The Sensitivity and Bias of Older and Younger Driver Judgments in Complex Traffic Environments.

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ABSTRACT

A previous investigation adapted a signal detection theory approach to an arrival-time task to establish the sensitivity and bias of traffic judgements. It was demonstrated that older drivers generally have a diminished sensitivity to the arrival-time of approaching vehicles. The conservative estimations of older drivers were also attenuated in response to faster speeds. These findings were demonstrated under simplistic single vehicle approaches of varying speed. Under the age-complexity hypothesis, it was expected that an increase in the complexity of the traffic environment would further reduce the sensitivity of older driver judgements. Twenty-four older drivers (71-82 years) and 24 younger experienced drivers (24-42 years) were presented with digitally edited video sequences of two approaching vehicles that disappeared at a constant distance. The three combinations of the two vehicles' speeds were 44km/h - 72km/h, 58km/h - 72km/h, and 58km/h - 86km/h. Order of speed presentations and lane positions were counterbalanced. Participants indicated, for each vehicle in turn, whether it would have reached a target line on the road when a car horn sounded. Preliminary analyses indicate that older drivers have a significantly degraded sensitivity to the arrival-time of two approaching vehicles in comparison to younger drivers. Lower levels of sensitivity were demonstrated in the higher velocity conditions and the conservatism of older drivers in particular, was reduced for higher speed presentations. These results confirm the difficulties of older drivers in response to more complex environments and implicate speed as a factor in traffic judgment errors.

KEYWORDS: Older drivers, arrival-time, speed, intersections, perception, complexity.

INTRODUCTION

Increasing concern is centred on the safety of older drivers due to their high crash risk per kilometre driven and their over-representation in crashes at complex road environments. One measure that may have consequence for older drivers and has received little attention is motion perception. The recovery of information from the environment regarding self-motion, and the detection of velocity and direction of opposing vehicles are critical for safe driving. It is possible that decrements in these skills may be contributing to crash risk for older drivers, particularly at intersections or when turning (Shinar & Schieber, 1991; Sivak, 1995; Staplin & Lyles, 1992).

Previous research on motion perception has mostly relied on the investigation of arrival-time (T_a) utilising a *disappearance paradigm*. This refers to the removal of an object or vehicle from the perceptual scene that is on an approaching trajectory with an observer. Several factors have been shown to affect T_a judgements, including object approach velocity, sex and age. In one of the few investigations of age effects, Schiff, Oldak and Shah (1992) reported greater under-estimations by older participants in push-button arrival-time judgements of vehicles approaching at 16 and 32km/h. These differences were manifest mostly in the estimates of older women and were attenuated at the higher velocity. Hancock and Manser (1997) confirmed age differences across a broader range of velocities. They demonstrated that older drivers had greater errors and more bias than younger drivers at low approach velocities.

Systematic underestimation of T_a has been demonstrated across a range of vehicle approach conditions (Caird & Hancock, 1994; Cavallo, 1988; Hancock & Manser, 1997; Schiff & Detwiler, 1979; Schiff et al., 1992). This finding has been described in terms of what it affords an observer. Under-estimating the arrival of a survival-threatening event provides the greatest opportunity to avoid the potential danger (Caird & Hancock, 1994). Thus, the characteristic under-estimation is a conservative error. However, a measure of bias needs to be separated from accuracy indices in order to establish the contribution of bias to the T_a under-estimation phenomenon. In a previous study by Andrea, Fildes and Triggs (2000), the contribution of bias and perceptual sensitivity were separated using an adaptation of signal detection theory. This study suggested that the under-estimation of T_a did contain a conservative bias element but this moved to a less conservative criterion at higher velocities (except for young males) and the sensitivity of judgements declined. This indicates that rather than being more accurate at higher speeds, judgements may incorporate less safety margin and are therefore in a position of higher vulnerability.

The Andrea, Fildes, and Triggs (2000) investigation provided an account for previous T_a using presentations of a single vehicle. Given that the accidents of older drivers typically involve more complex traffic interactions (Fildes, Corben, Kent, Oxley, Li, & Ryan, 1994), differences demonstrated between older and younger drivers may not be indicative of crash causation. Therefore, the current study sought to characterise the pattern of sensitivity and bias in arrival-time judgements made by older and younger drivers in more complex traffic conditions.

METHOD

Participants

The participants consisted of 24 independent elderly drivers aged between 71 and 82 years (mean = 77, SD = 3.3), and 24 younger participants aged between 24 and 42 years (mean = 30, SD = 4.9). Younger participants were recruited from Monash University and consisted mainly of Monash University employees. Older participants were recruited from a group of participants in The City of Whitehorse Falls Prevention Study conducted by the Monash University Accident Research Centre. All participants in the Falls Prevention study had already passed general health related exclusion criteria and had a medical clearance from a GP. All participants were required to have a current driver's licence and drive at least once per week.

Video Stimuli

Video recordings of scenes were conducted at the Holden Proving Ground at Lang Lang Victoria A Sony Digital Video Camera on a tripod was directed down a straight section of road (the "noise road") at drivers eye height, and was positioned immediately to the left of the road. Filming of each approach commenced when the stimulus vehicles (one silver and one gold Holden VX Commodore) were 200m away from the camera. In each trial the two vehicles were travelling at different speeds and three combinations of speed were recorded, 44 and 72km/h, 58 and 72km/h, and 58 and 86km/h. The two vehicles were co-ordinated so that one of the two vehicles would pass a target line (a line on the road adjacent to the camera position resulting from a grading change in the road surface), 5-8m ahead of the other. The finishing order was counterbalanced between the faster and slower vehicle and across lanes. The arrival-time scene is illustrated in Figure 1.

Figure 1. Still image of the arrival-time film scene.

Twelve digital film clips were selected based on accuracy of speed and arrival co-ordination (from field notes and slow motion video review), and downloaded onto an IBM compatible desktop computer. Digital editing of the film clips was executed using Adobe Premier 5.1c editing suite. Video clips were edited to incorporate the disappearance of both vehicles when the lead vehicle reached a distance of 38m from the target line. A car horn sound of short duration (200ms) was inserted at a point in the videos to indicate three possible finishing conditions. The car horn sounded when the front of the second finishing vehicle would have reached the line ('Both' condition), when the first finishing vehicle would have reached the line ('One' condition), or 72% of the duration from disappearance to when the lead vehicle would have reached the line ('Neither' condition). In total, 36 video clips were developed with three speed combinations, combinations of right/left and fast/slow vehicle passing a target line first, and three different finishing combinations based on the timing of the car horn. All videos were edited and presented on a 400 MHz IBM compatible computer with a 17inch monitor. Stimulus video files were displayed using Microsoft Windows Media Player version 6.01.05.0217 on full screen view.

Experimental Procedure

Participants were seated 55cm from the monitor and their chair height was adjusted to position eye height to the center of the screen. Participants were informed that on the test trials, the approaching vehicles would disappear and then they would hear a car horn sound. In blocks of 18 trials, participants were asked to state whether the vehicle in a given lane would have reached the line (if the vehicle had not disappeared) when the horn sounded, and then state whether the vehicle in the other lane would have reached the line. Half the participants in each age and sex group started with a block of 18 trials responding to the vehicle in the left lane first and then the right, the other half of participants started with a block requiring the reverse order. Participants were informed that the car horn would sound at various points corresponding to when both, neither or one of the two vehicles would have reached the line. It was also explained that the vehicles could be travelling at any speed but the speed would be constant (i.e. no acceleration or deceleration), and the speed of the two approaching vehicles would always be different.

All participants were first shown practice trials with vehicles approaching at 58km/h and 72km/h. Two practice trials were administered for each of the three finishing conditions with knowledge of the finishing condition. A total of 72 test trials were administered with two separate responses required in each trial

Data Analysis

The analysis of arrival-time was separated into two dimensions of the judgement, sensitivity and bias. This was performed using the general framework of signal detection theory. See McNicol (1972) for an introduction to this approach. Both measurement indices were analysed for age and sex effects across the three speed conditions.

Sensitivity is a pure index of accuracy uncontaminated by the subjective utility of judgements. The conditional probabilities of hits, false alarms, misses, and correct rejections were calculated and an estimate of sensitivity, P(*A*), was determined from ROC area tables (McNicol, 1972). Analysis of variance was used to assess differences in P(*A*) between age groups and gender. Bias represents an index of decision criterion that reflects the subjective utilities and heuristics that determine decisions. Bias was determined for each group by the point in the response scale (0-1, where 0 = vehicle reached the line and 1 = vehicle had not reached the line) where the combined probabilities of the signal and noise conditions were equal to 1 provided the measure of bias.

Lane position (left or right) and order of response (left 1st or right 1st) were investigated using the mean number of errors for each driver group as the dependent variable. Analysis of variance was used to investigate the reliability of differences.

RESULTS

Speed Conditions: Sensitivity

Mean P(A) results were calculated for each speed condition. The results for Young Males, Young Females, Older Males and Older Females can be seen in Figure 2.

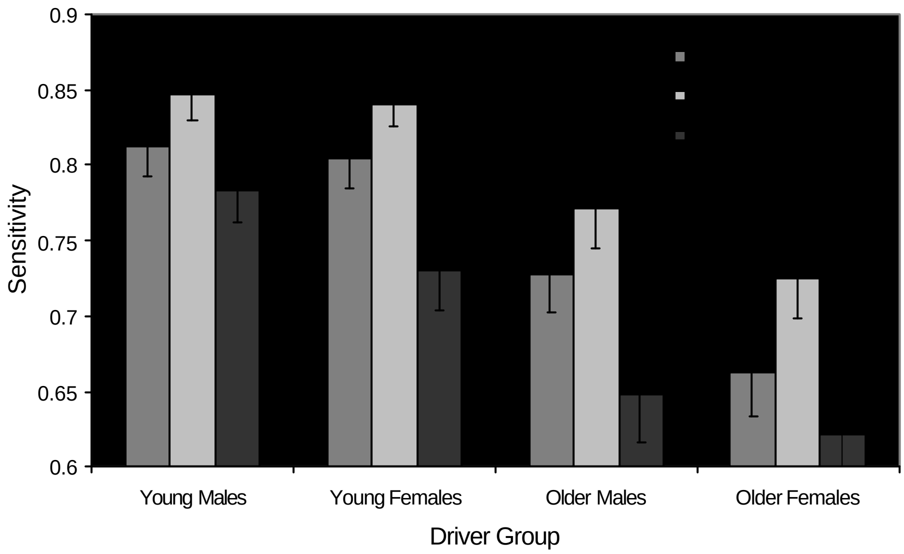

Figure 2. Mean sensitivity (P(A)) of four driver groups across all speed conditions.

Figure 2 shows that the three speed conditions were not equally well judged. The faster speed condition (58-86km/h) resulted in a lower level of sensitivity than the other two combinations of speed for each driver group. The difference between speed conditions was significant, $F(2,88) = 14.772$, $p < .001$. The pattern of sensitivity results across speed conditions was consistent for the four driver groups and no interactions of speed with age or sex were revealed. However, significant main effects were demonstrated for age, $F(1,44) = 84.305$, $p < .001$, and sex, $F(1,44) = 8.225$, $p = .006$. The effect of age was a particularly strong result with power of 1. It was also worthy of note that the between-subject variability was higher for the older driver groups than the younger driver groups.

Speed Conditions: Bias

Bias measures (*B*) were calculated for each participant across the speed conditions. Measures of *B* closer to 0 indicate a bias toward a more conservative response (the vehicle had reached the line), and higher measures indicate a bias toward a more risky response (the vehicle had not reached the line). Bias results can be viewed for the three speed conditions in Figure 3.

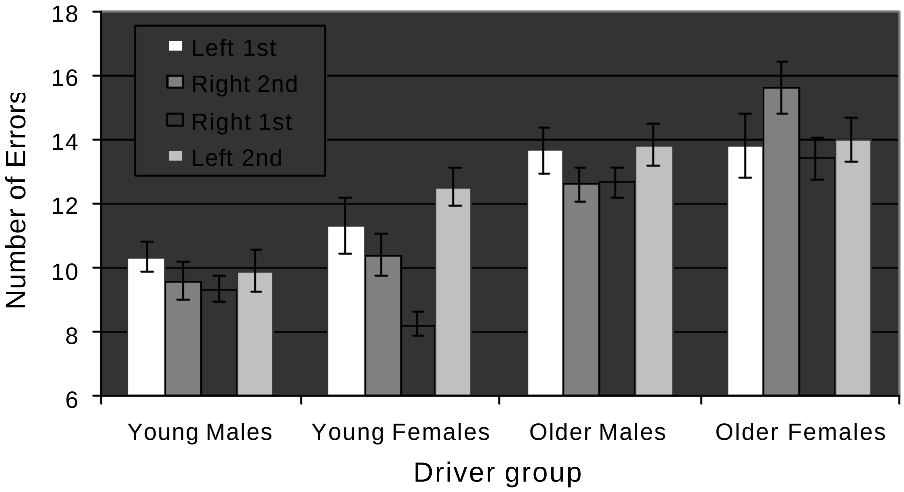

Figure 3. Bias measures for the four driver groups in the three speed conditions.

Figure 3 illustrates that older male drivers have a conservative response pattern compared to the other drivers. The fastest speed condition produced the least conservative response for all driver groups except for young females and a reliable difference between the speed conditions was found, $F(2,88) = 6.60$, $p = .002$. A different pattern of response across the three speeds can be seen for the older groups (and in particular older females) compared to the younger drivers. This interaction between speed and age was found to be significant, $F(2,88) = 4.422$, $p = .015$. Tests of between-subjects effects found a significant effect of age group, $F(1,44) = 16.620$, $p < .001$, and a significant interaction between age group and sex, $F(1,44) = 11.550$, $p = .001$. These results largely reflect the difference in bias for the older male group demonstrating a tendency to respond in a more conservative manner.

Lane Position and Order of Response

The number of errors recorded by each participant across the 36 responses recorded for each lane position and order were calculated and the effects of age group, sex were analysed. The results for each of the four driver groups can be viewed in Figure 4.

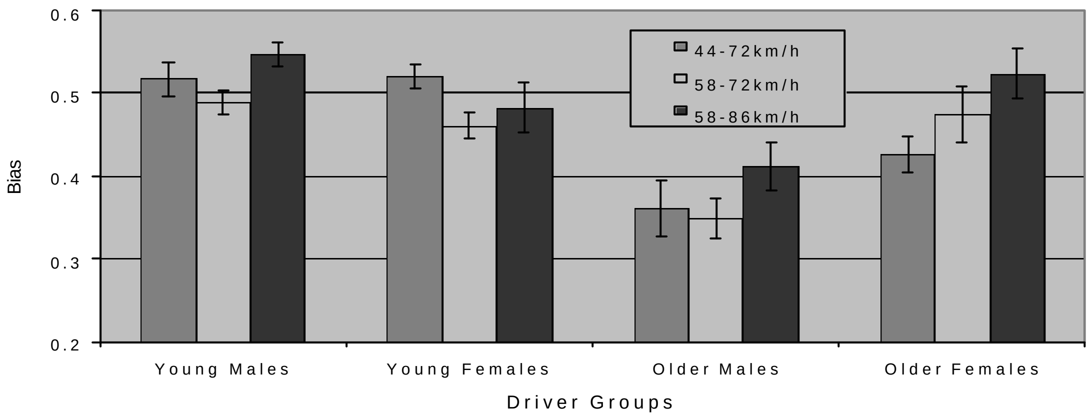

Figure 4. Mean Number of Errors by the Four Driver Groups for Approaching Vehicles in the Left and Right Lanes and the Order of Response.

The lowest number of errors can be seen for vehicles approaching in the right lane when that lane required the first response. The older male group had approximately the same number of errors for both orders of response for right lane vehicles. In all driver groups except older females, errors on the two left lane conditions were greater than on the right lane conditions. Older females had the greatest number of errors for vehicles in the right lane when that decision was required after the decision for the left lane. Figure four again illustrates the difference between the two younger and older driver groups. Main effects were revealed for lane position, $F(1,44) = 5.421$, $p = .025$, lane order, $F(1,44) = 5.716$, $p = .021$, age group, $F(1,44) = 107.524$, $p < .001$, and sex, $F(1,44) = 7.590$, $p = .009$. However, there were no interactions of lane position or order with age group of the drivers. This would suggest that neither of these conditions constitute specific deficits for the older drivers. There was an interaction of lane order by sex, $F(1,44) = 6.062$, $p = .018$, indicating that females had a greater number of errors compared with male drivers on responses required second.

DISCUSSION

The objective of this study was to separate the contributions of subjective bias and sensitivity of perceptual judgements comparatively between older and younger drivers in a more complex driving situation than has been studied previously. Differences between older and younger drivers were demonstrated in both measures of bias and sensitivity. Combinations of approaching vehicle speed also resulted in reliable differences in these measures.

The results demonstrated in the current study were consistent with the earlier findings of Andrea et al. (2000) using a simple traffic environment. However, the age effects for both sensitivity and bias were more robust than previously reported by Andrea et al. Although the two studies used similar methodology, the current study departed from the previous one in the use of a multi-stimulus environment. It's acknowledged that increasing the task complexity results in increased magnitude of age differences in cognitive performance (Bashore, van der Molen, Ridderinkhof, & Wylie, 1997; Salthouse, 1991). In the current investigation, the average sensitivity scores across the speed conditions were approximately .80 and .69 for the younger group and older groups respectively. In the earlier study, the respective sensitivity scores were .87 and .83. It has been argued that the added cost to older drivers results from a reduction in general processing resources available to cope with the demands of the more complex environment (Salthouse, 1991, 1992; McDowd & Craik, 1988; Stelmach & Nahom, 1992). Alternatively, the dual vehicle approach may have created a divided attention task that has been shown to create specific deficits for older adults (Salthouse, Rogan, & Prill, 1984; Triggs, Fildes, & Koca, 1994). It is interesting to note that the 58-72km/h speed condition appeared to have the greatest sensitivity. This is interesting since the speed differential is smaller than the other two conditions resulting in the vehicles being in closer proximity. This condition potentially requires less division of attention. The lane order results give further insight into this explanation. Lane order was a factor in the accuracy of responses however the memory requirement of responding to the second vehicle did not provide additional cost for older drivers. This suggests that demands on processing resources were not overly taxing and that a reduction in the ability to divide attention may be a more appropriate explanation of age effects on this task. The understanding of specific limitations of older drivers is important if engineering countermeasures or vehicle technologies are to be implemented in order to reduce road trauma for the growing elderly driving population.

It has been found consistently that estimates of arrival-time are more accurate when vehicles, or objects are approaching at higher velocities (Caird & Hancock, 1994; Cavallo & Laurent, 1988; Hancock & Manser, 1997; Manser & Hancock, 1996; Schiff & Detwiler, 1979; Schiff et al., 1992). Previous studies have relied on basic error measurements and have been unable to adequately characterise the errors in terms of their sensory and subjective components. The current study demonstrated that higher speeds result in a reduction in sensitivity and a reduction of the conservative bias. Therefore, as Andrea et al, (2000) point out, the velocity effect may be a consequence of reduced conservative bias (that is a reduction in under-estimating T_a) at higher speeds rather than improved perceptual accuracy. Older drivers demonstrated reduced sensitivity and a less conservative bias for the fastest vehicle approach combination. Although older males appeared to be at least partially compensating for reduced sensitivity by responding with the highest conservatism, this bias was reduced with higher approach speeds. Therefore, higher speed traffic interactions clearly provide conditions for increasing risk for older drivers if these perceptual judgements translate into driving decisions.

It is important to note the possible influence of the presentation on the task responses. The current manipulations and real world digital images aimed to simulate conditions that represent accident situations. In particular, the dual approach of vehicles is characteristic of turning right across multiple lanes of traffic however, the scene was devoid of traffic control devices or the extensive visual clutter typical of suburban intersections. These complex conditions may result in a further contraction in the sensitivity of older driver motion perception. The current results extrapolate the findings of Andrea et al (2000) to a more complex arrival-time task. This required approaches with different and relative speeds of two vehicles, and different approach angles. It is possible that the greater cost to older drivers illustrated in this study may be specified by some perceptual or contextual difference in the two manipulations and not a cost of complexity. Nevertheless, the stand-alone results of the application of signal detection to dual approach vehicles for older and younger T_a judgements further clarifies the factors involved in the assessment of traffic characteristics by these driver groups.

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