The Sensitivity and Bias of Older Driver Judgements in an Arrival-Time Task.

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A signal detection theory approach was adapted to an arrival-time task to establish the sensitivity and bias of traffic judgements. The factors of age, gender and vehicle approach speed were examined with 20 older drivers (over 70 years of age) and 20 younger (24-39 years) experienced drivers. A disappearance paradigm was generated using digitally edited video sequences of a vehicle approaching a stationary observer. The vehicles were travelling at 44km/h, 58km/h or 72km/h and vanished at a constant distance. Participants gave a rating of confidence on a five point scale from totally confident that the vehicle would have reached a white target line, to totally confident the vehicle would NOT have reached the target, and provided an estimate of the vehicle's speed. Older drivers demonstrated a diminished sensitivity when estimating the arrival-time of approaching vehicles in comparison to younger experienced drivers. A reduction in sensitivity to the higher approach speed was found for all driver groups. A conservative bias of older drivers was confirmed in the 44km/h approach condition but not the 72km/h condition. Older females demonstrated the most risky combination of low sensitivity and less conservatism at the highest approach speed. These results are used to clarify previous findings and the implications for accident risk of each driver group are discussed.

Increasing concern is centred on the high crash risk of older drivers. Although older drivers currently represent only a small number of accidents, the older driver problem is highlighted when accident statistics are presented per distance travelled. In Victoria, drivers over 60-74 years have a casualty crash risk per kilometre driven, approaching that of the youngest driver groups (considered to be at the greatest risk). Drivers over 75 have a casualty crash risk substantially exceeding any other driver age group (Diamantopoulou, Skalova, Dyte, & Cameron, 1996). These trends are unlikely to abate given the ageing population and increasing vehicle use among older age groups.

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, the detection of moving objects, as well as the velocity and direction of opposing vehicles are critical to successful driving. It is possible that decrements in this skill may be contributing to crash risk for older drivers, particularly when entering 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 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 criterion needs to be separated from accuracy indices in order to establish the contribution of

bias to T_a estimations. The relative contribution of accuracy and bias in judgements of older drivers compared to their younger counterparts could also provide key information accounting for the over-representation of older driver in certain accidents.

METHOD

Participants

The participants consisted of 20 independent elderly drivers aged between 71 and 81 years (mean 76 years), and 20 younger participants aged between 25 and 39 years (mean 30 years). Both age groups were split into an equal number of males and females. All older participants had passed general health related exclusion criteria and had a medical clearance from a GP. All participants were required to have a current driver's license and drive at least once per week.

Video Stimuli

A Sony Digital Video Camera on a tripod was pointed down the road at drivers eye height. Three approaches of the stimulus vehicle (a white Mitsubishi Lancer Coupe) from 380m away were recorded at speeds of 44km/h, 58km/h, and 72km/h (accuracy of ±1.5km/h). These digital film clips were edited using Adobe Premier 5.1a editing suite on an IBM compatible computer. During editing a white stop line (target) was inserted across the road six metres in front of the observer. A car horn sound of short duration (200ms), was inserted at a point where the front of the vehicle would have been located 20.5m back from the target line (the 'before target' condition) or 1m past the target (the 'after target' condition). The arrival-time scene is illustrated in Figure 1.

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

Six video clips ("avi" files) were developed with three vehicle speeds, a constant disappearance distance of 64m from the camera, and two temporal locations for the car horn. A 400 MHz IBM compatible computer with a 17inch monitor was used to the display video clips.

Experimental Procedure

Participants were seated 60cm from the monitor and were asked to imagine they were the drivers of a stationary vehicle viewing the road ahead. They were told that on the test trials the approaching vehicle would disappear and they would be required to indicate whether they believed the vehicle would have reached the white line (if the vehicle had not disappeared) when they heard a car horn sound. Their verbal response had to be given on a five-point confidence rating scale. The rating scale was, 1 Totally confident the vehicle had reached the line, 2 Confident the vehicle had reached the line, 3 Unsure if the vehicle had reached the line, 4 Confident the vehicle had NOT reached the line, and 5 Totally confident the vehicle had NOT reached the line. They were informed that the car horn would sound at various points in the clips and the vehicles could be travelling at any speed. All participants were first shown a practice trial with an approaching vehicle travelling at 58km/h using the after target condition, followed

by the before target condition. Up to four subsequent practice trials were administered without feedback to establish if they understood the instructions correctly. Trials were paced by the participant.

A total of 60 test trials were administered, 24 in each of the 44km/h and 72km/h speed conditions with half in each target condition. Twelve additional trials were presented at using, 58km/h with half in the before target and after target (the same conditions as in the practice trials).

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 (SDT). See McNicol (1972) for details of this approach. Both measurement indices were analysed for age and sex effects across the 44km/h trials, 72km/h trials and total trials (including trials in the 58km/h condition).

Sensitivity is a pure index of accuracy independent of the decision tendencies (referred to as the criterion or bias). The analysis of sensitivity required a split in the 5 rating categories for each individual such that the best approximation of an equal proportion of responses lay above and below the split. All responses on the side of the split that included rating category 1 were recorded as a response that the vehicle had reached the target when the horn sounded (an after target response). All responses corresponding to category 5 were recorded as a response that the vehicle had not reached the target (before target response). The conditional probability of hits, false alarms, misses, and correct rejections were tabulated by adding up the number of after target and before target responses in the after target and before target conditions. An estimate of sensitivity, P(*A*), was then determined from ROC area tables (McNicol, 1972).

Bias represents an index of decision criterion that reflects the subjective utilities and heuristics that determine decisions. Bias was determined for each group by adding the cumulative probabilities of a response in each rating category, using category 1 as the minimum reference category, for the 'before target' condition (analogous to the noise condition in SDT) and for the 'after target' condition (the signal condition). The point in the rating scale where the combined probabilities of the signal and noise conditions were equal to 1 provided the measure of bias.

RESULTS

Sensitivity

Mean P(A) results were calculated for each group. The maximum possible score for sensitivity was 1.0 indicating an after target response for every after target condition trial, and a before target response for every before target condition trial. The results for Young Males, Young Females, Older Males and Older Females collapsed across all speed conditions can be seen in Figure 2.

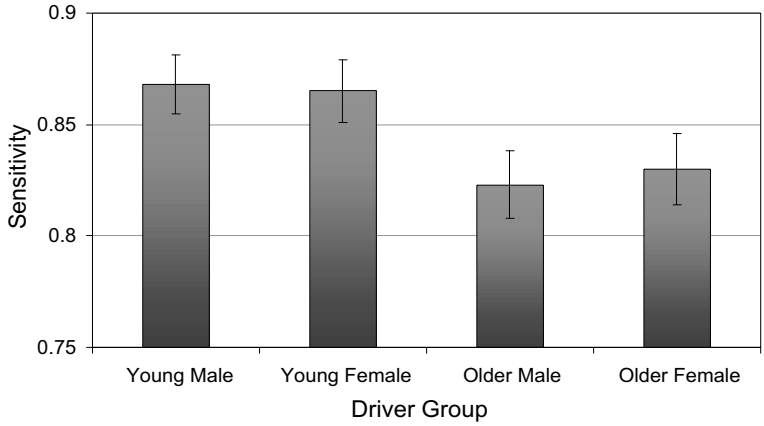

Figure 2. Mean sensitivity of four driver groups across all speed conditions.

The sensitivity values in Figure 2 illustrate a significant difference between the two older and two younger driver groups in arrival-time rating judgements [$F(1,36) = 7.719$, p=.009]. There was no effect of sex.

Analysis of sensitivity for the 44km/h and 72km/h speed conditions demonstrated that the two speeds were not equally well assessed and increased variability for older drivers was evident. The sensitivity of these two speeds for each driver group is displayed in Figure 3.

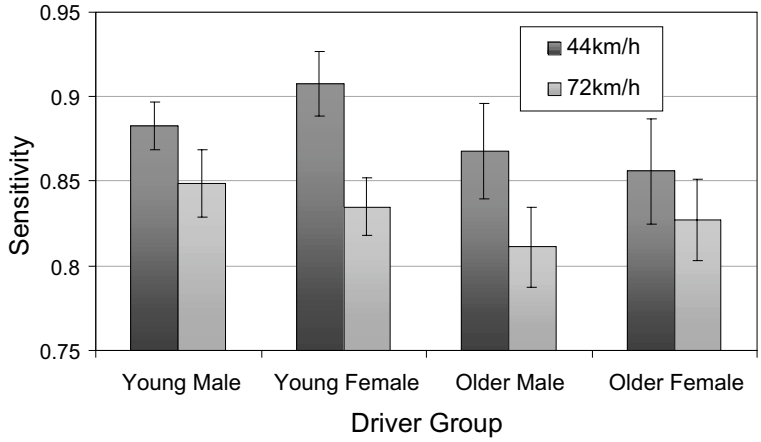

Figure 3. Mean sensitivity of four driver groups across the 44km/h and 72km/h speed conditions.

For each driver group shown in Figure 3, the 72km/h condition resulted in a lower level of sensitivity. The difference in speed conditions was significant [$F(1,36)=9.216$, p=.004]. This was particularly evident for younger females and older males, however no interactions of speed with age or sex were revealed. Although both younger groups scored higher sensitivity than older groups with the two speed manipulations, only a trend was indicated by statistical analysis [$F(1,36)=3.028$, p=.090]. Of note in this result, are the relatively low power (0.395) and the higher between-subject variability in older driver sensitivity.

Bias

Bias measures (*B*) were calculated for each participant across the speed conditions. Measures of *B* closer to 1 indicate a bias toward the more conservative 'after target' response, and higher measures indicate a bias toward the more risky before target response. Bias results can be viewed for the 44km/h and 72km/h speed conditions in Figure 4.

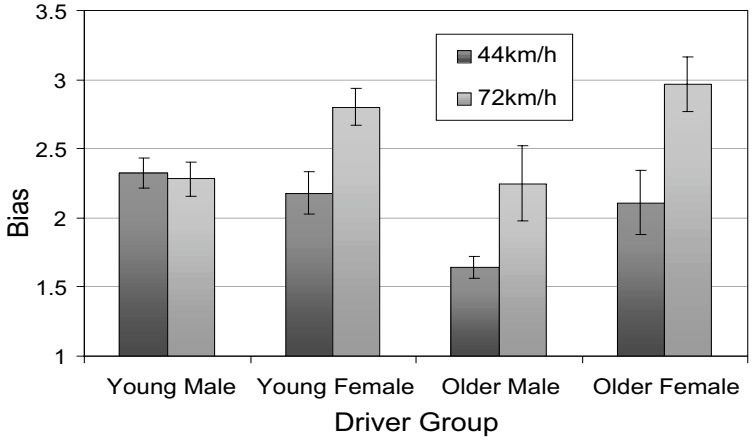

Figure 4. Bias measures for the four driver groups in the 44km/h and 72km/h conditions.

Figure 4 clearly illustrates that participants in each driver group apart from the young male group, varied their bias in response to different vehicle approach conditions. A reliable difference between the speed conditions was found [$F(1,36)=5.221$, $p<.001$]. Interactions between speed and age [$F(1,36)=4.456$, $p=.042$], and speed and gender [$F(1,36)=4.504$, $p=.041$] were also revealed. Older females displayed the greatest discrepancy between the 44km/h and 72km/h conditions, responding in a relatively conservative manner at the slower speed and with more risky tendencies at the faster speeds. Younger females similarly demonstrated a tendency to respond with less conservatism to higher approach speeds. Older males showed the strongest bias towards after target judgements for both speeds.

DISCUSSION

The objective of this study was to separate the contributions of subjective bias and sensitivity of perceptual judgements comparatively between older and younger driver groups, and between males and females. Differences between driver groups were demonstrated in both measures of bias and sensitivity. The velocity of the approaching vehicle also modified these measures.

It has been consistently found that observer estimates of T_a 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). Vehicle velocity also had a strong and consistent influence on T_a judgements in the current study. However, 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. Findings in the current study indicate that higher speeds result in a reduction in perceptual accuracy with a corresponding reduction of the conservative bias. Therefore, the velocity effect may be a consequence of reduced bias at higher speeds rather than an improvement in the sensitivity of assessing the T_a. This result has important implications for traffic interactions at higher speed areas.

Arrival-time judgements are a combination of bias and sensitivity so it is instructive to describe how each driver group adjusted their judgements with respect to both measures. Younger males had a high total sensitivity, and sensitivity was reduced only slightly with higher velocity presentations. With high sensitivity, younger males also demonstrated a moderately conservative and consistent bias across vehicle speeds. Younger females showed a high overall sensitivity, however, this appeared to be reduced at higher approach speeds and bias became less conservative. If these perceptual judgements translate directly into driving decisions then this could indicate a potential problem for younger females with higher speed traffic interactions. Older males demonstrated the most conservative bias of any group. This would indicate that they are at least partially compensating for reduced perceptual accuracy. However, older females demonstrated similar sensitivity levels to older males but had a bias in the 72km/h condition toward responses indicating the vehicle had not reached the target. Low sensitivity and less conservatism clearly provide conditions for increasing risk in traffic manoeuvres requiring motion perception judgements. It should also be noted that the older driver groups had much higher between-participant variability suggesting that more risky judgements may be limited to a subset of the driver group.

These T_a findings cannot be meaningfully compared with other arrival-time studies due to our more explicit breakdown of measures, but they do help to clarify some previous results. Several studies contend that female estimates are less accurate than male estimates but this difference is attenuated at higher velocities (Caird & Hancock, 1994; Hancock & Manser, 1997; Manser & Hancock, 1996; Schiff et al., 1992). These differences appear to exist mainly in the criterion measures. The attenuated difference can be explained by a reduction in conservative bias by females rather than an increase in the accuracy of higher speed judgements. Schiff et al. (1992) also suggested that the sex difference existed in an interaction with age such that older women displayed a notably larger magnitude of error. Hancock and Manser (1997) observed a similar result but additionally suggested that older participants were more biased than younger participants using a measure of constant error. Although these results appear incongruent with the current research given the finding that older females had a similar

sensitivity to older males and have less conservative bias, the previous findings were observed under different kinematic conditions. Schiff et al. only examined the unusually slow approach speeds of 16 and 32km/h, and Hancock and Manser only observed these differences at approach speeds less than 24km/h. This implies that the a very different pattern of results occur with approach conditions less realistic to street traffic conditions.

It may be important to note that the conditions and the presentation of the task could have influenced responses. There was a clear indication that older participants were reluctant to use the 'unsure' rating category and the number of trials in individual speed conditions was relatively low for signal detection theory applications. These factors may have added to between-participant variability and the robustness of some measures. I have also outlined several differences between the current study and other studies examining T_a estimates with older drivers. The current manipulations and real world digital images aimed to more accurately simulate conditions that represent accident situations. The current findings require replication in a more broad range of conditions to establish older driver limitations in motion perception. Nevertheless, the novel application of signal detection to older and younger T_a judgements has added substantial insight into the assessment of traffic characteristics by these driver groups.

These results more clearly underline the difficulty that older drivers have with higher or more variable traffic speeds (Andrea, Fildes, & Triggs, 1999; Cremer, Snel, & Brouwer, 1990). Keskinen, (1998) reported that older drivers experienced turning problems with approaching younger drivers travelling at higher speeds and Cremer et al (1990) found that it is the more variable speed conditions that cause increasing errors. These conditions may place increasing demands on older drivers such that cognitive strategies are unable to compensate for reduced sensitivity to prevailing traffic characteristics.

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