OLDER PEDESTRIAN SAFETY: The role of perceptual and cognitive factors and the ability to compensate for age-related changes.

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Older pedestrians are over-involved in serious injury and fatal crashes compared to younger adults. This may be due, in part, to diminished perceptual and cognitive skills which act to reduce the older pedestrians' ability to sense danger and take measures to avoid hazards. Two experimental studies were undertaken to investigate decision-making processes involved in gap selection and the ability to process vehicle distance and speed information. The findings support the notion that age-related limited cognitive capacity reduces the ability to simultaneously integrate vehicle distance and speed information and interferes with sound judgements of when to cross safely. The implications for engineering, behavioural and training countermeasures are discussed.

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Making the decision about when it is safe to cross roads in relation to available traffic gaps is a difficult everyday task and accurate perception of the motion of the approaching vehicle is paramount when making judgements of the traffic in which to cross safely. However, the ability to estimate the time-of-arrival of the closest vehicle in order to make a safe decision may be difficult for older adults, especially in conditions of uncertainty or when a decision needs to be made quickly.

The evidence regarding age-related deficits in motion detection suggests that older adults experience difficulty perceiving the details of moving objects (Burg, 1966; Kosnik, Winslow, Kline, Rasinski & Sekuler, 1988), tracking fast moving stimuli (Sharp & Sylvester, 1978) and are less accurate in estimating time-of-arrival than younger adults (Schiff, Oldak & Shah, 1992). The processes involved in making these estimates, however, is not clear. Even less clear is the capacity of older adults to compensate for age-related changes to optimise their use of available sources of perceptual information for judging impending collisions with traffic.

This paper presents the results of two experimental studies undertaken to investigate decision making processes involved in deciding whether to cross a road or not in a simulated road crossing task.

EXPERIMENT ONE

The first experiment aimed to investigate age effects on decisions concerning the safety of crossing based on estimation of the time-of-arrival of oncoming vehicles and the perception of safe margins.

METHOD

Participants – Fifty-four participants took part in this experiment. Three groups consisted of 18 young adults aged between 30 and 45 years, 18 young-old adults aged between 60 and 69 years and 18 old-old adults aged 75 years and over. All participants were volunteers and in good health. All participants completed a battery of functional assessments, revealing group differences with the oldest group performing more poorly than younger adults on cognitive, perceptual, visual and physical measures but within the normal range.

The simulated road environment – A simulated road environment depicting an undivided two-way residential road from the perspective of a pedestrian waiting at the kerb was utililsed in this experiment. Moving traffic scenes of two near-side approaching vehicles were generated from data files from a mid-level driving simulator, downloaded onto VCR tapes and projected onto a large curved white screen. Forty-five scenes were presented in random order to participants in which time-of-arrival and vehicle speed of the vehicles were manipulated based on group average walking speeds identified in previous observational studies (Oxley, Fildes, Ihsen, Charlton & Day, 1997).

Procedure – Participants were seated at a desk in front of the screen and were instructed to respond to each traffic scene as if they were to cross the road immediately behind the first passing vehicle and in front of the second approaching vehicle. A buzzer sounded as the first vehicle passed, and participants were instructed to look at the traffic at this time and make two responses on a keyboard. The first response was a simple 'yes' or 'no' response to indicate whether they would have crossed or not. The second response was a rating of the safety of the road crossing using a nominal rating scale from 1 (very unsafe) to 9 (very safe). These responses and decision time were recorded on a simple Windows-based program.

RESULTS

Yes/no responses – these responses indicated whether individuals would have crossed the road or not in front of the approaching vehicle. While a yes or no response in itself is an interesting measure, it seemed important to take walking time into account when examining crossing decisions. Group differences were found for walking time, $F(2,51) = 48.17$, $p < 0.001$. Tukey tests revealed that walking times of young and young-old participants did not differ, however, the old-old group walked slower than both younger groups, p's < 0.001. Analysis of crossing responses was therefore undertaken by employing hierarchical logistic regression modelling of the data to examine the independent variables including age, time-of-arrival, vehicle speed and gap distance while holding the effects of mobility statistically constant. All variables were significant predictors of crossing decisions: walking time, $\chi^2(1) = 32.33$, $p < 0.001$, $R = 0.10$, time-of-arrival, $\chi^2(4) = 191.33$, $p < 0.001$, $R = 0.24$, vehicle speed, $\chi^2(2) = 90.76$, $p < 0.001$, $R = 0.16$, and distance gap, $\chi^2(14) = 426.27$, $p < 0.001$, $R = 0.36$. An interaction between time-of-arrival and age group was also found, $\chi^2(8) = 152.53$, $p < 0.001$, $R = 0.21$.

Figure 1 shows the proportion of positive crossing responses by distance gap, vehicle speed and time-of-arrival for each age group. It should be noted that distance gap does not increase in a linear way with time-of-arrival because of speed manipulations. It is for this reason, that corresponding time gap and vehicle speed measures are also provided on the X axis. The data show that all participants were generally less likely to indicate that they would cross when there were small distance gaps than when these were larger. The young-old and old-old groups were less likely to cross than the younger group when distance gaps were smaller than about 110 m. At distances between 11 m and 22 m the response rate was close to zero and from about 144 m almost 100 percent of young and young-old participants indicated they would cross. The old-old participants waited until gaps were larger than 200 m before most of them decided to cross.

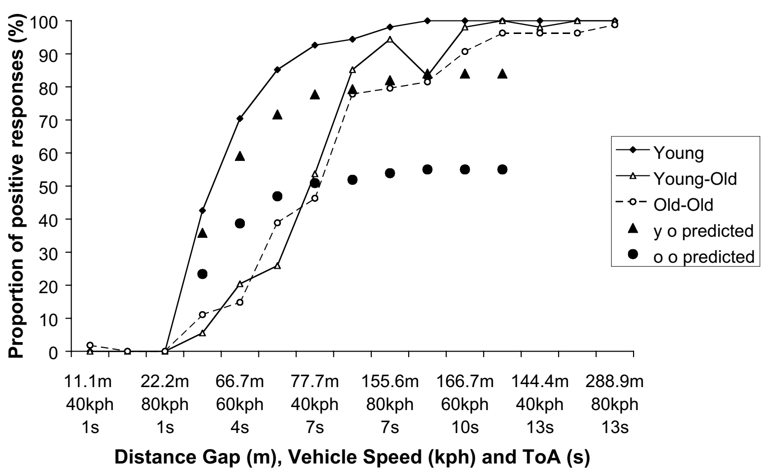

Figure 1: Proportion of yes responses – age group by distance gap, vehicle speed and time-of-arrival.

Expected values for young-old and old-old participants are shown for critical gaps between 44 m and 200 m in Figure 1. The expected values for the two older groups were calculated based on their walking speed relative to the average of the young group (1.54 m/s). Average walking speed of the young-old participants (1.22 m/s) expressed as a proportion of the walking speed of young participants is 84%. Likewise, average walking speed of old-old participants expressed as a proportion of the walking speed of young participants is 55%. With respect to predicted responses, the young-old participants' responses were more conservative up to distance gaps of about 90 m, then at predicted levels or just above for distances above 90 m. In contrast, while old-old participants also made conservative decisions when distance gaps were short, their responses greatly exceeded the expected level at the longer distance gaps. This indicates that old-old participants tended to make unsafe crossing decisions when vehicles are further away.

Safety margins – these were calculated as walking time plus decision time on each trial subtracted from the time-of-arrival in each traffic condition. The distributions of crossing time by safety margin for each group for the most critical time-of-arrival conditions (4 and 7 seconds) are shown in Figure 2. The line intersecting the zero safety margin denotes where time-of-arrival and crossing time coincide. Any point below this line indicates an unsafe crossing, while points above the line indicate a safe crossing. The distributions show that for all age groups level of safety margin accepted decreased as crossing time increased and this was particularly so for the oldest group. Group differences are also apparent. The distribution of the young participants show little variability and fast crossing times, along with only a small proportion indicating they would have crossed in an unsafe manner. Moreover, the unsafe crossings for this group were only marginally unsafe, generally falling between the zero line and –1 second. Most importantly, the distributions of the older groups showed more variability, slower crossing times and a tendency for the slower walkers to cross in a more unsafe manner than the fast walkers. This was most noticeable in the distribution of the old-old group, where a very large proportion of them made very unsafe responses with safety margins extending from the zero line to –10 seconds. This confirms the results reported above in Figure 1 which showed that old-old participants were likely to decide to cross with a 7 s time gap when their walking times indicated that they should have said 'no'.

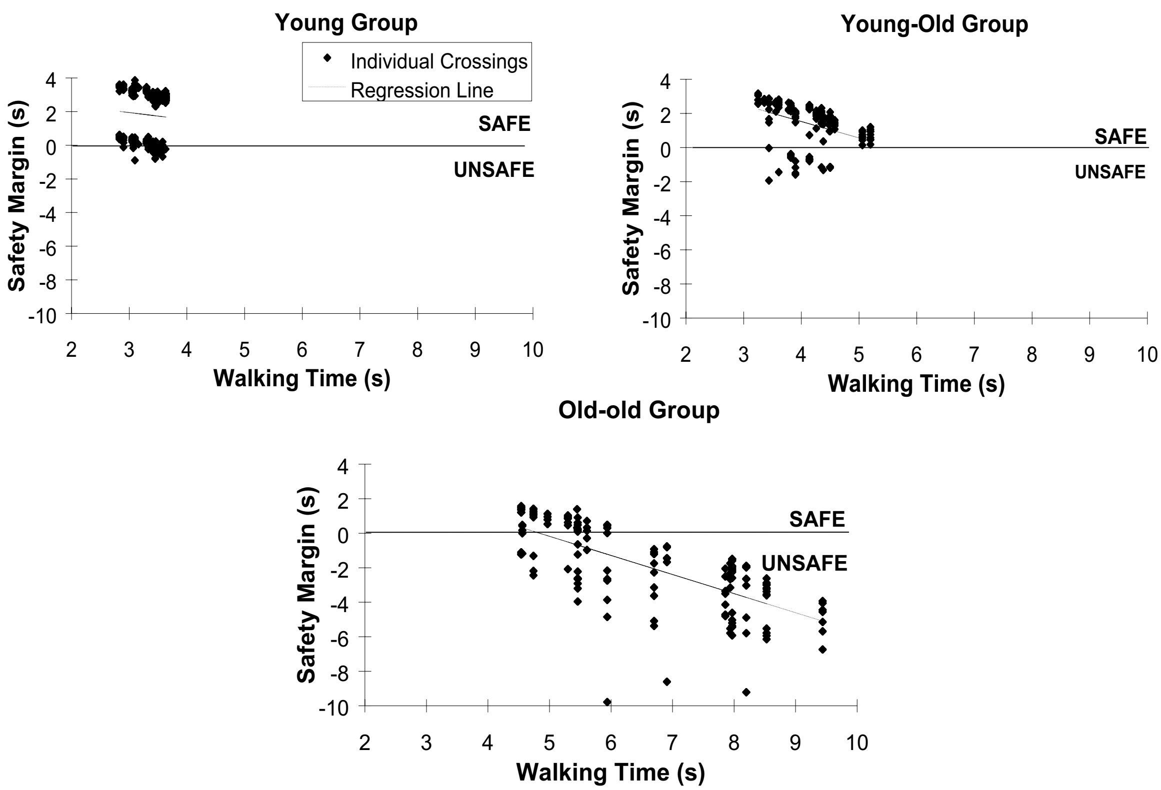

Figure 2: Safety margin distributions of each group for critical time-of-arrival conditions (4 and 7 seconds)

Safety rating responses – Like for the yes/no responses, all independent variables predicted safety rating responses and participants perceived themselves to be safer as time and distance gaps increased. Similarly, safety ratings seemed to be determined primarily by the distance of the vehicle away from the observer. There was some suggestion, however, that at longer distance gaps older participants based perceived safety more so on distance, not time gap. Furthermore, like for the yes/no responses, young-old participants perceived risk as higher than predicted for short distance and time gaps, while the old-old participants perceived themselves as much safer than they were estimated to be, particularly at long distances.

DISCUSSION

Overall, the results of the first experiment demonstrated that the distance gap of the vehicle, and to a lesser extent the time gap and vehicle speed, were predictors of crossing decisions. In other words, all participants appeared to rely more on spatial than temporal information about oncoming vehicles to make crossing decision, and particularly the very old ones. While older participants seemed to compensate to some degree for physical limitations (they were less likely to say 'yes' and rated their safety as lower than younger participants), in reality these decisions were not safe based on average group walking speeds. These findings appear to highlight the processes involved in making crossing decisions and rating the safety of crossing. It seemed that older participants in particular were more likely to want to cross the road when vehicles were further away, regardless of the speed they were travelling at. In contrast, younger participants seemed able to take vehicle speed into account. While all participants appeared to base their decisions to some extent on both distance and speed information, old-old participants seemed only able to do this accurately for closer distances. For the longer distances, they tended to base their decisions more on the distance gap than the younger ones and experienced difficulty taking vehicle speed into account.

While the likelihood of a positive crossing response increased as time and distance gaps increased for all participant groups, both of the older groups were less likely than the younger group to indicate that they would have crossed in distance gaps that were smaller than about 110 m. This was so despite the finding that young-old participants did not walk that much more slowly than the young participants, and could have crossed the road with similar gaps. It was, however, appropriate for the old-old participants to indicate that they needed larger gaps than young participants, as their walking times were significantly longer. This suggests that young-old participants were far more cautious than they needed to be and old-old participants less cautious and therefore less safe.

Considering slower walking and decision times of old-old participants it was not surprising to find age differences in safety margins as well. The majority of old-old participants who decided to cross did so when safety margins were negative, indicating that their decision and walking times were longer than the time-of-arrival of vehicles. Lee, Young and McLaughlin claimed that perceiving the affordance of a gap entails combining information about the environment with information about one's own walking speed. With diminished perceptual, cognitive and motor abilities, however, some older adults may experience difficulty in accommodating their judgements of safe gaps in the traffic to slowed walking speeds. It is unlikely that the old-old participants in this study would have intentionally chosen a risky decision strategy in this situation over their younger counterparts. More likely, they had great difficulty in integrating speed and distance information, necessary to predict the time-of-arrival of the approaching vehicle and respond appropriately to their walking time. Thus, they might adopt a simplistic strategy that simple says "the further away the vehicle is, the safer it is for me to cross". This could be a function of their reduced cognitive capacity or their visual deficits. In any event, it is clearly a dangerous strategy to adopt as they are likely to find themselves caught out in the traffic in complex situations. Furthermore, the ability to make appropriate and quick decisions, particularly in critical time gaps would seem paramount to safe road crossing. The combination of slow decision and walking time, and the failure to integrate both distance and vehicle speed information, may increase risk of collision considerably for old-old pedestrians.

EXPERIMENT TWO

The findings of the first experiment showed that participants judged the safety of a gap primarily on the basis of the distance of the approaching vehicle, but old-old participants seemed to experience difficulty discriminating between speeds with small differentials when vehicles were further away. In addition, this group required more time to make their decision. This raises the question as to whether old-old adults would make safer crossing decisions if given more or less time to make their judgement. It is possible that increased inspection time might facilitate perception of vehicle speed, in particular, differences between the velocity of two vehicles, and the integration of this information with vehicle distance in order to process time-of-arrival of vehicles. It is also conceivable that shorter inspection times might push older adults into greater reliance on distance as the critical cue, given that they are less able to process information simultaneously than younger adults (Wickens, 1989; McDowd & Craik, 1988; Triggs, Fildes & Koca, 1994).

The second study was conducted to explore further the effect of short and long displays on an adults' ability to judge safe crossing situations on the road. In this experiment, viewing times of traffic scenes were varied along with vehicle speed and time-of-arrival. It was hypothesised that viewing time would have no effect on the decisions of younger adults because they should be able to instantaneously take distance and vehicle speed information into account. Conversely, it was expected that viewing time would affect crossing decisions of older adults, pointing to a difficulty in sequentially integrating distance and velocity information.

METHOD

Participants – Forty five participants took part in this experiment, consisting of 15 young adults (30 – 40 years), 15 young-old adults (60 – 69 years) and 15 old-old adults (75+ years). All participants had taken part in the first experiment and were familiar with the task.

Procedure – The same apparatus as used in the first experiment was utilised in this study and the same stimulus images presenting two vehicles travelling in the same direction, with one following the other, were presented here. All traffic scenes were downloaded from the mid-level driving simulator onto VCR tapes and edited to produce views of traffic scenes beginning with the first vehicle passing the pedestrian crossing point and ending after a time interval of either 1 s or 5 s.

RESULTS

Yes/no responses – As in the first experiment, hierarchical modelling of the data was employed to hold the effects of mobility constant while examining the relationship of other independent variables including age, time-of-arrival, vehicle speed, gap distance and viewing time. Figure 4 shows the proportion of positive responses by distance gap, vehicle speed and time-of-arrival and viewing time.

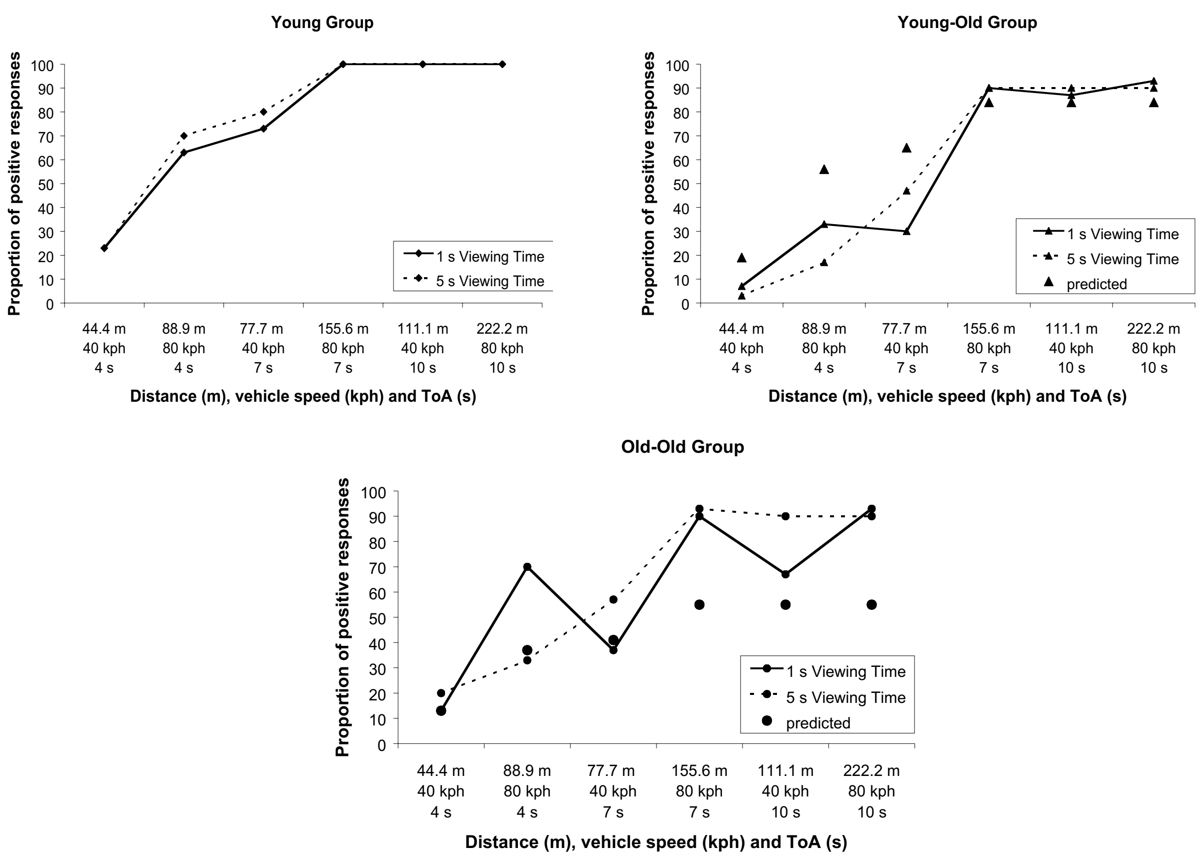

Figure 4: Proportion of positive responses – age group by distance gap, vehicle speed and time-of-arrival and viewing time.

Age, $\chi^2(2) = 51.17$, $p < 0.001$, $R = 0.30$, time-of-arrival, $\chi^2(2) = 131.45$, $p < 0.001$, $R = 0.30$, vehicle speed, $\chi^2(1) = 102.01$, $p < 0.001$, $R = 0.27$, and distance gap, $\chi^2(5) = 56.06$, $p < 0.001$, $R = 0.18$, were all found to be significant predictors of crossing decisions. Significant two-way interactions were revealed between time-of-arrival and age group, $\chi^2(4) = 12.12$, $p < 0.05$, $R = 0.06$), vehicle speed and viewing time, $\chi^2_{(1)} = 8.36$, $p < 0.01$, and between distance gap and viewing time, $\chi^2(5) = 13.96$, $p < 0.05$, $R = 0.05$. In addition a three-way interaction between age group, vehicle speed and viewing time was found, $\chi^2(2) = 6.03$, $p < 0.05$, $R = 0.04$.

Viewing time seemed to make little difference to the proportion of yes responses of young participants. Their data indicated that in both viewing time conditions distance gap as well as time gap influenced their decision to cross. That is, young participants were more likely to cross when distance gaps were longer even though time gaps did not vary, but they also said 'yes' more often when the reverse was true (up to asymptote). Thus, younger adults are clearly able to process both distance and speed of vehicles in very short periods of time.

Safety rating responses – The safety ratings largely confirmed the trend in the yes/no responses that viewing time did not affect safety ratings of young and young-old participants, but clearly did for the old-old group. Both young and young-old participants seemed to rate their safety on the basis of both distance and time gaps in both viewing time conditions, whereas the old-old groups' safety ratings were determined by distance alone in the short viewing time condition and both distance and time when exposure times were longer.

DISCUSSION

The second experiment was conducted to examine the effect of short and long viewing times on road crossing decisions. While all aged participants processed vehicle distance and speed information when making these judgements, old-old participants appeared to experience difficulty doing so in short viewing times. In these conditions they could only make their decisions based on the distance of an oncoming vehicle whereas they were able to take vehicle speed into account when viewing times were longer. This shows that under time pressure, crossing decisions of the oldest participants were potentially unsafe as they were based solely on vehicle distance with little adjustment for vehicle speed. This finding supports the notion that older people are less able to process information simultaneously, instead adopting more of a sequential approach. Time permitting, they might then moderate their first decision in the light of the speed of the vehicle. Younger adults, on the other hand, seem more able to process both distance and speed information simultaneously (Wickens, 1989). The young-old group seem to be mid-way between the two extremes, suggesting that even at these ages (60-69 years) information processing ability is changing. With higher cognitive capacity, however, they may be more aware of these difficulties than older adults and seem to respond more cautiously.

GENERAL DISCUSSION AND CONCLUSIONS

The experiments reported here have provided a detailed account of decision-making processes on crossing the road. They have also highlighted differences between the decision-making processes of younger and older adults regarding gaps in the traffic in which to cross roads safely which may, in part, contribute to the increased crash injury rates of older pedestrians. The most interesting finding of these experiments was that despite their apparent ability to process speed and distance of vehicles, older adults made very risky crossing decisions and over-estimated their safety by not always allowing sufficient gaps in the traffic when crossing the road. It may be argued that physical limitations such as slower walking, and difficulty in initiating actions may contribute to these findings. However, this research has shown that cognitive limitations also play a role.

Old-old adults (and to a lesser extent young-old adults) experienced great difficulty integrating distance and velocity information of oncoming vehicles when under time pressure, when vehicles are further away and when speed differentials are small. The oldest adults seemed less able than younger adults to process multiple sources of information quickly and sequentially. Others, too, have found that older pedestrians experienced difficulty combining speed and distance information and lack appropriate consideration of the speed of approaching vehicles (Carthy, Packham, Salter & Silcock, 1995; Elliott, Elliott & Lysaght, 1995). This may mean that in some situations, for instance, in complex traffic or perhaps when decisions need to be made quickly, old-old pedestrians experience difficulty processing or perceiving information efficiently, particularly limited time or capacity to modify their distance-based perception. The findings also point to adoption of a conservative strategy by adults in their 60's, possibly as a result of being more aware of age-related limitations. In contrast, it appears that some older adults may experience difficulty in judging safe gaps in which to cross as a result of a reduced awareness of limitations, a reduced ability to compensate for limitations and as a result of perceptual misjudgments in estimating appropriate time-of-arrival of approaching vehicles.

The finding that behavioural factors contribute to increased risk of collision have practical implications for behavioural and engineering road safety countermeasures for reducing pedestrian crashes. An emphasis on designing countermeasures aimed at simplifying the road crossing task (such as centre median strips) are clearly warranted in areas commonly frequented by older pedestrians. A greater use of pedestrian crossing facilities, or perhaps the establishment of pedestrian precincts where vehicle speeds are lower and priority is given to pedestrians would also be of great assistance in aiding older pedestrian road crossings. Finally, it is worthwhile considering the development of specialised training programs aimed at older pedestrians to assist awareness of declining abilities and adoption of safe road crossing practices.

REFERENCES

Burg, A. (1966). Visual acuity as measured by dynamic and static tests. Journal of Applied Psychology, 50, 460-466.

Carthy, T., Packham, D., Salter, D., & Silcock, D. (1995). Risk and safety on the roads: The older pedestrian. University of Newcastle Upon Tyne; Report prepared for the AA Foundation for Road Safety Research.

Elliott, D., Elliott, B., & Lysaght, A. (1995). Older driver risks and countermeasures: Source book. Report CR163. Canberra, Australia: The Federal Office of Road Safety.

Kosnik, W., Winslow, L., Kline, D., Rasinski, K., & Sekuler, R. (1988). Visual changes in daily life throughout adulthood. Journal of Gerontology: Psychological Sciences, 43(3), 63-70.

Lee, D., Young, D., & McLaughlin, C. (1984). A roadside simulation of road crossing for children. Ergonomics, 27(12), 1271-1281.

McDowd, J., & Craik, F. (1988). Effects of aging and task difficulty on divided attention performance. Journal of Experimental Psychology: Human Perception and Performance, 114, 267-280.

Oxley, J., Fildes, B., Ihsen, E., Charlton, J., & Day, R. (1997). Differences in traffic judgements between young and older adults pedestrians. Accident Analysis and Prevention, 29(6), 839-847.

Schiff, W., Oldak, R., & Shah, V. (1992). Aging persons' estimates of vehicular motion. Psychology and Aging, 7(4), 518-525.

Sharpe, J., & Sylvester, T. (1978). Effects of aging on horizontal smooth pursuit. Invest. Opthal. Visual Sci., 17(5), 465-467.

Triggs, T., Fildes, B., & Koca, H. (1994). Human Factors Study of Pedestrian Behaviour. In B. Fildes (ed.) Injuries Among Older People. Falls at Home and Pedestrian Accidents, (pp.155-174). Melbourne: CollinsDove Publishers.

Wickens, C. (1989). Attention and skilled performance. In D. Holding (ed.). Human Skills,(pp. 71-105). North Holland: Elsevier Science Publishers.