The impact of age-related functional impairments on the ability to cross roads safely.

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Abstract

Older pedestrians are over-represented in serious injury and fatal crashes. The task of making gap judgements in order to cross roads safely may place high demands on older pedestrians and it is possible that they are at increased risk as a result of age-related sensory, cognitive and physical limitations. This paper describes an experiment conduced to investigate the effect of age and age-related changes in functional performance on crossing decisions. The findings suggest that age and age-related declines in physical, perceptual and cognitive function are associated with an increased likelihood of making an incorrect (unsafe) crossing decision. These findings have practical implications for behavioural and engineering road safety countermeasures for reducing older pedestrian crashes.

INTRODUCTION

Crash statistics show that the elderly are involved in significantly more serious injury and fatal pedestrian crashes than younger adults per head of population and number of roads crossed (1,2,3). Few studies, however, have investigated the extent to which the road crossing behaviour and functional performance of older pedestrians compared to younger ones increases their risk of crash involvement. There are likely many factors impacting on the greater crash risk for older pedestrians and functional performance is thought to contribute to increased risk on the road because the road crossing task is a complex one that requires integration of a number of visual, cognitive and psychomotor skills.

In order to cross a road safely without engineering assistance, pedestrians must, while approaching or stopping at the edge of the road, inspect the roadway in both directions and look for approaching vehicles. This part of the task involves detecting objects and motion, ascertaining the direction and velocity of objects, the identity of the object and estimating when the vehicle will arrive at the crossing point. Furthermore, pedestrians must, on many roads, integrate and remember information about traffic in both directions and in multiple lanes as well as combine vehicle arrival times with own walking speed in order to reach a decision to cross.

Making the decision to cross the road, therefore, is a complex task requiring reasonably intact perceptual, cognitive and physical skills. For older pedestrians, however, the task of making gap judgements in order to cross the road safely may place high demands on them and it is possible that they are at increased risk while crossing the road as a result of age-related sensory, cognitive and physical limitations. There have been numerous studies that associate age-related change in functional performance with increased crash risk for older drivers (4,5,6). These associations, however, have not been clearly identified or established for pedestrian performance. The experiment described in this paper examined age differences in road crossing decisions in a simulated crossing environment and reports on the association of functional performance with ability to make appropriate crossing decisions.

METHOD

Participants – Fifty-four participants took part in this study. 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.

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 utilised 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 gap and speed of the approaching vehicles were manipulated.

Tests of functional performance – All participants completed a battery of functional assessments designed to assess visual, attentional, cognitive and physical abilities. These included the Verbaken high/low contrast visual acuity test, the Trail-making tests (Parts A and B), the Digit-Symbol test (sub-test of the WAIS), the Mattis Organic Mental Syndrome Screening Examination (MOMSSE) (a shortened version of the Dementia Rating Scale), measures of walking time (fast and normal walking pace) and the 'get-up-and-go' test (assessments of physical fitness).

Procedure – Tests of functional performance were administered initially and all participants completed each test. Following this, participants were seated at the road simulation 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 activated a timer), and participants were instructed to look at the traffic at this time and make a simple 'yes' or 'no' response on a keyboard to indicate whether they would have 'crossed' or not. Yes/no responses and decision time were recorded.

RESULTS

Yes/no responses – These responses indicated whether individuals would have crossed the road or not in front of the approaching vehicle. Table 1 shows the number of 'yes' and 'no' crossing responses by time gap condition for each age group. The data show that all participants were generally less likely to indicate that they would cross when there were small time gaps than when these were larger. Some age group differences were also found. The young-old and old-old groups were less likely to make a 'yes' response (and more likely to make a 'no' response) than the younger group when time gaps were smaller than 7s. This was not surprising, particularly for the old-old group, given that their walking time was slower than the younger group. At time gaps of 1s the number of 'yes' responses was close to zero and from 10s almost all young and young-old participants indicated they would cross. The old-old participants waited until time gaps were 13s before most of them decided to cross.

Table 1: Number (and proportion) of yes and no responses by age group.

		Young Group	Young-Old Group	Old-Old Group
1s time gap	Yes responses	0	0	1(1%)
	No responses	162 (100%)	162 (100%)	161 (99%)
4s time gap	Yes responses	106 (65%)	29 (18%)	35 (22%)
	No responses	56 (35%)	133 (82%)	127 (78%)
7s time gap	Yes responses	154 (95%)	126 (78%)	110 (68%)
	No responses	8 (5%)	36 (22%)	52 (32%)
10s time gap	Yes responses	162 (100%)	152 (94%)	143 (88%)
	No responses	0	10 (6%)	19 (12%)
13s time gap	Yes responses	162 (100%)	161 (99%)	156 (96%)
	No responses	0	1 (1%)	6 (4%)

Initial analysis of yes/no crossing responses was undertaken by employing hierarchical logistic regression modelling of the data to examine the independent variables including age group, time gap and vehicle speed while holding the effects of walking time statistically constant. All variables were significant predictors of crossing decisions: walking time, $?^2(1) = 32.33$, $p < 0.001$, $R^2 = 0.10$, time gap, $?^2(4) = 191.33$, $p < 0.001$, $R^2 = 0.24$, and vehicle speed, $?^2(2) = 90.76$, $p < 0.001$, $R^2 = 0.16$. An interaction between time gap and age group was also found, $?^2(8) = 152.53$, $p < 0.001$, $R^2 = 0.21$.

While a ‘yes’ or ‘no’ response in itself is an interesting measure, the response needs to be put into context of whether it was ‘correct’ (safe) or ‘incorrect’ (unsafe or missed opportunity), allowing for walking time and decision time, particularly in critical time gaps (4s and 7s). For example, if an individual with a combined walking and decision time of 5s responded ‘yes’ in the 4s time gap condition, that response would be recorded as an ‘incorrect’ (or unsafe) response. If a ‘no’ response was made in this time gap condition, it would be a ‘correct’ (or safe) response. If a ‘yes’ response was made by this person with the same combined walking and decision time in the 7s time gap condition, that response would have been recorded as a ‘correct’ response. Conversely, if a ‘no’ response was made in this time gap condition, it would be an ‘incorrect’ (or missed opportunity) response.

Figure 1 shows the proportion of correct ‘yes’ and ‘no’ responses for the critical time gaps of 4s and 7s and demonstrates clear group and time gap condition differences. A logistic regression model was employed to predict correct response as a function of age group, time gap, yes/no responses and their interactions. The model utilised fitted the data well, with an R^2 value of .71. The analysis revealed that age group and time gap were predictors of correct responses and that there were clear age group and time gap differences. Interactions were found between age group and time gap, $?^2(2) = 5.946$, $p = 0.05$, between age group and yes/no response, $?^2(2) = 99.203$, $p < 0.05$, and between time gap and yes/no response, $?^2(1) = 95.243$, $p < 0.001$. Overall, the young group was more likely to make a correct ‘yes’ response than the older groups in both the 4s and 7s time gap conditions. Young participants who responded ‘yes’ in the 7s time gap were correct 100% of the time, and, in the 4s time gap, the proportion of correct ‘yes’ responses dropped to 54%. Young-old participants who responded ‘yes’ in the 7s time gap, were correct 99% of the time, however, this dropped markedly to only 3 % in the 4s time gap condition. In contrast, old-old participants were less likely to be correct than their younger counterparts when they responded ‘yes’ in both the 4s and 7s time gap conditions. They were correct only 38 % of the time in the 7s time gap condition and incorrect all of the time in the 4s time gap condition. It is interesting to note that the young-old group performed similarly to the young group in the 7s time gap condition and made a correct ‘yes’ response most of the time, however, performed more like the old-old group in the 4s time gap condition. This finding might suggest that young-old participants experienced more problems when the time gap was shorter or more critical than when the time gap was longer.

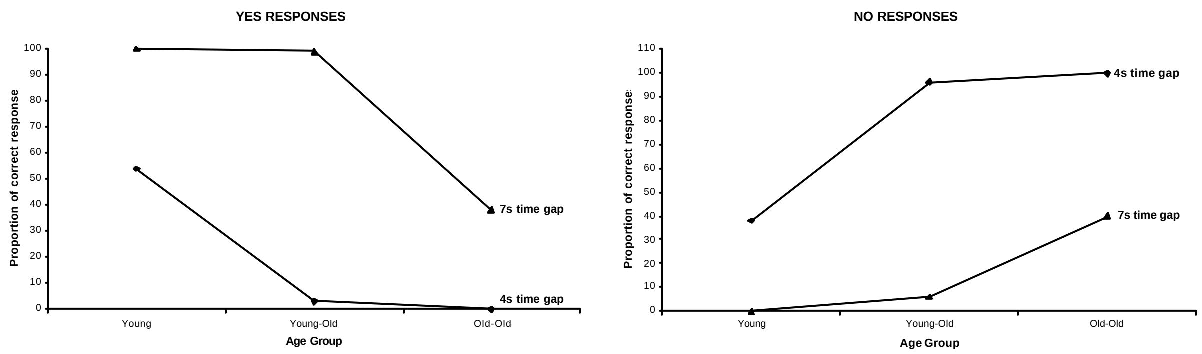

Figure 1: Proportion of ‘correct’ responses by age group for both ‘yes’ and ‘no’ responses.

Interestingly, the ‘no’ responses showed an inverse relationship to the ‘yes’ responses. While the old-old group was more likely to respond ‘no’, particularly in the 4s time gap, they were also more likely to make a correct ‘no’ response than their younger counterparts. Of the few young and young-old participants who made a ‘no’ response’ in the 7s time gap condition, the majority made an incorrect response, meaning that they said ‘no’ when they should have said ‘yes’ (a missed opportunity). Like for the ‘yes’ responses, when making a ‘no’ response, the young-old group performed similarly to the young group in the 7s time gap condition, however, performed more like the old-old group in the 4s time gap condition.

These initial analyses considered age group membership as a predictor of crossing decisions and the findings suggest that age itself is a good predictor of ability to cross roads safely. The main focus, however, of this research was to examine the effect of functional performance on the ability to cross roads safely.

Table 2 presents mean scores on each functional assessment test by age group. For all tests, performance declined significantly with age. Simple one-way ANOVAs with post hoc Tukey tests were performed on the data for each assessment, examining differences between age groups. In comparison with the young group, the old-old group performed more poorly on all tests. In comparison with the young-old group, too, the old-old group performed more poorly on physical tests, trail-making tests (parts A and B), digit/symbol test and the

MOMSSE assessment for mental status. No significant difference in visual acuity was found between these groups, except under one low contrast condition.

Table 2: Mean score on functional assessment tests by age group.

	Young Group (n=18)		Young-Old Group (n=18)		Old-Old Group (n=18)	
Assessment	***Mean Score***	***SD***	***Mean Score***	***SD***	***Mean Score***	***SD***
Get-up-and-go	6.15s	0.97s	7.86s ***	1.05s	11.43s ***	2.94s
Normal walking time	3.87s	0.31s	4.60s ***	0.61	6.96s ***	1.57s
Fast walking time	2.77s	0.32	3.57s ***	0.55	5.74s ***	1.72
Visual acuity (r/low)	0.75	0.22	0.37 ***	0.11	0.32	0.19
Visual acuity (r/high)	1.17	0.24	0.62 ***	0.22	0.63	0.28
Visual acuity (l/low)	0.74	0.24	0.39 ***	0.12	0.31 *	0.15
Visual acuity (l/high)	1.14	0.29	0.68 ***	0.23	0.61	0.33
Trail-making test (A)	21.71	4.85	38.13***	12.68	61.80***	23.06
Trail-making test (B)	51.40	12.97	90.26**	36.68	131.77**	53.87
Digit/symbol	67.39	6.89	47.83 ***	9.29	35.83 ***	9.78
MOMSSE	53.39	1.29	49.61 ***	3.35	45.72 ***	5.80

*** $p < 0.001$
* $p < 0.05$

In order to examine the association between performance on functional assessments and ability to make appropriate crossing decisions, comparisons between 'correct/incorrect' responses in the most critical time gap conditions (4 s and 7 s) and functional performance were made. Given that the decision to cross the road rather than wait may be a better predictor of 'riskiness' based on a safety outcome, and that the fit of the model to the 'yes' response was as good as the complete data (R^2 = .70), 'yes' responses only were considered in the following analyses.

A series of logistic regression analyses were performed on the 'yes' response data to examine the association between each functional assessment test and ability to make a correct 'yes' responses in both time gap conditions. Each regression model included the functional assessment measure along with the time gap condition as predictors. Interactions between time gap and score on functional assessments were considered, however, they did not improve the model significantly and were therefore not included in the final analyses. In addition, walking time was not included in these analyses as this measure was used to generate the 'correct/incorrect' response variable. Table 3 summarises the outcomes of these analyses.

All tests of functional performance were predictors of correct 'yes' responses, shown by the high and significant ?^{2} values in Table 3. This means that, the better one performs on functional assessments, the more likely a correct 'yes' response would be made. Conversely, poor performance on these tests is associated with the probability of making an incorrect 'yes' response. The get-up-and-go test was the strongest predictor of correct response suggesting that individuals with good physical ability were more likely to make a correct 'yes' response than those who were slow to complete the test, demonstrate by R^2 values. The digit/symbol also predicted responses strongly, suggesting that individuals with good visuo-motor co-ordination, fine motor speed, divided attentional skills and speed of cognitive operations were more likely than individuals whose abilities were poorer to make a correct 'yes' response. Visual acuity was the least strongest predictor of a correct 'yes' response.

Table 3: Summary of logistic regression analysis outcomes for each functional assessment test

Assessment	Wald Statistic ? ^{2} Value	R^2 Value
Get-up-and-go	97.55 *	0.720
Mean Visual Acuity	43.64 *	0.375
Trail-Making Tests (Part A)	74.05 *	0.469
Trail-Making Test (Part B)	71.01 *	0.451
Digit/Symbol Test	99.73 *	0.604
MOMSSE	77.57 *	0.461

* $p < 0.001$

DISCUSSION

The experiment reported here has highlighted age differences between the ability to select 'correct' or safe gaps in the traffic in which to cross roads safely and suggests that age itself is a good predictor of safe road crossing ability. It has also demonstrated significant association between performance on physical, perceptual and cognitive skills and road crossing responses.

In recent years, the appropriateness of using chronological age spans a number of road safety issues. For instance, it has been argued that statistics depicting crash risk by chronological age may lead to the inaccurate conclusion that age per se is the major determinant of driving safety. Waller (7) further argued that years since birth can be a misnomer in terms of performance ability, may not serve as a predictor of the capabilities of any aged individual, and may ignore alternative or complementary functional definitions. It is argued that age itself does not lead to crashes – this is evident because crashes are not equally distributed among all ageing drivers. Rather, it seems that age-related declines in particular abilities may be important to safe driving. However, this has been difficult to establish for pedestrian risk. Indeed, this debate continues to be a challenging issue in mandating license re-assessment for older drivers worldwide. Currently, older driver re-licensing requirements in Australian are a State responsibility and, for the most part, age-based. However, there is general support within Australasia for a more strategic targeted licence re-assessment procedure utilising valid test procedures and a more systematic objective approach (see Fildes et al. (8)). Despite these assertions, the current findings suggest that advancing age does increase risk on the road. However, it should be noted that the age groups considered in this experiment were quite distinct from each other and spanned 10-year minimum age cohorts. Moreover, it is a difficult task to separate the effects of age per se and age-related changes in functional performance on crash risk. Given that functional performance varies considerably within age groups, particularly for the older age groups, variability within groups was not able to be clearly identified in the initial analysis.

Generally, young-old and old-old participants were less likely to indicate that they would have crossed than younger participants. 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 safely 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 would suggest that they took their slower walking times into account when making road-crossing decisions. However, the current analysis demonstrated that agility was a significant indicator of road crossing decisions. It seemed that many slower walking participants (who were generally the old-old participants) made risky crossing decisions in critical time gaps and over-estimated their safety by indicating they would have crossed when, in fact, they should not have.

Intuitively, good motor performance is of prime importance when crossing roads, particularly the ability to adjust walking pace and execute actions quickly when faced with traffic emergencies. Reduced physical capabilities means that older pedestrians are less mobile and less able to move out of the way of approaching cars. While a number of studies have investigated walking speed and start-up time and found that older adults initiate movement and walk more slowly than younger adults (9,10,11,12), no previous research has associated physical agility with crash risk. The current finding that slower walkers made more incorrect crossing decisions supports Lee et al's (13) argument that older people may not compensate appropriately for their slower walking speeds. Lee et al. claimed that perceiving the affordance of a gap in the traffic entails combining information about the environment with information about one's walking speed. It is unlikely that slower walking older participants in this study would have intentionally chosen a risky decision strategy in this situation over their younger counterparts. However, this finding may be explained as a difficulty in adjusting behaviour to suit changing abilities. As Lee et al argued, while younger adults maintain calibration through daily experience, older adults need to re-calibrate as they become infirm and slower and this may be a very difficult task to achieve.

The findings show that attentional and cognitive abilities also play some role in ability to cross roads safely. The finding that participants who performed poorly on tests of visual search, attention and cognitive skill were more likely to make an incorrect 'yes' crossing response suggest that the road crossing task places overwhelming demands on attentional and cognitive resources of old-old participants and to a lesser extent for young-old participants. In a complex road environment with approaching traffic, it seems that inabilities in attending to, integrating and processing many sources of information could have reduced the ability to respond safely to the approaching traffic. Normal ageing brings declines in a number of cognitive domains that may be important to crossing roads. These include: inflexibility of visual scanning particularly when a rapid decision is required (14); problems in efficiently focussing and switching attention to the most relevant source of information and excluding irrelevant information (15); and difficulties of working memory, particularly holding information in memory and integrating it with incoming information (16).

It is interesting to note that the measure of visual acuity was not a strong predictor of correct crossing response, despite the continued argument that traffic participation is a highly visual task, and with the majority of research on older drivers focussing on the role of age-related visual declines in crash risk (17,18, 19). There is no doubt that vision is important to perform daily activities, to detect potential hazards, and maintain balance and ambulation, however, static visual acuity may not be the most appropriate measure of visual skill for pedestrian performance. Indeed, previous correlations between static visual acuity and increased risk of crashing are weak at best (17,20). Dynamic visual acuity (the ability to resolve details in a moving target) seems to be a better predictor of crash risk in a number of studies (21,22,23,24) and should be considered in future research. Given that many of the visual requirements for road-crossing require the detection and assessment of changing information on the retina, declines in dynamic visual acuity may lead to inaccurate estimations of vehicular movement.

In summary, this experiment has shown that, although all functional assessment tests predicted the ability to cross roads safely, age group was generally a very strong predictor of safe crossing decisions. The 'get-up-and-go' test was the only functional assessment that predicted safe crossing decisions more strongly than age group, suggesting that this test encompassed more than age alone. However, all other functional assessments predicted safe crossing decisions less strongly. This would suggest that individual functional assessment tests may not discriminate adequately all factors involved in making this decision. It is possible, however, that a combination of these tests can predict safe crossing decisions and is worthy of future research.

CONCLUSIONS

This experiment examined age differences in crossing responses in a simulated road environment. It showed that older participants were less likely to cross a road than younger participants, indicating some awareness of risk and some attempt at compensation for slower walking times. Despite this, however, they were also more likely to make an incorrect response. The usefulness of tests of functional performance for predicting crash risk of older pedestrians was also examined here and significant associations between physical, perceptual and cognitive function and the likelihood of making an incorrect crossing response were found. It appears that those with reduced physical, perceptual and cognitive skills (generally the old-old participants) were at increased risk of collision while crossing the road because they were more likely to respond incorrectly to approaching traffic, believing themselves to have more time to cross in safety than in reality. The findings that physical, perceptual and cognitive factors contribute to increased risk of collision have practical implications for behavioural and engineering road safety countermeasures for reducing older pedestrian crashes.

REFERENCES

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

2. Fontaine, H., & Gourlet, Y. (1997). Fatal pedestrian accidents in France: A typological analysis. *Accident Analysis and prevention, 29(3)*, 303-312.
3. Australian Transport Safety Bureau (2000). Monograph 3: Pedestrian Safety – Australia's international pedestrian safety performance 1990 to 1997. www.atsb.gov.au.
4. Janke, M. (1994). Age-related disabilities that may impair driving and their assessment: Literature review. Sacramento: California Department of Motor Vehicles.
5. Ball, K., Owsley, C., Sloane, M., Roeneker, D., & Bruni, J. (1993). Visual attention problems as a predictor of vehicle crashes in older drivers. *Investigative Opthalmology and Visual Science, 34*, 3110-3123.
6. Marottoli, R., Richardson, E., Stowe, M., Miller, E., Brass, L., Cooney, L., & Tinetti, M. (1998). Development of a test battery to identify older drivers at risk for self-reported adverse driving events. *Journal of the American Geriatrics Society, 46(5)*, 562-568.
7. Waller, P. (1991). The older driver. *Human Factors, 33(5)*, 499-505.
8. Fildes, B., Pronk, N., Langford, J., Hull, M., Frith, B., & Anderson, R. (2000). Model licence re-assessment procedure for older and disabled drivers. (Report No. AP-176/00). Austroads, Sydney.
9. Stelmach, G., & Nahom, A. (1992). Cognitive-motor abilities of the elderly driver. *Human Factors, 34(1)*, 53-65.
10. Knoblauch, R., Pietrucha, M., & Nitzburg, M. (1996). Field studies of pedestrian walking speed and start-up time. *Transportation Research Record, 1538*, 27-38.
11. Eubanks, J., & Hill, P. (1998). Pedestrian crash reconstruction and litigation. Tucson, AZ. Lawyers & Hudges Publishing Co.
12. Oxley, J. (2000). Age differences in road-crossing behaviour. Unpublished PhD Thesis. Monash University, Melbourne.
13. Lee, D., Young, D., & McLaughlin, C. (1984). A roadside simulation of road-crossing for children. *Ergonomics, 27(12)*, 1271-1281.
14. Rabbitt, P. (1982). How do older people know what to do next? In F. Craik & S. Trehub (Eds), *Aging and Cognitive Processes: Advances in the Study of Communication and Affect, Volume 8*, (pp. 79-98). New York, Plenum Press.
15. Madden, D., Connelly, L., & Pearce, Y. (1994). Aging and focussed attention. *Psychology and Aging, 9(4)*, 528-538.
16. Johnston, M., de Leonardis, D., Hashtroudi, S., & Ferguson, S. (1995). Aging and single versus multiple cues in source monitoring. *Psychology and Aging, 10(4)*, 507-517.
17. Shinar, D., & Scheiber, F. (1991). Visual requirements for safety and mobility of older drivers. *Human Factors, 33(5)*, 507-519.
18. Kosnik, W., Sekuler, R., & Kline, D. (1990). Self-reported visual problems of older drivers. *Human Factors, 32(5)*, 597-608.
19. Klein, R. (1991). Age-related eye disease, visual impairment and driving in the elderly. *Human Factors, 33(5)*, 521-525.
20. Owens, D., & Andre, J. (1996). Selective visual degradation and the older driver. *Journal of International Association of Traffic Safety Sciences, 20(1)*.
21. Burg, A. (1964). An investigation of some relationships between dynamic visual acuity, static visual acuity and driving record, (Report 64-18), University of California, Department of Engineering, LA.
22. Burg, A. (1967). The relationship between vision test scores and driving record: General findings, (Report 67-24), University of California, Department of Engineering, LA.
23. Hills, D. (1975). Some studies of movements, perception, age and accidents. Proceedings of the First International Congress on Vision and Road Safety, (pp. 65-80). Paris, Routiere Internationale.
24. Shinar, D. (1977). Driver visual limitations, diagnosis and treatment. NHTSA, US Department of Transport.