual acuity, ocular media and ocular health. They may not therefore be representative of the majority of the elderly population who do not demonstrate these characteristics. We might expect therefore that the general aged population would perform even more poorly than their younger counterparts who do not demonstrate such age-related ocular changes.

Summary

This present study has investigated the performance of young and older subjects in a task detecting the movement of a target simulating the motion-in-depth of a motor vehicle at night. The older subject group demonstrated reduced sensitivity to movement detection compared to the young group.

Acknowledgements

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