AN INVESTIGATION OF ROAD CROSSING BEHAVIOUR OF OLDER PEDESTRIANS

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An Investigation of Road Crossing Behaviour of Older Pedestrians

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Abstract:  
Road safety literature suggests that the oldest road users have a high accident risk and that they are much more likely to be severely injured or killed once involved in an accident than any other group of road users. There is also considerable evidence that older people experience deficits not only in their physical abilities but also in sensory, perceptual, and cognitive abilities. Little is known, however, about how these affect road-crossing behaviour and their safety. The purpose of this study was to investigate the road-crossing behaviour of both old and young adult pedestrians to determine whether older pedestrians' behaviour was more risky than that of younger pedestrians. The study also aimed to identify target groups and road situations for intervention and to recommend countermeasures designed to reduce the frequency and severity of older pedestrian accidents. Road crossing behaviour of older and younger pedestrians was filmed at two two-lane undivided road strip shopping centre sites, and at one four-lane divided road strip shopping centre site in the Melbourne metropolitan area. Individual road-crossings were filmed unobtrusively from a parked van in which two cameras were set appropriately to record both oncoming near-side traffic and pedestrian movements. Pedestrian behaviour was scored for a number of determinants of safe road crossing actions. Significant differences were observed between young and old pedestrian road crossing behaviour on a number of critical key variables. Overall, the results show that older pedestrians' road crossing behaviour in complex traffic situations was less safe than their younger counterparts. In less complex situations, older pedestrians' behaviour was more like that of younger pedestrians. The findings are discussed in relation to age-related sensory, perceptual, cognitive and motor changes and recommendations for countermeasures and further research are made.

Key Words:  
Pedestrian, elderly, behaviour, injury, countermeasure

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EXECUTIVE SUMMARY

The road safety literature shows that older people are over-involved in pedestrian crashes and more likely to be severely injured or killed than younger pedestrians. There is evidence that older people experience declines in their physical, sensory, perceptual and cognitive abilities. Little research, however, has been conducted examining the extent to which age-related mobility and/or sensory or motor deficits affect their road crossing behaviour and whether they are able to adopt compensatory behaviours to overcome these disabilities.

This study set out to investigate the road crossing practices of older people, relative to younger ones in order to show whether they experience particular problems crossing the road and whether their road crossing behaviour rendered them more vulnerable to accidents. The study aimed to explain how their sensory, motor or perceptual deficits might influence road crossing practices among the elderly, to identify opportunities for behavioural intervention to reduce the frequency and/or severity of older pedestrian accidents, and highlight areas where additional research may be required.

Research Design

The method adopted for this study involved "black-spot" analysis of older pedestrian crashes as well as observational studies of road crossing practices. Behaviour was filmed at a number of locations in and around Melbourne and scored relative to younger pedestrians and traffic conditions. These findings are discussed in terms of actions that might put older pedestrians more at risk of crash involvement and what could be done in terms of publicity, education, enforcement and engineering to reduce these risks.

Black-spot Analysis

A "black-spot" analysis of police reported pedestrian accidents was conducted at several locations in and around Melbourne where older pedestrians were involved in road crashes to highlight the types of crashes that older (and younger) pedestrians were having. It revealed that the majority of road crossing accidents occurred as pedestrians stepped off the kerb, often as they walked out behind parked cars and into the path of oncoming vehicles. Older pedestrians, too, were involved in a number of far-side collisions, indicating that they might have been caught out by traffic while crossing the road. From this analysis, a number of specific road crossing actions were identified that were worthy of closer investigation.

Observational Studies

A pilot study was first conducted to develop a suitable method for collecting these data and to identify relevant independent variables and measures. Unobtrusive filming of road crossing behaviour was conducted from a van parked on the side of the road and set up with two cameras to provide simultaneous video images of oncoming traffic and pedestrian movements.

Two observational studies were then undertaken at strip shopping centres frequented by young and old pedestrians. The first study involved two-way traffic on an undivided roadway while the second focussed on one-way traffic and divided roads. Behaviour was scored leading up to and crossing the road itself in terms of times taken and looking behaviour.
Two-way Roads - Complex Environment

 Differences were observed in times spent waiting and leaving the kerb and crossing two-way undivided roads illustrating that older people take longer to execute these actions than younger people. There were significant differences in looking behaviour while crossing the road where older people were more focussed on their walking track and less on the near- and far-side traffic. The longer period spent crossing the road inevitably means that older pedestrians are more exposed to the likelihood of an accident.

 Their road crossing behaviour forced them to interact with the traffic more often in these environments. Given their diminished motor skills and ability to react quickly to danger, this means that these older people are less able to take evasive action and hence more vulnerable in dangerous road crossing situations.

 Comparing road crossing times with time of arrival of vehicles in the near-side lane showed that while the majority of older (and younger) pedestrians crossed the road safely, slower younger walkers tended to over-compensate in their crossing judgements while slower older pedestrians under-compensated. This demonstrated that older people do not adequately adjust for their physiological and psychological declines when crossing the road.

 It was argued that crossing a two-way undivided road is a complex multi-task skill requiring a high level ability to integrate multiple sources of information simultaneously. The findings from this study seemed to suggest that the reduced cognitive abilities associated with the ageing process may penalise older pedestrian judgements, placing them more at risk of a collision when crossing the road.

 One-way Roads - Less Complex Environment

 The effect of reduced cognitive abilities through ageing and its likely effects on road crossing behaviour of older pedestrians was examined further in a second observational study involving one-way traffic and divided roads. It was expected that in these less complex settings, older pedestrians would behave more like younger pedestrians.

 Indeed, the findings confirmed that older pedestrian behaviour improved when crossing one-way roads. Road crossing and time of arrival plots were quite similar for both old and young pedestrians. There were practically no differences in judging when to cross the road between faster and slower pedestrians in both groups, clearly demonstrating the benefits of simplifying the task for the aged as well as all pedestrians.

 There were still differences, though, in the time to cross and looking behaviour while crossing between young and old pedestrians. The elderly still took roughly twice as long to cross the road as their younger counterparts and were much more focussed on the road surface immediately ahead of them (their tracking path across the road).

 Both groups spent considerably less time looking at the far-side traffic appearing to cross one road first and then the other. The presence of a median strip considerably simplified the road crossing task and was of particular importance for older pedestrians. There was a suggestion, however, that the attentional and search strategies of older people were still not optimal even in these more simple road crossing environments.

 Summary of Problems Facing the Aged

 The findings from these accident and observation studies can be summarised as follows:
• Older pedestrians took twice as long to assess the traffic and cross the road than younger adults.

• Older people spent more time looking at the ground on the approach to and while crossing the roadway and less time studying the traffic in near- and far-side lanes.

• While they spent more time deciding when to cross the road, older people often found themselves caught out in the traffic and vulnerable.

• They were more likely to be confused crossing the road in complex traffic situations where decisions involve the integration of multiple sources of sensory information.

• They were slow to react to approaching traffic.

• Slower, older pedestrians appeared to be particularly at risk crossing the road and appeared to be more confused than faster (more fit) elderly pedestrians.

• Older pedestrians often failed to compensate adequately for their reduced abilities.

• Older pedestrians failed to check and re-check traffic once they commenced their crossing and more commonly were forced to interact with the traffic around them.

• In less complex road settings, older pedestrian behaviour was more safe and more like that of younger pedestrians.

Countermeasure Implications
These findings have implications for road safety countermeasures aimed at the elderly. Suggested countermeasures would be most effective when linked appropriately and implemented in an integrated way.

Publicity
These unsafe risky behaviours should be publicised widely to inform older pedestrians of actions that place them at risk of crash involvement and injury while crossing roads. Campaigns could also be aimed at improving driver awareness of older pedestrian limitations and difficulties. A number of specific messages stem from this research and these are outlined in the final chapter of the main report.

Training Packages
The findings from this study also have implications for training packages aimed at improving older pedestrian safety. Current packages such as “Walk-With-Care” which are used to alert older pedestrians to the dangers of using the road could incorporate many of these messages in their materials to help inform older people of their limitations and potential risk factors when crossing the roadway.
Laws and Enforcement
Several possible legal and/or enforcement measures are discussed in the final chapter such as a reduction of travel speed in high pedestrian areas, enforcement of crossing in appropriate places, awareness of current road laws and adherence to them, and reduced or restricted parking provisions in areas commonly frequented by older persons. Many of these measures apply equally as well for pedestrians of all ages.

Traffic Engineering Solutions
While this study was primarily concerned with behavioural interventions, nevertheless, a number of engineering treatments are likely to have positive behavioural consequences and are listed here for completeness. These include the provision of median refuges and kerb extensions, more formal pedestrian crossings, barrier fencing to prevent crossings in high hazardous locations, and complete separation of pedestrians and vehicles in some areas.

Areas Where Further Research is Required
This study has identified a number of dangerous practices that older people tend to adopt when crossing the road and possible physiological and psychological causes for them. Gap acceptance, speed estimation and critical attentional cues were raised as key factors involved in safe road crossing behaviour on the road. Observational studies in themselves are not sufficient to explain fully the road safety consequences of deficits in these abilities and further detailed laboratory research is warranted to gain a full understanding and hence additional behavioural measures aimed at improving the safety of older pedestrians.
CHAPTER 1

INTRODUCTION

1.1 Background

As the proportion of elderly people in western countries is increasing (Sjogren & Bjornstig, 1991; Waller, 1991), concern about safety in all types of environments is also expanding. In the last decade, a major effort has been made to reduce the number and frequency of deaths and injury on the road. In particular, dangers to the elderly in traffic environments is receiving increasing attention.

1.1.1 Crash Involvement

Several investigators have shown that older road users are over-involved in serious casualty crashes and fatal crashes (Mackay, 1988; Safety for Seniors Working Group, 1989: Federal Office of Road Safety, 1986; Gilbert, 1990). Pedestrian deaths and casualties account for a sizeable percentage of these crashes and this rate is expected to increase in the next 10 years as the proportion of elderly in the population increases. Moreover, due to increasing fragility with age, older pedestrians are more susceptible to severe injury than their younger counterparts in the same circumstances and face the greatest risk of death when involved in a crash (Alexander, Cave & Lyttle, 1990; Allard, 1982; Sheppard & Pattinson, 1986). With young adults, one in every nine seriously injured pedestrian dies; in the case of pedestrians over the age of 60 years, this rises to one in every four (Federal Office of Road Safety, 1986).

A study conducted by the Ministry of Transport and Planning, Western Australia (Safety for Seniors Working Group, 1989) found that each year around 550 pedestrians die on Australia’s roads and a further 3,500 are hospitalised with serious injuries. Pedestrians aged over 60 years were found to be disproportionately represented, accounting for 40% of total pedestrian fatalities, even though they made up only 15% of the population.

A more recent study undertaken at the Monash University Accident Research Centre revealed that in 1991 pedestrians accounted for 19% of all road fatalities and approximately 30% of these pedestrian deaths were people 65 years or over. Roughly 12% of all serious casualties in the same year were persons of similar age (Fildes, Corben, Kent, Oxley, Le & Ryan, 1994).

This study further revealed that for all casualty crashes and all injury severity levels (including fatalities, serious injury and other injury requiring hospitalisation) there is a consistent and marked increased rate of casualties per head of population with ages above 44 years. Most noticeably, pedestrian casualty rates increased sharply for pedestrians aged over 75 years, particularly fatal and serious injury crashes (Figure 1.1). These increased rates, however, may simply be due to an increased exposure as pedestrians; older people tend to stop driving and become pedestrians, they may use public transport more frequently and need to walk further to get to transport and shops, and probably spend longer walking the same distances that do younger pedestrians.
1.1.2 Cost of Crashes

Pedestrian crashes in Australia involving those aged 65 years and over have been estimated to cost the community around $248 million per year. In Victoria alone, the yearly cost of fatal pedestrian crashes and those resulting in hospitalisation or medical treatment to persons aged over 65 years is estimated to be $61 million annually (Fildes, Corben, Kent, Oxley, Le & Ryan, 1994).

1.1.3 Crash Causation

A simple explanation for the over-involvement of the elderly in pedestrian crashes would be that with reduced physical capabilities they are less able to get out of the way of cars approaching them when crossing the road. However, a number of human factors studies (particularly those involving older drivers) suggest that other performance deficits, including perceptual, sensory and cognitive deficits, are major contributing factors to their high risk. Studies have illustrated that elderly drivers are involved in crashes involving complex decisions such as at intersections, when altering direction, or entering a traffic flow (Transportation Research Board, 1988; Ernst & O'Connor, 1988).

There has to date been little research to substantiate these claims for the older pedestrian. For example, it is not known how age-related mobility and/or cognitive deficits affect road-crossing behaviour in elderly people, or whether they adopt compensatory behaviours that may be appropriate in some situations and inappropriate in others. Due to a paucity of research in this area, little is known about the behaviour of elderly pedestrians and whether this contributes to older pedestrian crashes. Further, no measures of 'pedestrian exposure' are available in Australia, which is a major impediment to understanding older pedestrian risk factors.
1.2 STUDY OBJECTIVES

The aim of this study was to investigate road-crossing behaviour of both old and young adult pedestrians in order to establish whether older pedestrians experience particular problems crossing the road and whether their behaviour differs in significant ways from that of younger pedestrians rendering them more vulnerable to accidents. In particular, the study aimed to:

- highlight behavioural differences between older and younger adults when crossing the road and attempt to explain these in terms of age-related sensory, perceptual, cognitive, and motor deficits,
- identify target groups and road situations suitable for intervention,
- recommend countermeasures to reduce the frequency and severity of older pedestrian accidents, and
- identify areas for which further research is required.

1.3 RESEARCH TASKS

The project involved three main tasks described below.

1.3.1 Literature Review

An extensive review of both Australian and international literature was undertaken first to gain background information on the ageing process and specific age-related decrements likely to be associated with increased risk of pedestrian accidents.

The review of previous research focussed on patterns of pedestrian accidents involving older adults, functional decrements that may lead to a loss of efficiency in crossing roads, including sensory, perceptual, cognitive and motor deficits, and suggested countermeasure design and intervention. The findings of the Literature Review are presented in Chapter 2.

1.3.2 Black-Spot Pedestrian Accidents (1987 - 1994)

An analysis of all-age Police-reported pedestrian accidents at a number of strip shopping centre sites nominated as pedestrian “black-spot” areas in the Melbourne metropolitan area was conducted. The aim of this phase was to identify common accident patterns for older pedestrians, and to investigate possible differences between younger and older pedestrian crashes.

The type of accident for younger and older pedestrians was classified into several discrete categories such as stepping off the kerb, accidents in the centre of road (near-side or far-side lanes), and others. Further characteristics of individual accidents were examined including sex, age, time of day, and details of circumstances of each accident. The results of the Black-Spot analysis are found in Chapter 3.

1.3.3 Pilot Observations

Pilot observations were conducted in order to establish the most efficient and suitable method for on-road observations. This preliminary stage aimed to design methods to observe actual on-road pedestrian behaviour to be used in the main study.
Unobtrusive roadside filming of older and younger pedestrians as they crossed the road was performed. A van equipped with two cameras set appropriately to provide video images of both near-side oncoming vehicles and pedestrian movements was parked at a strip shopping centre site where a large number of older pedestrians shopped. Unobtrusive roadside filming of both older and younger adult pedestrian behaviour as they crossed the road was performed.

Differences in behaviour of both older and younger adult pedestrians as they crossed the road was investigated in detail, and measures on dependent and independent variables that may conceivably be significant determinants of safe road crossing behaviour were identified.

Three phases of the road-crossing task were identified and results of behavioural differences between the two groups of pedestrians are presented in Chapter 4.

1.3.4 First Observational Study - Two-way Road Observations

The observational method designed in the pilot study was used in the first observational study. Video recordings of individual road-crossings of younger and older adult pedestrians were made in two strip shopping centre sites with two-way traffic nominated as "black-spot" areas for older pedestrian accidents.

Again, the three phases of the road-crossing task identified in the pilot study were applied in the first observational study. Identical behaviours as in the pilot study were scored along with some additional calculations. Results of behavioural differences between the two groups are presented within the phases of the road cross in Chapter 5.

1.3.5 Second Observational Study - One-way Road Observations

Data collected in the first observational study reflected a number of problems older pedestrians may experience, particularly when confronted with a complex situation. In order to investigate these issues further a second observational study was conducted in a less complex traffic environment.

Individual road-crossing manoeuvres of younger and older adult pedestrians were made using the same method as before. The site chosen for this phase was a 4-lane divided road with a wide median strip in the centre where pedestrians needed only to be concerned with the near-side traffic to cross safely before negotiating the far-side traffic. The results are presented in Chapter 6.

1.4 CONCLUSIONS AND RECOMMENDATIONS

The findings from all these tasks were then brought together and discussed in terms of the study objectives. The results of the observational studies were compared with overseas findings to throw light on the processes and difficulties faced by older people crossing the road. The role of sensory, perceptual, cognitive, and motor deficits through the ageing process was paramount to this discussion. Potential countermeasures to reduce older pedestrian crashes and areas requiring further research were identified.

This study set out to address significant road safety issues for the elderly pedestrian by providing a detailed assessment of the skills involved in crossing roads safely. In addition, it was intended to give road safety authorities a better understanding of the reasons for older pedestrian over-involvement in crashes.
CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION
Injury is one of the leading causes of death and morbidity in the elderly. Accidents represent the fifth leading cause of death for people aged between 65 and 74 years, and the sixth leading cause for those aged over 75 years (Australian Bureau of Statistics, 1989). Further, motor vehicle fatalities represent the most common aetiology for those aged 65 to 74 years and the second most common for those aged 75 years or more (Copeland, 1989).

Interest in older people's injuries and concern about their safety in all types of environments is expanding. Older people face many problems as participants in the community, particularly in the transport domain as drivers, passengers, pedestrians and users of public transport. In particular, the problem of the elderly in the traffic environment has received little attention in the last decade.

Moreover, Australia's aged population is increasing more rapidly than other age groups in the population. In Victoria between 1981 and 1986 the population aged over 65 years of age increased by 12.6% (more than twice as fast as the total population). This rate is expected to increase by a further 20% by the year 2031 (Rudd, 1989).

2.2 THE AGEING PROCESS
Ageing is a complex process resulting in reduced performance in a variety of areas. Although there is no single accepted theory of human ageing, a system of classification by which age effects can be considered has been developed. Traditionally, most studies have chosen to define 'the elderly' as persons aged 65 years or more (OECD, 1985). However, chronological age may not be a good predictor to an individual's functional and subjective age (Waller, 1991). Ageing is a gradual process over the whole lifetime, and impairments do not occur all at once nor do they occur at the same rate in different individuals. Variability in performance on various measures of motor skills, cognition, perception, complex reaction time, and other road-related skills makes it difficult to select a chronological age at which road users are labelled as 'elderly' (Waller, 1991).

Many age-related differences and changes in behaviour have been identified (Birren & Renner, 1977; Welford, 1985; Corso, 1981; Verillo & Verillo, 1985). Birren and Renner (1977) suggest that ageing involves biological, psychological, and sociological changes which inevitably result in reduced seemingly irreversible capacities in a number of functional and behavioural areas. These changes, however, occur so gradually that the individual is usually able to make adjustments in order to compensate to some extent for their reduced abilities (Verillo & Verillo, 1985).

The literature on ageing suggests that as age increases the individual develops and experiences deficits in sensory, perceptual, motor, and cognitive efficiency which have implications for overall adaptability and welfare (Kausler, 1991; Sheppard & Leith, 1990; Corso, 1981). One of the most clearly established characteristics of ageing is the slowing of processes (Birren, 1965; Botwinick, 19873; Welford, 1977; Belsky, 1990). While it is thought that the major
source of slower responses lies within central cognitive processes, some part of the delay can be attributed to peripheral effects including inadequate detection and registration of sensory stimuli diminishing the quality and quantity of information provided for brain processing, slower nerve conduction, and slower mobility patterns (Sheppard & Leith, 1990; Welford, 1985).

Efficient pedestrian performance in traffic requires a combination of well developed skills, which allow the individual to assess complex traffic situations, and to choose and execute appropriate responses. Despite the vitality of many older persons, the effects of age-related deficits predict that the ability to perform these complex tasks becomes more difficult (van Wolffelaar, Brouwer & Rothengatter, 1991). This may lead to difficulty in estimating distance and speed (particularly at dusk and in darkness), difficulty in the use of preparatory information, difficulty in processing stimuli and selecting information, poor decision making, and difficulty in regulating performance speed and executing appropriate responses (van Wolffelaar et al., 1991; Stelmach & Nahom, 1992). Decisions are less likely to be taken almost simultaneously and executed in parallel; rather there is a propensity for sequential processing (Wounters & Welleman, 1988; Triggs, Fildes & Koca, 1994).

2.3 COMMON ACCIDENT PATTERNS

A number of common patterns have been identified in crashes involving older pedestrians (Federal Office of Road Safety, 1986; Sheppard & Pattinson, 1986). In addition to being linked with reduced mobility (that is, they are less able to get out of the way of an oncoming car quickly enough), crashes involving the elderly often occur at intersections; they are generally hit on the nearside of the road, they often do not see the vehicle that hit them, and when they do see a vehicle they usually believe that the driver has seen them and will take evasive action. Sheppard & Pattinson (1986) found that elderly pedestrians expect the driver to brake or alter their course to avoid them. They attributed this to a lack of understanding by elderly pedestrians of what a driver is likely to do, or could achieve even if he/she tried to do so. They further suggested that the elderly pedestrian generally does not accurately assess a driver’s future actions.

Further, the Federal office of Road Safety suggested that elderly pedestrians are usually observing the law and not behaving irrationally (as children or younger adults might). A recent study at Monash University (Fildes, Lee, Kenny & Foddy, 1994) found that elderly road users lack knowledge and understanding of current road rules, particularly in situations of right of way. In particular, elderly pedestrians who have never had a licence to drive would not have been required to formally learn these rules.

Alexander et al. (1990) found that these crashes involving older pedestrians were generally close to home, occurring within one kilometre of their home. They occurred on a regular trip (such as shopping) and occurred at or near shopping centres or recreational venues where, no doubt, these people tend to spend much of their time away from home. They further found that most fatal and serious injury crashes involving older pedestrians occurred in inner city suburbs, on sealed arterial roads, on straight road sections and most occurred in daylight hours. This concurs with stated patterns of pedestrian movements reported by Fildes et al. (1994).

In the case of fatal elderly pedestrian crashes, the Federal Office of Road Safety (1986) further reported an increase in winter compared with summer, with the most likely time of day...
between 4pm to 8pm, presumably when light conditions are not optimal. In addition, they showed that in almost half of the cases where an elderly pedestrian was killed crossing the road, the victim had already crossed one lane of traffic and was on the second half of the road appearing not to have been aware that a vehicle was approaching.

2.4 RISK FACTORS

The nature of performance change with increasing age may be usefully approached by identifying specific decrements in sensory, cognitive and motor function which may lead to difficulties in performing everyday functions. By this method, it is possible to identify a number of actions that potentially heighten the probability for the older pedestrian to be involved in a crash.

Older people face major problems as pedestrians and accidents may occur as a result of age-related declines in various skills used while crossing the road. These include visual and auditory acuity, use of preparatory information, perception of motion and depth, proprioceptive responses, memory capacity, information processing, attentional performance, reaction time, and physical mobility such as the ability to rotate neck, walking and muscle control, balance and postural control (Alexander et al., 1990).

Yanik and Monforton (1991) further suggested that visual and cognitive changes in the elderly road user might overwhelm some of the normal attempts at compensation, such as maintaining longer gaps between cars to allow for increased response time.

2.4.1 Sensory and Perceptual Efficiency

It is through our senses that we initiate contact with or avoid stimulus events and objects in the environment, thus age-related changes in sensory sensitivity and perceptual functioning have obvious implications for the overall adaptability and welfare of elderly people. There is little doubt that sensory performance of the elderly is generally below that of younger persons. In each sensory system, changes occur in the anatomical structure of the end organs and neural pathways, as well as in the physiological functioning of the system as a whole (Verillo & Verillo, 1985).

Visual Capacities

Knowledge of the environment is gained through complex sensory systems and it is thought that vision is the principal sense for acquiring information for normally sighted people. Further, age-related declines in the visual system are perhaps the most recognised performance change in the ageing literature.

It is the relationship between visual capability and traffic performance in the elderly which has attracted the attention of many researchers. Yet, while researchers typically consider vision to be responsible for up to 95% of traffic-related sensory inputs for drivers (Shinar & Scheiber, 1991; Kline, Fozard, Scheiber & Sekuler, 1992), it is difficult to determine what specific visual skills are essential for safe road crossing.

Further, there is a marked increase in individual differences with increasing age: the visual difference found between the best and the worst performing older adult are many times larger than the difference found between the best and worst performing younger adult (Briggs, 1987).
Physical Changes - Most visual problems associated with ageing are due to changes within the five major structures in the eye itself: 1) the cornea, 2) the anterior chamber between the cornea and lens, 3) the lens, 4) the pupil, and 5) the retina. The best recognised (and easiest to correct) age-related change is the decrease in depth of focus of the eye with is due to the lens becoming less flexible and thus less able to accommodate to bring objects at difference distances into focus. This condition, known as presbyopia, results in many older adults requiring correction glasses (Scheiber, 1992).

The appearance of the cornea changes with age. There is increased irregularity in its surface properties along with a loss of lustre, both of which may affect its refractive power. It also has a tendency to flatten along the vertical meridian, contributing to its refractive errors (Scheiber, 1992).

The lens of the eye continues to add layers of cells throughout its life and as a result becomes larger, more dense, harder, and less flexible. The increased density of the lens and additional yellowing causes it to be a less efficient transmitter of light, so that less light reaches the retina and more light scatters when entering the eye causing glare (Olson, 1988). With the growth and hardening of the lens, accompanying reductions or shallowing of the anterior chamber occurs resulting in increased difficulties in refractory efficiency and accommodation (Bouwhuis, 1992).

Further reductions in the amount of light reaching the retina result from reductions in the diameter of the pupil along with a decline in its ability to dilate in dim light (Scheiber, 1992). This results in losses of acuity, and in difficulties in seeing in situations where there is low illumination and contrast.

Changes begin to occur in the circulation and metabolism of the retina from about 55-65 years of age leading to a decline in the number and function of retinal receptor cells (Fozard, Wolf, Bell, McFarland & Podolsky, 1977). These changes result in a decrease in the size of the visual field, sensitivity to low levels of light, and sensitivity to flicker.

Accompanying normal sensory changes with ageing, is an increase in eye disease such as glaucoma, cataracts, macular degeneration, and diabetic retinopathy. The incidence of these problems is much greater for the older population (Fozard et al., 1977; Klein, 1990; Kline et al., 1992).

Functional Changes - Normal ageing of the visual system generally leads to deficits in dynamic and static visual acuity, peripheral field loss, resistance to glare (glare tolerance and glare recovery time), a reduction in contrast sensitivity, deficits in visual processing speed, visual search capacities, low light sensitivity, perception of angular movement and alignment and movement in depth, and colour vision (Kosnik, Sekuler & Kline, 1990; Klein, 1991). The effects of various aspects of these functional deficits will be discussed separately.

1. Visual Acuity

Age-related declines have been noted in visual acuity capacity. Visual acuity refers to the ability to discriminate fine details. There is a steady decline in acuity from around 20 years to 90 years, with the greatest loss appearing to take place between the ages of 60 years and 90 years (Verillo & Verillo, 1985). Loss of visual acuity may result in difficulties in perceiving vehicles from the rest of the optic array, and can affect depth perception as the ability to discriminate details affects an individual's perception of texture gradient (Carthy, Packham, Salter & Silcock, 1995).
Two forms of visual acuity are recognised, both of which show age-related declines. Static acuity proficiency (defined as the ability to resolve fine detail of spatial patterns) begins to decrease at about age 40 years. By age 70 years, acuity has declined by almost 30% of the proficiency of younger adults. Further, the time required to detect a target increases with age (Fozard et al., 1977). Dynamic acuity (defined as acuity when there is relative motion between the observer and the visual target) also shows age-related losses. Salthouse (cited in Kausler, 1991, p.91) found progressive decrements in dynamic acuity beginning at an earlier age than for static acuity, and the rate of decline with age was much steeper, being nearly 60% loss for people in their seventies.

2. **Contrast Sensitivity**

Contrast sensitivity refers to the ability to distinguish differences in brightness of spatially distributed variations of luminance (Cohn & Lasley, 1985). If intensity differences between light and dark components of a stimulus is great, its contrast is said to be high, while a small difference means the contrast is low. A person is highly sensitive if they require little contrast to see a pattern (Sekuler & Blake, 1985). With the yellowing of the lens and its decreased efficiency for transmitting high spatial frequencies, older people often experience problems with sensitivity, particularly at higher spatial frequencies (Bouwhuis, 1992). In addition, reduction in the size of the pupil with consequential reductions in light reaching the retina reduces the sensitivity to high frequencies.

Reduced contrast sensitivity to high spatial frequencies in an environment may put the older pedestrian at higher risk of an accident. The older person may adequately see the general shape of a large object, however, may find difficulty in discriminating fine details of objects (such as the kerb), particularly moving ones (such as an oncoming vehicle). In their survey of older road users, Fildes et al. (1994) found that older pedestrians noted difficulty with edges that are hard to see and high gutters. They suggested greater use of edge delineation where there is a lack of contrast between uneven surfaces and steps on the road.

3. **Visual Field**

With increasing age, people tend to experience a contraction in their field of view (Corso, 1981; Scheiber, 1992) and the relevance of a large visual field for good performance in traffic is often called for. Although few studies have focussed on the performance of elderly pedestrians, studies conducted with elderly drivers report an association between peripheral visual field loss and declines in driving performance. Hedin (1980) and Keltner and Johnson (1989) suggest that the elderly population may be at greater risk of traffic crashes because of their peripheral visual field loss. Keltner & Johnson found that prevalence of visual field loss was between 3% and 3.5% for persons aged under 60 years, about 7% for the 60 to 65 years age group, and 13% for those aged over 65 years. While there is a paucity of evidence relating visual field loss with older pedestrian crashes, studies with elderly drivers suggest declines in visual performance are associated with increased risk of an accident. A recent US study by Ball, Owsley, Sloane, Roenker and Bruni (1994) found that older adult drivers with 61-90% shrinkage in their useful field of view were six times more likely to have incurred one or more crashes in the previous five years.

Findings from studies targeting groups with low vision can be applied to older pedestrians. Lovie-Kitchin, Mainstone, Robinson and Brown (1990) examined the relationship between binocular visual field size with mobility performance for low vision patients. Their results showed that visual field extent significantly influenced mobility performance. While good
central visual field appeared to be most important for mobility, loss of visual field in the mid-
peripheral or peripheral inferior and lateral areas also adversely affected mobility.

4. **Effect of Glare**

Age-related increases in susceptibility to the effects of glare have been demonstrated by
numerous investigators, particularly at low levels of background illumination and at night
(Fozard et al., 1977; Mortimer & Fell, 1988; Mitchell, 1992; Scheiber, 1992). Although glare
sensitivity has been ascribed to changes in light absorption, light scatter, and increased opacity
in the lens (Fozard et al., 1977), recent studies suggest that contrast sensitivity may also
contribute to glare effects (Elliott, 1987; Scheiber, 1992). Studies focussing on elderly drivers
at night note a high involvement in fatal night time crashes (Mortimer & Fell, 1988) and
suggest that older drivers are at risk in the hours of darkness because they need greater
brightness contrast and minimum glare.

With great difficulties experienced in reduced levels of illumination, greater scattering of light,
and reduced retinal functioning, the older pedestrian (as well as driver) is under a significant
handicap in using the roadway. When light entering the eye is too bright and interferes with
the focussing of the central image in the retina, a reduction in the quality of the retinal image
results. This is often accompanied by significant decrements in visual performance, specifically
loss of good visual contrast, so that details are lost (Shinar & Scheiber, 1991). Further,
prolonged exposure to a glare source is problematic for the older pedestrian and can result in
muscular fatigue and tenseness (Shinar & Scheiber, 1991) resulting in longer times required to
recover and reach stable visual performance (Olson & Sivak, 1984).

5. **Visual Information Processing**

It is well recognised that marked changes occur in all stages of visual information processing
with advancing age, yet the underlying causes are not well defined. Investigators have shown
that adults aged over 60 years require longer processing times than younger adults to complete
peripheral and central visual information processing (eg. Walsh, 1982). It has been established
that sensory input is gradually diminished with ageing, thus elderly people require more time to
interpret incoming stimuli successfully. Further, as input is uncertain, it may induce the elderly
perceiver to employ more strict criteria that will benefit correct performance. While
interpretation and decision-making processes are also subject to general slowing (see later
sections), it is expected that these slowed visual processes will add to information processing
times (Bouwhuis, 1992).

Some investigators believe that the requirement for longer presentations among older people
stems from greater delays between the presentation of a stimulus and when information is
extracted from the sensory organs (Fozard et al., 1977). Studies using backward visual
masking support the general hypothesis that there is a time frame or moment during which
information is extracted from sensory messages and that this is longer for older persons (Kline
& Szafran, 1975; Walsh, 1982), possibly because they require more time to ‘clear’ a stimulus
through the nervous system.

Others believe that older people tend to adhere more strongly to the initial perception of a
given stimulus than younger people do, and are either resistant to or incapable of reorganising
the perception, resulting in longer processing times (Corso, 1981). It is not clear, however,
whether this is due to decrements in the visual system (eg. loss of visual acuity) leading to
poorer discrimination of the environment, or whether it reflects some aspect of cognitive
information processing. Rabbitt (1965) noted that older persons took longer to identify stimul
in a visual search task and suggested that they have difficulty in detecting and identifying relevant visual cues and in ignoring irrelevant information.

Further, the efficiency of the visual search task has been shown to involve the use of optimal scanning strategies. For younger adults, objects of scenes which convey most information relevant to a necessary decision are typically scanned first and less crucial parts of the environment are neglected or scanned at a later stage. Rabbitt (1982) found that people aged between 65 years and 78 years were unable to use efficient scanning strategies. They seemed to have lost flexibility in exercising control particularly in situations in which they must rapidly decide.

**Auditory Capacities**

Research indicates that there is a decrement in hearing with increasing age. The prevalence of hearing impairment rises sharply with age from less than 2% of those under 17 years, to 24% of those aged between 65 years and 74 years, and to 39% of those aged over 75 years (Committee for the Study on Improving Mobility and Safety for Older Persons, 1988). A loss of auditory capacity may put the elderly pedestrian at higher risk of an accident. Hearing impairments may cause problems in localising sounds and consequently in ascertaining in which direction a vehicle is approaching. Little research, however, has been conducted to examine the relationship between age-related hearing loss and safe traffic participation, thus a connection between the two has not been established.

Hearing impairment associated with ageing has been attributed to conductive or sensorineural problems or both. Degenerative changes at found virtually all levels of the auditory system typically resulting in a gradual and progressive loss of hearing most often at high frequencies but sometimes across all frequencies - or known as presbyacusis. The majority of hearing losses in the elderly may be traced to degrading physiological processes located in the outer ear, within the cochlear, in the nerve cells that conduct impulses from the receptors in the cochlear to the central nervous system, and in the central nervous system itself (Verillo & Verillo, 1985). Auditory losses of this kind have also been attributed to prolonged exposure to high sound levels (Bouwhuis, 1992).

Changes in hearing in the outer ear can involve increased secretion of ear wax with resulting blockage of the auditory canal (Scheiber, 1992). In the middle ear, calcification of the ossicular bone chain resulting in less elasticity has been noted (Scheiber, 1992), while at the inner ear level, changes in the structure and function of the cochlear are commonly diagnosed (Verillo & Verillo, 1985; Scheiber, 1992). Structural changes include degeneration of the hair cells and their supporting cells, atrophic changes in the cochlear nucleus supplying nutrients to the cells, a loss of neurons in the auditory pathway, and diminished cochlear blood flow.

**Perceptual Performance**

Age differences in perceptual sensitivity (that is, the ability to integrate, organise, and interpret incoming stimuli registered from the senses) have been investigated for a number of the phenomena which may be related to safe road crossing in the elderly. These include depth, motion, and colour perception as well as pattern recognition.

Although it is difficult to identify the exact causes for age-related perceptual performance changes, an age change in stimulus persistence in the nervous system (advanced originally by Axelrod, 1963, cited in Kausler, 1991, p.105) has been applied to explain functional differences.
For the older person, increased persistence of neural activity evoked by a stimulus may be associated with difficulty in responding accurately and quickly to a number of incoming stimuli. The stimulus-persistence concept may help to explain some perceptual problems for the elderly pedestrian; other stimuli perceived immediately prior to an unexpected stimulus (such as an oncoming vehicle) may not have "cleared the nervous system" and a fused perceptual response along with confusion results. It should be stressed, however, that this hypothesis has not been tested in a road safety situation.

**Depth Perception**

The ability to perceive depth is affected by the ageing process (Verillo & Verillo, 1985). Diminished proficiency in depth perception for elderly people leads to difficulty in orientation and misjudgments of the nearness of obstacles in the environment, such as the distance of an oncoming vehicle or the distance of a step from the ground. It has been suggested that such misperceptions are major contributing factors to the increased incidence of postural instability and the frequency of accidents found for elderly adults relative to younger adults (Kausler, 1991).

Accurate judgments of distance arise from the coordination of several different sources of information. Age-related difficulties in depth perception can be attributed to physical and functional changes in the eye such as accommodation and convergence, transmissiveness of the lens, scatter of light, and sensitivity to glare (Fozard et al., 1977; Kausler, 1991; Mitchell, 1992). Further, contrast sensitivity is believed to be the major contributing skill for depth perception and studies have shown that aged subjects display a decline in performance with low illumination (Cohn & Lasley, 1985).

**Motion Perception**

There are two major components of motion; distance travelled and speed of travel, and it is thought that age differences in motion perception in critical traffic situations are important factors in older road users' over-involvement in certain accident types (Staplin & Lyles, 1991). In particular, the older pedestrian may experience difficulty in determining accurately the movement of an oncoming vehicle.

A decline in the efficiency of processing information is thought to lead to difficulty in estimating distance and speed, particularly at dusk and in darkness (Wounters & Welleman, 1988). Studies examining the ability to judge the distance between objects accurately have shown that older drivers are much more likely to underestimate the relative depth separating visual targets than are younger drivers (Hill & Mershon, cited in Transportation Research Board, 1988, p.59).

Simulation studies by Kline (1986) showed that older adults are likely to underestimate the distance between themselves and a vehicle and overestimate the velocity of oncoming vehicles. Although no studies have been formally conducted with elderly pedestrians, a relationship between safe road crossing and motion perception ability presumably exists.

Motion perception skills are pertinent to traffic participation (Staplin & Lyles, 1991) and the perceptual-cognitive ability to predict correctly the future position of a moving object such as a vehicle travelling fast is fundamental to safe road crossing. The ability to judge whether a gap between oncoming vehicles is large enough to cross through safely (gap acceptance) and "time-of-arrival" judgements (a person's estimate of how long it will take an object moving at a constant speed to reach a specified point) involve motion perception decisions. For the older
pedestrian, the affordance of a gap is vital; information about environmental states must be combined with information about their own walking speed, and this must be re-assessed as age increases and walking speed slows (Lee, Young & McLaughlin, 1984).

2.4.2 Cognitive Efficiency

Traffic participation requires a combination of skills in which cognitive performance must play a major role. Accurate cognitive performance is fundamental to attentiveness to the road crossing task, incorporating recognition of a stimulus, selection of relevant inputs for processing, integration of information, choice of the appropriate way to respond, and coordination of resultant behaviour. Kosnik et al., (1990) suggested that cognitive factors, rather than purely sensory and perceptual factors, contribute to a large proportion of accidents in the elderly. The complexity of many traffic situations demand quick and accurate judgements and decisions may place overwhelming demands on cognitive processes of elderly pedestrians resulting in higher risk of accident than for younger pedestrians.

Cognitive abilities are especially important in pedestrian behaviour as decisions to cross involve the simultaneous processing of past experience and incoming perceptual information. Quick performance of these processes simultaneously may be difficult for the older person who may not be able to collect and process enough information in time in order to decide on a safe course of action.

Deficiencies that may affect road crossing ability in the elderly can include confusion and inattention, slowed psychomotor reaction and decision time, lower levels of performance in recognition and response, greater difficulty in adjusting to traffic conditions, incorrect interpretation of complex cues, and inappropriate choice of response (Staplin & Lyles, 1991; Lerner, 1991; Stelmach & Nahom, 1992; Cooper, Tallman, Tuokko & Beattie, 1993).

Triggs, Fildes and Koca (1994) further argued that good road crossing skill requires accurate responses to spatial and temporal information from the environment while coordinating head-neck and limb movements, and locomotion. They suggested that the requirement to divide attention and integrate information from several different sources of information is a more difficult task for the older person than for the younger person and is a likely contributing factor to pedestrian safety.

Attention Capacity

Attention is a fundamental aspect of the cognitive system and age-related changes have implications for a wide variety of behaviours. A number of accident examination studies report that inattention contributed to between 25% and 50% of crashes (Transportation Research Board, 1988). In particular, crashes involving elderly drivers have been attributed to neglect or inattention to relevant information from road signs and from other traffic participants (McFarland, Tune & Welford, 1964; Planek & Fowler, 1971) indicating a lack of attention capacity (Ranney & Pulling, 1990).

In skilled performance, different mental operations must be carried out and performance on each of these activities requires some level of attentional processing. Evidence suggests that processing resources are more limited for older adults than for younger adults (McDowd, Vercruyssen & Birren, 1991; Salthouse, 1985) thus the ability to focus on a task diminishes with age. Older persons are more easily distracted by irrelevant stimuli, they have more difficulty than younger adults selectively attending to the most important stimuli (Transportation Research Board, 1988), and have difficulty in detecting and identifying...
relevant visual cues and in ignoring irrelevant or distracting information while performing a visual search task (Corso, 1981; Kausler, 1991).

Selective Attention

Selective attention involves focussing on and shifting attention among information source or stimulus features. For younger adults selective attention is known to aid cognitive processing of information in complex environments by optimising or enhancing the selection of information needed for further processing. Research has shown, however, that one of the major problems experienced by older adults in dealing with complex situations involves the effectiveness of selective attention (Plude & Hoyer, 1985; Plude, Enns & Brodeur, 1994). In the traffic environment a number of sources of information must be sampled periodically. For the elderly pedestrian, continuous monitoring of the environment involving efficient focus of attention as well as switching of attention to task-relevant sources of information may be difficult (Parasuraman & Nestor, 1991).

Age-related deficits in selective attention capacity are thought to involve either reduced sensitivity of a filtering mechanism that prevents or reduces the processing of irrelevant information (Rabbitt, 1965), or a diminished capacity to operate efficiently the selective attention mechanisms, resulting in a decline in the ability to locate task-relevant information in the visual field (Plude & Hoyer, 1985). Further, use of an inefficient strategy for engaging and maintaining focussed attention on a critical part of the environment (McCalley & Bouwhuis, 1992), or a decrement in the ability to prioritise the appropriateness of multiple sources of information and shifting attentional emphasis accordingly (Korteling, 1994) may result in a reduced selective attention capacity.

Divided Attention

The ability to divide attention between concurrent tasks appears to be highly age-sensitive. Older individuals perform more poorly in situations that require division of attention (Welford, 1958; Craik, 1977; Kausler, 1991; McDowd & Craik, 1988). The requirement to divide attention and integrate information from several different sources is likely to be a major contributing factor to elderly pedestrian crashes. When crossing the road, several subtasks such as judging speed and distance of traffic from both sides of the road, kerb step height, and road surface, are presumably involved. Attention needs to be divided in order to focus on information sources when appropriate or necessary.

A number of studies show that older adults have difficulties in situations of increasing complexity such as those involving dual- and multiple-task performance (Korteling, 1991, 1992; Transportation Research Board, 1988; van Woffelaar, Brouwer & Rothengatter, 1991; McDowd et al., 1991), particularly where some time or speed stress is involved.

McDowd and Craik (1988) reported two experiments that examined young and older adults' performance in dual-task situations of varying complexity. Their results showed not only that older individuals experienced more difficulty in dividing attention between tasks compared to the younger adults, but that as the complexity of the task increased, the age-related deficits in divided-attention increased.

In addition, Triggs et al. (1994) examined the division of attention capacities of older versus younger individuals when they were placed under some time stress requiring perceptual judgements in two simultaneously presented tasks. They demonstrated that older subjects
were impaired in their capabilities to divide attention compared with the younger group and showed a greater tendency to use attention sharing strategies.

Global slowing of behaviour has been claimed to be responsible for age differences in performance (Birren, 1965; Salthouse, 1986). This implies that mental operations take longer to perform with increasing age and that cognitive slowing is amplified as tasks take on a greater number of operations as in the case in dual-task situations. A second related hypothesis suggested by McDowd and Craik (1988) predicts an age-related decline in the ability to deal with the overall task in a coordinated, holistic manner. They suggest that it is the requirement of parallel processing, whether in a single- or multiple-task situation, that puts older adults at disadvantage. A third hypothesis argues that limitations in the integrated uptake and processing of information from multiple sources, and limitations in combining related actions result in deteriorations in attention switching and ability to prioritise the appropriateness of subtasks (Fisk & Rogers, 1991; Korteling, 1992).

**Information Processing**

It has been assumed that all or most changes in cognitive performance result from a marked change in information processing rate (Birren, 1965; Salthouse, 1986). The human information processing system regulates the registration, transformation (encoding), storage, and retrieval of information that is received from the environment.

The literature shows a general agreement among researchers that older persons process information, both peripherally and centrally, more slowly than younger persons. Welford (1958) described a number of studies reporting reduced ability with age to initiate and monitor actions while at the same time preparing for a subsequent action. Moreover, recent traffic-related studies showed that older adults perform less well than younger adults in situations requiring simultaneous processing of multiple sources of information (Transportation Research Board, 1988; Wounters & Welleman, 1988; Kausler, 1991; Stelmach & Nahom, 1992).

In complex situations demands are placed on the individual that presumably tax the diminishing cognitive capacity of older people. This deterioration has been mostly explained as a general decline in the information processing chain, termed a ‘global decline’ by Birren (1965). However, the prime cause of changes in central processing of information is still unclear. It has been suggested that a progressive loss of neurons is a contributing factor. Cross-sectional studies have shown a 10% to 20% loss of cerebral mass from ages 20 to 90 years, with a reduction in the number of giant cells and horizontal dendrites interconnecting the pyramidal cells, decreases in the amount of transmitter substances, and broadening and lengthening of cerebral capillaries with reduction of intercapillary distance (Sheppard & Leith, 1990).

Researchers have suggested that younger adults can overlap processing stages and tend to perform smoothly representing parallel processing. Older adults on the other hand tend to process information in serial, often at the expense of one task (McDowd et al., 1991). An inability to combine or overlap decision and movement processes may account for at least part of the increased response times of older adults in complex situations (McDowd et al., 1991). Rabbitt (1982) further suggests that while elderly people can successfully anticipate single events they may lose the ability to anticipate any of several different events at the same time as well as to control efficiently momentary changes in selectivity on the basis of previously learned information. This implies a gradual loss of power simultaneously to employ useful information held in memory.
Other researchers refer to age-related influences on controlled and automatic processes to explain performance difficulties experienced by older adults. Controlled processing is characterised as relatively slow, serial, capacity limited, requiring effort and needed in situations in which responses are inconsistent, while automatic processing is characterised as fast, parallel, requires little effort, and not under subject direct control. By providing general-purpose resources, controlled processes allow performance in novel and inconsistent situations. Automatic processes allow for rapid execution of well-practiced tasks.

Research has been conducted previously which examined resource capacity for controlled and automatic processing and suggested there is, generally speaking, a fixed task-specific amount of resources available for task performance (Fisk, Ackerman & Schneider, 1987). They argued that all processes consume resources from a limited pool, thus there is an upper limit to human processing ability. It has been suggested that older people have less cognitive resources to devote to a task (Fisk et al., 1987; Kail & Salthouse, 1994). Human performance is thought to be limited by the number of, and extent to which, cognitive operations required controlled processes (Fisk & Rogers, 1991). Thus, in complex (or inconsistent) task performance, such as crossing the road, age-related performance declines may affect controlled processing through the limited amount of available resources.

Further, it is suggested that older adults, impaired in their ability to modify previously learned automatic skills, require acquisition of new processes along with and inhibition of automatic routines (Korteling, 1994). Older people who are capable of performing particular tasks in a particular way tend to have unusual difficulty in modifying these familiar procedures to meet changes in task demands (Rabbitt, 1992).

In the road environment, Ranney and Pulling (1990) found large differences between young and older drivers on measurements of perceptual style, selective attention, reaction time, visual acuity, perceptual speed and risk-taking propensity. They suggested that an overall decline of all information-processing abilities, rather than selective differences, as a possible explanation for the greater difficulty in performing tasks experienced by the older subjects. Although no studies relating risk of age-related pedestrian crashes to information processing capacities have been conducted, the above findings also apply in the road crossing task.

A further factor that may cause delays in central processing in older people is a reduction in the quality and quantity of information offered to the brain for processing from a diminished perception of external events. Sheppard and Leith (1990) suggest that physical and functional declines in the various sensory and perceptual organs (as discussed above) result in deterioration in the signal/noise ratio in central processes; the true signal becoming increasingly confused with electric 'noise' arising both at the periphery and within the central nervous system.

**Reaction Time**

A widespread slowing of most behavioural activities with increased age is a well known phenomenon. Reaction time, defined as the time interval between the representation of a stimulus and the initiation of a response, is critically important in the road crossing task and is commonly regarded as a measure of the speed of executing central operations (Welford, 1977). With advancing age, there is a tendency toward slowness of perceptual, motor, and cognitive processes, thus taking longer to acquire information, process that information, select and plan a response, and execute that response (Lerner, 1991). Further, reaction times for complex decision making are disproportionately slow, compared with reaction times for simple choice,
suggesting slowing as a major feature of the central nervous system (Birren & Renner, 1977). Increased reaction time means that the older pedestrian has a shorter interval than a younger pedestrian in which to respond to a stimulus and to correct a misguided action, thus avoiding a crash.

The literature on slowing with age suggests a number of reasons for age-related changes in reaction time. Basic deterioration in the central mechanisms has been suggested, including failure to use preparatory information, difficulty in processing stimuli and making responses, an initiation deficit in dealing with increased task complexity, and an inability to regulate performance speed (Stelmach & Nahom, 1992). Slower behaviour may also result from performance strategy changes such as hesitancy in order to compensate for other deficits, less neural arousal, or continued after-effects acting as ‘noise’ blurring any subsequent decision process (Welford, 1977).

**Decision Time**

One of the most persistent beliefs about human ageing is that people tend to become more cautious or conservative in decision-making and risk taking as they age. Rabbitt (1968) suggested that cautiousness in decision-making may serve as compensation for real or imagined decrements in information processing capacities. Time-critical tasks such as in road crossing, may be difficult for the aged indicating functional impairment in their decision-making.

Various experimental studies have found that older adults require more time and information prior to responding (Botwinick, Robbin & Brinley, 1959), especially under conditions of uncertainty (Panek, Barrett, Sterns & Alexander, 1977). In his review of age differences in reaction time, Welford (1977) reported that the speed of decisions required to guide movements and the time taken to monitor them affect reaction times.

Botwinick, Robbin and Brinley (1959) studied age-related differences in decision-making using a perceptual discrimination task and found that older subjects could respond almost as fast as the younger subjects but preferred to gather more information from the display before committing themselves to a response. These findings suggest that older adults require more data for decision-making compared to younger adults or are more cautious before responding.

**Memory Capacity**

Numerous investigators have proposed that age differences observed in a variety of cognitive tasks might be explained in terms of age-related limitations in working memory (Welford, 1958; Salthouse, 1990; McDowd & Craik, 1988). Studies have found that older people demonstrate age-related losses performances losses when a task requires complex mental processing of material held in working memory (Craik & Bosman, 1992).

The resource theory postulates that increased age is associated with a decline in some important attribute of processing resources, and that it is this reduction in resources that is responsible for many of the age differences observed in various skilled performance measures (Salthouse, 1990). Welford (1958) suggested that a primary characteristics of increased age was a reduced ability to retain information in memory while simultaneously processing the same or other information. He argued that this limitation may be critical in a wide range of tasks because an important feature of many cognitive activities is that early information must temporarily be preserved while other information is being acquired or manipulated. Older adults may therefore be impaired in cognitive tasks because, compared with younger adults,
they have less of the relevant information available when it must be integrated or evaluated to reach a decision.

Although a great deal of research has been conducted on age differences in performance on working memory tasks as a function of divided attention, few reports have related this to explain performance differences in traffic situations.

2.4.3 Motor Performance

Motor performance, along with sensory, perceptual, and cognitive performance, slows with age. With slowing movement patterns responses become more variable and rely more on feedback control processes than on programmed representations of movement (Stelmach & Nahom, 1992). Motor control is of prime importance when faced with traffic emergencies where actions must be executed quickly. The proficiency of motor performance is greatly dependent on the ability to coordinate movements with rapidly changing visual inputs. Stelmach & Nahom (1992) suggested that older adults may plan and prepare for movement in a manner different to that used by younger adults, with action sequences becoming more complex and involving additional cognitive/motor processes.

Neuromuscular and Strength Changes

The musculature of the body is a vital factor mediating movement performance. The elderly suffer general physical weakening; they lose agility (Brummel-Smith, 1990) and endurance (Grob, 1989) and they experience cardiovascular degeneration, musculoskeletal wasting, and neuromuscular weakening (Grob, 1989; Bishu, Foster & McCoy, 1991). Further, age-related motor impairments have been linked to known changes in loss of sensory receptivity, decreases in muscle mass and elasticity, decreases in bone mass, and a reduction of central and peripheral neural mechanisms and connections supplying them (Welford, 1985; Stelmach & Nahom, 1992). These physical changes may result in associated pain, stiffness, abnormal movements, and impaired coordination and reaction abilities (especially in situations requiring fast action).

A number of physical and functional changes occurring with age are thought to be associated with age-related changes in strength capacity. There is a decrease in the speed of fast motor units due to reduced transmitter release and a decrease of latency period and contraction time resulting in decreased strength (Espenschade & Eckert, 1980). In addition, the direct excitability of the muscle fibres declines as a result of age-related changes in the level of polarisation of the muscle. Coordination also tends to be disrupted with ageing resulting in decreased strength, speed, and resistance to fatigue (Espenschade & Eckert, 1980). Further, decline in muscle size, efficiency of the nervous system, capacity of the respiratory system, cardiac output and blood circulation, joint flexibility and coordination, and sensory-motor integration result in loss of strength (Espenschade & Eckert, 1980; Welford, 1985).

While time taken to respond to a stimulus increases with age, so too the period between the initiation of movement and its completion is also slower and more variable for older adults. While studies indicated that muscle activation necessary to initiate movements remains relatively intact with increasing age, others have found that motor time increases with advancing age, particularly among physically inactive people (Stelmach & Nahom, 1992).

There is some evidence that the flexor muscles of the lower extremities are most affected by the ageing process (Espenschade & Eckert, 1980). Older people thus experience increased difficulty in lifting their legs, stair climbing or stepping off kerbs.
Postural Control and Gait Changes

A number of researchers have investigated postural stability in aged persons and associated injury risk. Postural control involves both sensory and motor systems and research indicates that muscle weakness, poor balance control mechanisms and declines in postural reflexes in the elderly is consistently related to impaired mobility and injury risk (Overstall, Exton-Smith, Imms & Johnston, 1977; Wolfson, Whipple, Amerman & Kleinberg, 1986; Verillo & Verillo, 1985). Postural responses underlying effective motor responses are visual, vestibular (located in the inner ear), and proprioceptive (located predominantly in the ankle-foot muscle and joint) functions (Lord, Clark & Webster, 1991; Verillo & Verillo, 1985). Receptors in the vestibular canals respond to angular accelerations of the head, and to the resultant of linear accelerations and gravity, while ankle-foot receptors provide proprioceptive information on the movement of the body relative to the support surface.

Vision is thought to be the most powerful source of information for efficient balance control and locomotor activity. A number of studies have examined the role of the visual system in the maintenance of postural stability and explore the effects of ageing (Lee & Lishman, 1977; Cohn & Lasley, 1985; Owen, 1985). Movement of the head relative to the environment gives rise to an optic flow field affording proprioceptive information, and age-related visual declines, particularly decreased visual field, loss of contrast and spatial sensitivity for fine details, and slower horizontal eye movements (as discussed earlier) have pronounced effects on self-motion perception (Owen, 1985; Konczak, 1994). Without efficient visual motion information about one’s movement relative to the environment, locomotion might be hazardous.

Deteriorating balance mechanisms in the older person means that they are more at risk of a fall not only when they are mobile but also when they are standing still. For the elderly pedestrian, balance control is an important aspect of safe and efficient movement. Elderly people, however, tend to sway more than younger persons (Overstall et al., 1977; Lord et al., 1991), are less able to quickly correct balance after a stumble (Brummell-Smith, 1999), and when confronted with fast moving traffic often hesitate and find decision-making difficult (Stelmach & Nahom, 1992). In order to maintain balance older pedestrians often move slowly and cautiously, look for some support when standing, and prolong the decision to cross a road.

Few studies have assessed the contributions of age-related declines on the overall decline in postural control that occurs with age. Lord et al. (1991), however, examined the relationship between specific sensorimotor functions and measures of postural stability. Their results suggested that reduced sensation, muscle weakness in the legs, and increased reaction time are all important factors associated with postural instability. Results further indicated that peripheral sensation is the most important sensory system in the maintenance of postural stability.

Studies comparing gait patterns of young and older adults show that gait patterns change with age resulting in decreased foot pickup and toe clearance, decreased stride length and velocity, and decreased arm swing (Kallman & Kallman, 1989; Brummel-Smith, 1990; Wyman, 1990). Older adults appear to adopt a guarded or restrained type of walking in an attempt to obtain maximum stability and security (Murray, Kory & Clarkson, 1969). In general, elderly women tend to walk with a waddling gait, they demonstrate shorter stride lengths, less ankle movement, lower average velocities, and greater variability in stride than do younger women (Hageman & Blanke, 1986). Older men generally tend to walk with a small-stepped gait, show decreased foot elevation, walk with a stooped posture, experience stiffness on turning, and have a wider walking and standing base than do younger adult males (Murray et al., 1969;
Kallman & Kallman, 1989). These differences have obvious implications on the safety of elderly pedestrians while crossing the road.

2.5 SUMMARY

Various issues of the ageing process have been covered in the review of the literature and many of them might be relevant in older pedestrian safety. However, care must be taken in relating age-related physiological or anatomical changes to increased risk of accidents on the road.

It is clear that older adults are over-represented in pedestrian crashes and that they are much more likely to be severely injured or killed once involved in a crash than any other group of pedestrians. Evidence suggests that the over-involvement in accidents among older road users, particularly for older drivers, is attributable to age-related decrements in skilled performance combined with an increased susceptibility to serious injury and death following trauma. In particular, a number of risk factors for elderly pedestrians have been suggested. Older people face many age-related sensory, perceptual, and cognitive declines and substantial physical disability. They walk more slowly, they take longer to react to danger and they are less able to get out of the way of an oncoming vehicle if they misjudge a situation. Sensory changes including visual loss, a reduced ability to judge distances and speeds of vehicles, failure to recognise dangerous situations, confusion in complex situations, decreased balance mechanisms, and slowed reaction and decision times all may place the elderly pedestrian at a disadvantage when on the road and are worthy of further investigation.

The elderly are often thought to precipitate their own accidents because they behave incompetently or irresponsibly when crossing the road. The way older people go about crossing the road may be quite different from how younger people act. Observations show that they behave more cautiously than other adults, and that they are often unaware of the changes in their own ability to cope with the risks involved in being a pedestrian. Thus, it may be doing them a severe injustice to attribute their over-involvement in road crashes to deliberate unsafe action when in fact they may be totally unaware of how their declined abilities place them at greater risk of a collision.

Little research has been undertaken examining in detail differences between young adult pedestrian and older adult pedestrian behaviour in the real world. A detailed assessment of pedestrian movements in a number of traffic environments along with recommendations to overcome the trauma associated with pedestrian crashes is thus warranted. This is a significant road safety issue and an investigation of behavioural differences between younger and older pedestrians while crossing the road will provide road safety researchers with a better understanding of the reasons for older pedestrian over-involvement in crashes.
CHAPTER 3

SUMMARY OF ACCIDENT HISTORIES

The literature has identified a number of common patterns in crashes involving older adult pedestrian accidents. The Federal Office of Road Safety (1986) found that elderly pedestrians are often hit when crossing at intersections, they are generally hit on the far-side of the road, they are usually observing the law and not behaving dangerously, and they often do not see the vehicle that hit them. In addition, Sheppard and Pattinson (1986) found that elderly people are more likely than younger adults to become confused in busy, complex road situations.

A number of characteristics of older pedestrian crashes were revealed from an analysis of VicRoads data between 1990 and 1992 (Fildes, Corben, Kent, Oxley, Le & Ryan, 1994). This analysis found that older pedestrians were over-involved in fatal and serious injury crashes, most occurred in daylight hours, and while near-side and far-side crashes account for the majority of all age casualty pedestrian crashes (about 63%), these types of crashes accounted for a greater proportion of older pedestrian crashes (around 73%). A greater proportion of older pedestrians were also involved in driveway crashes.

3.1 SITE SELECTION

This chapter summarises a detailed investigation of all age Police-reported pedestrian accidents at a number of sites in Melbourne. Detailed maps of older pedestrian accident locations in the Melbourne metropolitan area were obtained from VicRoads. Maps highlighted nominated “blackspot” areas and showed actual numbers of pedestrian accidents involving persons aged over 65 years at all locations. From these maps three sites with similar environments were chosen for investigation - High Street, Ashburton, Burgundy Street, Heidelberg, and Centre Road, Bentleigh.

Each of these sites were busy strip shopping centres with arterial roads running through. All sites were of similar length, road widths were similar, and incorporated two-lane undivided roads, roadside parallel parking, similar traffic densities, and no trams.

Furthermore, each of these sites were nominated “blackspot” sites for older pedestrian accidents and were in areas with a high population of older people.

3.2 METHOD

Police reports on pedestrian accidents between January 1987 and the present were extracted from VicRoads databases and analysed. Characteristics of individual accidents were examined and individual features, including sex, age, time of day, and details of circumstances of each accident were noted.

3.3 SUMMARY

Table 3.1 summarises the road location of pedestrian accidents for older adult pedestrians (aged over 65 years) and all-aged other pedestrians at each site.
Table 3.1: Location of Police-reported accidents between 1987 and mid 1995

**Younger Pedestrians**

<table>
<thead>
<tr>
<th>SITE</th>
<th>ON-ROAD NEAR-SIDE</th>
<th>ON-ROAD FAR-SIDE</th>
<th>STEPPING OFF KERB</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burgundy St, Heidelberg</td>
<td>25%</td>
<td>37.5%</td>
<td>37.5%</td>
<td>-</td>
</tr>
<tr>
<td>High St Rd, Ashburton</td>
<td>38.5%</td>
<td>7.7%</td>
<td>46.2%</td>
<td>7.75%</td>
</tr>
<tr>
<td>Centre Rd, Bentleigh</td>
<td>-</td>
<td>33.3%</td>
<td>58.3%</td>
<td>8.3%</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td>31.8%</td>
<td>26.2%</td>
<td>47.3%</td>
<td>8%</td>
</tr>
</tbody>
</table>

**Older Pedestrians**

<table>
<thead>
<tr>
<th>SITE</th>
<th>ON-ROAD NEAR-SIDE</th>
<th>ON-ROAD FAR-SIDE</th>
<th>STEPPING OFF KERB</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burgundy St, Heidelberg</td>
<td>14.3%</td>
<td>28.6%</td>
<td>42.9%</td>
<td>14.3%</td>
</tr>
<tr>
<td>High St Rd, Ashburton</td>
<td>-</td>
<td>33.3%</td>
<td>33.3%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Centre Rd, Bentleigh</td>
<td>11.1%</td>
<td>-</td>
<td>66.7%</td>
<td>22.2%</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td>12.7%</td>
<td>31%</td>
<td>47.6%</td>
<td>23.3%</td>
</tr>
</tbody>
</table>

A total of 52 casualty pedestrian accidents occurred at these sites since 1987. Of the total number, 19 involved pedestrians aged over 65 years, and 33 involved younger pedestrians. A greater proportion of the older pedestrians were female, while more younger pedestrians were male. Of the older pedestrians, there were 12 females and 7 males, while the younger pedestrians consisted of 18 males and 15 females. Further, the majority of accidents occurred between 9am and 6pm on weekdays for both age groups, however, slightly more younger pedestrian accidents occurred after dark.

For both groups of pedestrians, almost half of accidents occurred as pedestrians stepped off the kerb, and these generally happened as they walked out from behind parked cars into the path of an oncoming near-side vehicle. The second most common type of accident for younger pedestrians occurred in the near-side lane (approximately one-third), where the pedestrian had already completed their cross at least half-way over the near-side lane (perhaps reflecting their agility). For the older group of pedestrians, the second most common type of accident occurred in the far-side lane (approximately one-third), giving some indication that older pedestrians may not be able to efficiently process information about both the near-side and far-side traffic once they have commenced the road cross. Further, a number of these far-side accidents occurred as vehicles turned right at an intersection into the path of the crossing pedestrian.
While twenty per cent of older pedestrian accidents were classified as 'other' types, there were few 'other' types of accidents for younger pedestrians. These sorts of crashes included crashes in car-parks where a vehicle reversed, vehicles turning into driveways or lanes crossing the footpath, and vehicles reversing out of angle parks.

Figures 3.1 - 3.3 illustrate the circumstances of all pedestrian accidents at the selected sites. On each map the direction of the vehicle is shown. The dots and dotted lines show the path of travel of the pedestrian and position on the road when they were hit. Labels show the sex and age of each pedestrian.
Figure 3.1: Site map - Pedestrian accidents at Burgundy Street, Heidelberg (1987-1995)
Figure 3.2 Site map - Pedestrian accidents at High Street Road, Ashburton (1987-1995)
Figure 3.3  Site map - Pedestrian accidents at Centre Road, Bentleigh (1987-1995)
CHAPTER 4

PILOT OBSERVATIONS

On the basis of the performance declines outlined in Chapter 2, it is thought that older pedestrians may experience difficulties in crossing roads, and therefore may at least explain some of their over-involvement in pedestrian crashes. The pilot study was a preliminary stage aimed to design methods to observe actual on-road pedestrian behaviour to be used in the observational studies in order to understand how older people's road crossing actions might put them at risk of crash involvement and to highlight means by which their safety can be improved. The primary purpose of this phase was purely to identify independent and dependent variables of the road cross task as well as to determine the most efficient and appropriate procedure to observe behaviour as pedestrians crossed the road. The measures identified in the pilot study were included as possible indicators of motor, sensory, perceptual, and cognitive capabilities/deficits as discussed in the literature.

Differences in the behaviour of both older and younger adult pedestrians (control group) in the real traffic environment as they crossed the road was investigated in detail. In particular, the pilot study aimed to assess differences in the ability of both younger and elderly pedestrians to predict traffic situations and whether it is safe or unsafe to cross the road.

4.1 METHOD

Little is known about pedestrian behaviour and very few studies have investigated pedestrian movements while crossing roads in detail. Initially, observations of pedestrian behaviours that might determine safe road crossing were noted at a number of strip shopping centres. These included crossing times, hesitation behaviour, looking behaviour, traffic assessment, and gait patterns.

4.1.1 Site Selection

From maps obtained from VicRoads detailing older pedestrian accidents in Melbourne, several urban road environments were considered as appropriate sites for observation. It was necessary to select sites where there were sufficient numbers of older road users crossing the road, and which provided a variety of traffic situations. Sites considered to be appropriate included busy strip shopping centres, single- and dual-lane roads, and residential areas.

Video recordings of individual road crossings of both younger and older adult pedestrians were made at High Street Road, Ashburton. This site was selected on its location, suitable sight distance, the ease of parking in an appropriate section of the road, number of older pedestrians in the area, and having a suitable location where a number of pedestrians crossed at mid-block (that is, inbetween the pedestrian lights).

4.1.2 Equipment

Unobtrusive roadside filming of both older and younger adult pedestrian behaviour as they cross the road was performed. A van was set up with video equipment to record the observations. Figure 4.1 shows the general set up of the equipment. Two cameras were set appropriately to provide video images of both oncoming traffic and pedestrian movements. Camera 1 was attached to the steering wheel and was directed at the oncoming traffic, while...
camera 2 was directed at a crossing point directly opposite the van which tracked pedestrians as they crossed to the centre of the road.

Figure 4.1  Equipment used for on-road observations of pedestrian behaviour.

4.1.3 Procedure
A number of behaviours to be scored were chosen which were thought to reflect sensory, perceptual, cognitive, and motor declines in the elderly. These included:

- time spent completing the road crossing task
  - to investigate age-related slowed motor performance as well as slowed reaction time capacities.
  - to determine whether older pedestrians are more exposed to risk of a crash purely as a result of spending more time in a potentially risky situation.
  - to show that motor deficits (outlined above) lead to slower speeds.

- directional looking behaviour and head/body movements
  - to investigate age-related differences in attentional performance as well as reduced visual, decision-making, and information processing capacities.
  - to investigate differences in where older and younger pedestrians direct their attention. Maule & Sanford (1980) suggest that older people experience difficulties in allocating their attention to the most appropriate source of information in order to make appropriate
judgements. An investigation of age differences in direction of looking may reflect possible differences in sampling strategies of younger and older pedestrians. Fildes et al. (1994) found that a substantial proportion of older pedestrian crashes occurred in the far-side lane. An investigation of direction of looking (particularly looking in the direction of the near-side and far-side traffic) may give some insight into the reasons for this finding. In addition, the Safety for Seniors Working Group (1986) found that older pedestrians made less head movements per unit of crossing time, suggesting they may not take in as much information as younger pedestrians might. This variable was included to investigate these findings.

- gap acceptance judgements

- to illustrate age-related differences in motion perception capacities. Staplin & Lyles (1991) suggested that age differences in motion perception in critical traffic situations may be a contributing factor in older road users over-involvement in crashes. Time-of-arrival estimates were combined with individual walking speeds to assess differences in crossing strategies and to demonstrate difficulties older pedestrians might experience in judging speed and distance of an oncoming vehicle while taking slower walking speed into consideration.

Video recordings of individual road crossings of 31 younger pedestrians (estimated to be between 30 and 45 years old) and 24 older adult pedestrians (estimated to be over 65 years of age) were made. The van was parked on the opposite side of the road to where pedestrians would be filmed crossing the road (see Figure 4.2) and cameras were set accordingly. Pedestrians who crossed the road directly opposite the parked van were filmed, and with an image splitter, a smaller image of the near-side oncoming traffic (to the pedestrian) was superimposed onto the video image of the pedestrian. Video recordings of both pedestrian movements and oncoming near-side traffic were synchronised, such that pedestrian behaviour could be scored in relation to traffic changes. Time counts set at 1/25 sec were burnt onto video images enabling behaviour to be scored in detail.

Figure 4.2  Plan of observational filming
A random selection of participants was used. Pedestrians were filmed if they crossed the road at the chosen site, fitted into either age category, and did not show any apparent illness that may have altered their behaviour significantly.

The pilot phase necessarily involved unobtrusive observations of pedestrians crossing the road. Pedestrians were filmed without their knowledge to overcome possible changes in behaviour in the face of knowing they were being observed.

Due to the nature of the pilot study, that is, the aim was purely to develop an appropriate method to observe and assess differences in pedestrian behaviour, no statistical tests other than calculation of standard deviations were performed on the pilot data.

### 4.2 RESULTS

Measures on dependent and independent variables that may conceivably be significant determinants of safe road crossing behaviour were scored.

Three stages of the road-crossing task were identified, and these include:

- **on approach to kerb** - defined as the time from when a pedestrian was judged to make a decision to cross the road to the point at which they stop at the kerb to assess the traffic situation.

- **at the kerb** - defined as the time from when a pedestrian stops from the approach and assesses the traffic to the time of first step forward to cross the road. Pedestrians may stand either at the kerb, still on the footpath, or they may have stepped off the kerb and stand on the road inbetween parked cars.

- **road crossing** - defined as the time from first step forward to cross the road to the crossing point in the centre of the road.

#### 4.2.1 Total Times Spent in Road-crossing Task

Total times spent in each phase of the road-crossing task were scored for each participant and average times were calculated for both groups of pedestrians.

<table>
<thead>
<tr>
<th></th>
<th>On Approach To Kerb</th>
<th>At Kerb</th>
<th>Road Crossing (to centre)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Younger Pedestrians</strong></td>
<td>3.1s (1.81s)</td>
<td>9.2s (9.10s)</td>
<td>4.8s (1.97s)</td>
<td>17.1s</td>
</tr>
<tr>
<td><strong>Older Pedestrians</strong></td>
<td>3.9s (2.55s)</td>
<td>24.3s (17.23s)</td>
<td>6.2s (2.31s)</td>
<td>34.4s</td>
</tr>
</tbody>
</table>

While there is little difference on the approach to the kerb, average total times spent while at the kerb and during road crossing reflect the general slowness often seen with elderly people.
Older pedestrians spent, on average, more than twice as long as younger pedestrians to complete all phases of the road-crossing task. The greatest time difference between younger and older pedestrians was found while standing at the kerb.

Standard deviations indicate little difference in variation of times spent on approach to the kerb and while crossing the road between the groups. Greater variability between individuals was found, however, when subjects were waiting at the kerb (Table 4.1).

Part of the greater time standing at the kerb demonstrated by older pedestrians may be attributed to latency, or what other studies have termed kerb delay (Safety for Seniors Working Group, 1988). It has been suggested that older pedestrians delay at the kerb on average 3-4 seconds (Safety for Seniors Working Group, 1988). Table 4.2 shows the kerb delay for both groups of pedestrians.

**Table 4.2: Kerb delay**

<table>
<thead>
<tr>
<th>Younger Pedestrians</th>
<th>2.1 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older Pedestrians</td>
<td>3.0 s</td>
</tr>
</tbody>
</table>

Kerb delay was calculated as the time taken between the time that the front of the last vehicle passed a waiting pedestrian to when they took their first step forward to cross the road. While younger pedestrians delayed on average just over 2 seconds, older pedestrians showed an average kerb delay of 3 seconds.

### 4.2.2 Directional Looking Behaviour.

A number of looking behaviours as proportions of total time spent in each phase of the road crossing task were scored for older and younger pedestrians and are presented in Figures 4.3 to 4.5. "Near-side traffic" was defined as cars approaching from the near-side of the road, that is traffic from the right (from the perspective of the pedestrians); while "far-side traffic" was defined as cars approaching from the far-side of the road, that is traffic from the left (again, from the perspective of the pedestrian). "Looking at other" included any looking behaviour not including looking at the traffic, ahead or the ground. It included such behaviour as looking at other people, at shops behind, in bags, at objects in hands, etc.

On their approach to the kerb, both older and younger pedestrians spent most of the total time looking at the near-side traffic, however, notable proportions of time were also spent looking at far-side traffic, ahead and at the ground. Older pedestrians generally looked at the far-side traffic and at the footpath proportionately more than younger pedestrians, who spent proportionately more time looking at the near-side traffic and ahead than older pedestrians (Figure 4.3).
When standing at the kerb, again, both older and younger pedestrians looked mostly at the near-side traffic, with the older pedestrians looking more in that direction than the younger pedestrians. Older pedestrians also spent proportionately more time than their younger counterparts looking at the far-side traffic while standing at the kerb, however, this difference was not as great as during the approach to the kerb. Younger pedestrians again spent proportionately more time looking ahead than did older pedestrians, however, differences were not as great as on their approach to the kerb. Relatively little time was spent looking at the ground by both groups (Figure 4.4).
During the road cross to the centre it was the far-side traffic and objects located ahead to which both groups of pedestrians paid more attention to. Younger pedestrians spent a slightly greater proportion of time looking at the far-side traffic and ahead than older pedestrians, while the older pedestrians still looked proportionately more at the near-side traffic and at the ground that did younger pedestrians (Figure 4.5).

Measures of looking behaviour were included in the pilot study as possible indications of sensory, perceptual and cognitive processing; including visual capabilities, acquisition and retention of information, and attentional capacities. While Figures 4.3 to 4.5 generally shows similar patterns of direction of looking for both younger and older pedestrians in the three stages of the road cross, these measures seem to highlight differences in looking behaviour as a function of phase and as a function of age. These measures were included in the observational studies. In addition, measures of real time spent in each phase of the road cross and duration of looks in each direction were calculated for pedestrians in each group in the observational studies.

4.2.3 Head/body Movements

The frequency of head movements were scored at each stage of the road cross for both groups of pedestrians. Head movements (or turns) were defined as either 1) a head turn from looking to the side to the middle, and vice versa, or 2) a head turn from looking from one side to the other; that is, either a 90° turn or 180° turn. Results are presented in Table 4.3.
Table 4.3 Average number of head/body movements at each stage of the road cross

<table>
<thead>
<tr>
<th></th>
<th>On Approach To Kerb</th>
<th>At Kerb</th>
<th>During Road Cross</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>1.5</td>
<td>4.1</td>
<td>2.7</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>1.4</td>
<td>4.2</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Little difference was found between the two groups of pedestrians in the number of head turns at each stage of the road cross. Phase differences were noted, where, on average pedestrians made most head turns while standing at the kerb, and least while approaching the kerb. This, however, may be a function of total time spent waiting at the kerb.

4.2.4 Gap Acceptance and Time-of-Arrival Measures

Scoring of traffic variables allowed calculations of pedestrian judgements of gap acceptance and time-of-arrival estimates. A basic skill that is necessary for crossing a road safely is to judge whether a gap in the traffic is large enough to allow crossing without collision. This entails visually judging the time of arrival at the crossing point of the nearest vehicle with the planned crossing line and starting to cross only when the time-of-arrival is greater than the time required to cross. Gap acceptance judgements are based purely on distance, while time-of-arrival judgements take both distance and speed of an approaching car into account along with judgements of one's own walking speed. Both variables are of interest because the ability to make accurate decisions of safety based on judging accurately the speed and distance of oncoming vehicles is vital for safe road crossing. Further, gap acceptance and time-of-arrival measures can give an indication of depth perception abilities, and motion perception abilities associated with the ability to combine both sources of information with own walking speed and the ability to adapt travel speed in case of danger.

Gap acceptance and time-of-arrival measurements were calculated from the distance of a near-side oncoming vehicle to a pedestrian at the time of their first step forward to cross the road. Geometric calculation was necessary due to the angles of the cameras in the parked van. Reference points were measured veridically along the path, such that once a vehicle passed a certain point as viewed by the cameras, the absolute distance from the crossing pedestrian could be calculated. The width of the road, path, average width of cars, and their approximate path of travel were known, thus the absolute distance from the pedestrian was determined.

Table 4.4 shows gap acceptance and time-of-arrival measurements for the two groups of pedestrians. Note however that measures could only be taken from 8 young and 9 older subjects since the majority of pedestrians commenced to cross the road when the near-side traffic had stopped at traffic lights further up the road.
Average gap acceptance was longer for older pedestrians than for younger pedestrians, a difference of just under 16 metres. A difference was also found between pedestrian groups for time-of-arrival measures. On average older pedestrian estimates of safe times to cross were longer than those of younger pedestrians, a difference of around 2.75 seconds (Table 4.4).

By comparing average time-of-arrival measures with average crossing times, a difference was found between younger pedestrians and older pedestrians, where on average younger pedestrians left less time between reaching the centre of the road and time-of-arrival of the first approaching near-side vehicle (0.4secs vs 1.8secs).

To take this concept further, individual walking speeds were plotted against individual time-of-arrival measures in order to estimate the proportion of pedestrians who crossed the road safely. Adoption of a safe strategy to cross the road would include knowledge of walking speed and judgement of time-of-arrival, such that a person would allow him/herself enough time to cross to the centre of the road before a vehicle reaches the crossing line.

Figure 4.6 shows distributions of safe/unsafe crossings for the 8 young and 9 older pedestrians for which traffic variables could be calculated. The diagonal line indicates where time-of-arrival and crossing time coincides. Points above the line indicate safe behaviour and points below the line indicate unsafe behaviour. For example, if a person leaves 5 secs to time-of-arrival and crosses the road to the centre in 4 secs, this person's data point will be above the line indicating that he/she engaged in safe behaviour. The oncoming car would have arrived at the crossing line when the person was already in the centre of the road and would have passed behind. If this person estimated 5 secs to time-of-arrival and then taken 7 secs to cross the data point would be below the line indicating that he/she may have engaged in risky or unsafe behaviour. It is possible though that the car had slowed down to avoid collision.
Figure 4.6 Distribution of safe/unsafe road crossings

Table 4.5 Proportion of safe/unsafe road crossings

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Younger Pedestrians</th>
<th>Older Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoption of Safe Strategy</td>
<td>76%</td>
<td>63%</td>
<td>89%</td>
</tr>
<tr>
<td>Adoption of Unsafe Strategy</td>
<td>24%</td>
<td>37%</td>
<td>11%</td>
</tr>
</tbody>
</table>

The safety estimate is a conservative estimate as the time-of-arrival of the nearest oncoming vehicle at the crossing line is compared with the time that individual pedestrians reach the centre of the road. Aside from this, in general, the majority of all pedestrians (76 percent) adopted a safe strategy (Table 4.5). A higher proportion of older pedestrians adopted this safe crossing behaviour while quite a substantial proportion of younger pedestrians adopted an unsafe strategy. Since none of the pedestrians were hit by a car during these observations it is assumed that the relevant cars had slowed down to avoid collision.

4.2.6 Additional Observations

In general, this pilot study has focussed on near-side traffic and pedestrians’ judgements of safe gaps and time-of-arrival with oncoming near-side traffic only, and behaviour is only filmed while crossing the first half of the road. While a greater proportion of crashes involving elderly pedestrians occur with near-side traffic (over 42%), a substantial proportion also occur with the far-side traffic (approximately 30%). Further investigation of when and how much attention is given to the far-side traffic for both groups of pedestrians has been attempted. Calculation of the time from first step forward to the point of first look at the far-side traffic revealed a difference between pedestrian groups. Younger pedestrians, on average, initially shifted their attention to the far-side traffic sooner than older pedestrians. This age difference
was also reflected when time to first look was expressed as a proportion of crossing distance (Table 4.6).

Table 4.6 Average time taken to direct attention to far-side traffic during road cross to centre

<table>
<thead>
<tr>
<th></th>
<th>Time to First Look</th>
<th>First Look as Prop. of Crossing Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>0.9 s</td>
<td>18.4%</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>1.6 s</td>
<td>23.9%</td>
</tr>
</tbody>
</table>

Table 4.7 Proportion of time spent looking at near-side and far-side traffic as a proportion of traffic looking during road cross

<table>
<thead>
<tr>
<th></th>
<th>Prop. of Time Looking at Near-side Traffic</th>
<th>Prop. of Time Looking at Far-side Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>35.3%</td>
<td>64.7%</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>37.4%</td>
<td>62.6%</td>
</tr>
</tbody>
</table>

Calculations of proportions of time looking at near-side vs far-side traffic while crossing to the centre of the road revealed that both groups of pedestrians spent more of their time looking at the far-side traffic, the age differences were negligible (Table 4.7).

4.3 DISCUSSION

The pilot study has demonstrated that the method of observation developed has successfully been used to observe on-road pedestrian behaviour. The behaviours observed indicated that there are differences in the road crossing behaviour of older and younger adult pedestrians and that these variables might determine safe road crossing behaviour.

General observations in the pilot phase noted general uneasiness, hesitancy, appearance to be able to concentrate on only a few things at one time and faltering among older pedestrians. Younger pedestrians, on the other hand, generally appeared to execute smooth, fast actions when crossing the road, they appeared more relaxed and appeared to take in information about the traffic environment with ease.

4.3.1 Total Times Spent in Road-crossing Task

Findings from the pilot study suggested that older pedestrians were slower than younger pedestrians during all phases of the road-crossing task. Average total times spent approaching the kerb, waiting at the kerb and crossing to the centre of the road reflected the general slowness often seen with elderly people. Further, older pedestrians were observed to delay at the kerb longer than did the younger pedestrians.
Measures of total times spent on the task of road crossing were included in this study to give some indication of exposure differences, and general slowness in sensory, perceptual and motor processes. Past research has shown a general slowing with age not only in physical attributes, but also in association with sensory, perceptual and cognitive processes. Further, while little exposure data is available, it may be possible that older pedestrians are over-involved in pedestrian crashes purely because they spend a longer amount of time exposed in the traffic situation.

Kerb delay calculation was included in this study to give some indication of differences in hesitation behaviour, and differences in efficiency in the road crossing task. Past research has shown that older pedestrians delay longer than younger pedestrians and this study supports that contention.

These variables are valuable measures and were included in the observational studies. A number of changes were made, however. A more objective criterion was used to define the kerb approach, that is 2 seconds before the pedestrian stopped at the kerb to the time at which they stop at the kerb. Further, because group differences in time spent waiting at the kerb may reflect different traffic volumes, number of passing cars while at the kerb were recorded for each individual in the observational studies and pedestrian crossings were categorised according to traffic volume.

Kerb delay calculation was changed slightly in the observational studies to correlate with studies conducted by Lee, Young & McLaughlin (1984). Kerb delay was calculated from the average time taken between the time the rear of the last vehicle passed a waiting pedestrian to when they took their first step forward to cross the road. This may give a better understanding of efficiency in crossing strategy as well as hesitation behaviour.

Time taken to cross the entire road was also included in the observational studies as well as calculations of average walking speeds to cross to the centre and to cross the whole road for both groups of pedestrians.

4.3.2 Directional Looking Behaviour and Head/Body Movements

Directional looking behaviour was scored and proportions were calculated so that differences in behaviour could be compared with more ease. On approach to the kerb both older and younger pedestrians spent the majority of their time looking in the direction of the near-side traffic. Older pedestrians spent less time than the younger pedestrians looking towards the near-side traffic and ahead, and more time was spent looking towards the far-side traffic and at the ground.

While waiting at the kerb, again, both groups of pedestrians spent the majority of their time looking in the direction of the near-side traffic, however, the older pedestrians spent a greater proportion of their time looking in this direction. Older pedestrians spent more time looking in the direction of the far-side traffic and towards the ground than did the younger pedestrians.

While crossing the road both groups of pedestrians spent most of their time looking in the direction of the far-side traffic and ahead. Older pedestrians spent more time looking towards the near-side traffic and at the ground, while the younger pedestrians spent more time looking towards the far-side traffic and ahead. Further, younger pedestrians looked in the direction of the far-side traffic earlier than did the older pedestrians.
Little difference was found between the two groups of pedestrians in the number of head/body turns made in each phase of the road cross.

Measures of looking behaviour were included in the pilot study as possible indicators of sensory, perceptual and cognitive processing; including visual capabilities, acquisition and retention of information, and attentional capacities. While figures 4.3 to 4.5 generally shows similar patterns of direction of looking for both younger and older pedestrians in the three stages of the road cross, these measures seem to highlight differences in looking behaviour as a function of phase and as a function of age. These measures were included in the observational studies. In addition, measures of real time spent in each phase of the road cross and duration of looks in each direction were calculated for pedestrians in each group in the observational studies.

Past studies that argued that older pedestrians make more head turns than younger pedestrians before the road cross (Safety for Seniors Working Group, 1988). Number of head turns was included in the pilot study to substantiate these findings. This measure was included in the observational studies. In addition, rate of head turns per second based on length of time spent in each phase of the road cross were calculated in the observational studies for individual pedestrians to allow a more meaningful interpretation of the data.

4.3.4 Gap Acceptance and Time-of-arrival Measures

Average gap acceptance measurements were longer for older pedestrians than for younger pedestrians. Time-of-arrival measures were also longer for older pedestrians than for the younger pedestrians. Time-of-arrival measures were combined with individual walking speeds and distributions of crossings showed that, while all pedestrians crossed the road safely, a greater proportion of older pedestrians adopted a more safe crossing strategy than did the younger pedestrians.

Measures of gap acceptance, time-of-arrival, and safe behaviour were included in the pilot study as indicators of depth and motion perception abilities underlying safe judgements. It has been suggested that with age-related slowing, older pedestrians need to re-assess their judgements of safe gaps and time-of-arrival to compensate for their slower walking speeds (Lee, Young & McLaughlin, 1984). These measures were included in the observational studies as they were clearly showing up age differences in judgements and behaviour. Note, however, that the results of the pilot study are based only on a few subjects.

4.3 SUMMARY

All measures calculated in the pilot study were included in the observational studies along with a number of changes and additional calculations. First, a more objective criterion was made to define the approach to the kerb; second, traffic flow rates from each direction were calculated for times that pedestrians waited at the kerb, and as they crossed to the centre of the road; third, average mean durations of looking behaviour as well as total real times spent in direction of looking were calculated; fourth, walking speeds were calculated as pedestrians crossed to the centre of the road and for the whole road; fifth, rate of head turns were calculated on the basis of time spent in each phase of the road cross for each age group of pedestrians.

Further investigation of what pedestrians do if they adopt a less conservative strategy in road crossing and stand in the centre of the road was warranted. Classification of crossing styles
was undertaken to investigate in detail differences between groups of pedestrians in the degree to which they interact with the traffic when crossing.
CHAPTER 5

FIRST OBSERVATIONAL STUDY - TWO-WAY ROADS

5.1 SITE SELECTION

Data for the first observational study was collected from two strip shopping centre sites in Southern and Eastern Melbourne metropolitan areas. As in the pilot study, maps prepared by VicRoads were examined in order to select suitable sites. Burgundy Street, Heidelberg and Glen Eira Road, Ripponlea were selected as observational sites for this study (Figures 5.1 and 5.2).

These sites are nominated "blackspot" areas for older pedestrian accidents, and have a large number of older people shopping at these centres. Further, the road environment was similar for both sites in a number of respects. First, the width of the road was identical (11.2m wide); second, traffic volumes were similar for both sites; third, both sites had ramp constructions which overcame the difficulty found in the pilot study of parked cars and pedestrians either standing back on the footpath or on the road in front of parked cars while assessing the traffic situation.

Figure 5.1 View of Burgundy Street, Heidelberg - strip shopping centre (west)
5.2 METHOD

Observations were made between 10am and 1pm on weekdays in late December, 1994 at each site in fine weather. The observational method used in the pilot study was used in this study. Video recordings of individual road crossings of 40 younger adult pedestrians (estimated to be between 30 and 45 years old) and 40 older adult pedestrians (estimated to be over 65 years of age) were made at each site. A total of 80 younger pedestrians and 80 older pedestrians formed the sample for the results.

As in the pilot study, a random and concurrent selection of participants was used. Pedestrians were filmed if they crossed the road at the chosen site, fitted into either age category, and did not show any apparent illness that may have altered their behaviour significantly. Pedestrians were filmed without their knowledge to overcome possible changes in behaviour in the face of knowing they were being observed.

5.3 RESULTS

The three phases identified in the pilot study were used in this study. One change, however, was introduced. The stages of the road crossing task were defined in this study as:

- **on approach to kerb** - defined as the time from 2 seconds before a pedestrian stopped at the kerb to assess the traffic situation, to the time at which he/she stopped at the kerb. If a pedestrian did not stop at the kerb, the approach was taken from 2 seconds before a pedestrian stepped off the kerb to make the first step to cross the road.
• at the kerb - defined as the time from when a pedestrian stopped from the approach and assesses the traffic to the time of first step forward to cross the road. During this phase, pedestrians may make steps forward, or shuffle, but not commence the first step forward to cross the road.

• road crossing - defined as the time from first step forward to cross the road to the crossing point in the centre of the road.

5.3.1 On Approach to the Kerb

A number of behaviours were scored as pedestrians approached the kerb. These included directional looking behaviour as proportions of total time spent approaching the kerb, durations of bouts of looking in all directions, and number and rate of head turns. No times are given for the approach to the kerb, as scoring of behaviour was taken from 2 seconds before stop at kerb or road cross.

Directional Looking Behaviour

Figure 5.3 shows looking behaviours as proportions of total time spent while approaching the kerb. In order to control for age differences in times spent in each phase of the road cross, overall looking times were converted into proportions to investigate directional looking differences.

Figure 5.3 Direction of looking as proportion of total time spent on approach to the kerb

Figure 5.3 shows the distribution of direction of looking as a proportion of total time spent on approach to the kerb. A two-way analysis of variance (ANOVA) was performed on the proportional data for age and looking direction. A significant main effect for direction was found \( F(2.96,461.65)=72.22, p<0.001 \) as well as an interaction between the two factors \( F(2.96,461.65)=3.98, p<0.001 \).

A post hoc ANOVA for simple effects revealed a significant direction effect for both the young and old age groups \( F(2.96,461.65)=34.66, p<0.001 \), and \( F(2.96,461.65)=41.46, p<0.001 \) respectively.
Tukey comparisons showed that both groups of subjects looked mostly in the direction of the near-side traffic. This was significantly different from all other looking directions (p<0.01). Subjects were also found to spent around 25% of their time looking ahead, which was more than they spent looking at far-side traffic (p<0.01), or towards the ground (p<0.01).

The simple effects ANOVA also revealed significant age effects with younger pedestrians looking more at the far-side traffic ($F(1,156)=7.53, p=0.007$) and older pedestrians looking more towards the ground ($F(1,156)=12.80, p<0.001$).

Table 5.1 Direction of looking as proportion of total time spent on approach to the kerb including standard deviations

<table>
<thead>
<tr>
<th></th>
<th>Younger Pedestrians</th>
<th>Older Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearside Traffic</td>
<td>45.18% (0.52s)</td>
<td>50.28% (0.64s)</td>
</tr>
<tr>
<td>Farside Traffic</td>
<td>14.45% (0.35s)</td>
<td>5.87% (0.34s)</td>
</tr>
<tr>
<td>Ahead</td>
<td>28.28% (0.36s)</td>
<td>23.46% (0.43s)</td>
</tr>
<tr>
<td>Ground</td>
<td>5.38% (0.34s)</td>
<td>17.51% (0.49s)</td>
</tr>
<tr>
<td>Other</td>
<td>6.73% (0.54s)</td>
<td>2.87% (0.49s)</td>
</tr>
</tbody>
</table>

Standard deviation calculations showed few differences between groups for all looking behaviours on their approach to the kerb. However, for all behaviours the older group of pedestrians varied slightly (but not significantly) more than the younger group (Table 5.1).

Figure 5.4 shows overall mean time per look in each direction on the approach to the kerb. Older pedestrians spent longer each time they looked in almost all directions (except looking at other).
Figure 5.4  *Mean time per look in each direction on approach to the kerb*

**Head/body Movements**

The average number of head/body movements was scored and rate of head turns per second was calculated for the time spent approaching the kerb and are presented in Table 5.2.

Table 5.2  *Average number of head/body movements and rate of head turns per second on approach to the kerb*

<table>
<thead>
<tr>
<th></th>
<th>Number of Head Turns on Approach To Kerb</th>
<th>Head Turns/sec. on Approach To Kerb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>1.5</td>
<td>0.75</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>1.4</td>
<td>0.70</td>
</tr>
</tbody>
</table>

As in the pilot study, no significant group differences were found in number of head turns on the approach to the kerb. Further, calculation of head turns per second while approaching the kerb also showed no significant difference between the older and younger pedestrians ($T_{(158)}=0.59, p=0.28$).

5.3.2  *At the Kerb*

While standing at the kerb a number of behaviours and traffic variables were scored. These included proportions of individuals that waited at the kerb, average time spent waiting at the kerb, traffic volume, directional looking behaviour, number and rate of head turns, kerb delay, and gap acceptance measures.
Proportion of Individuals Waiting at Kerb and Average Time Spent Waiting

Table 5.3 presents the proportion of pedestrians that waited at the kerb, the average time spent waiting at the kerb, and traffic flow information for both groups of pedestrians while waiting at the kerb.

Table 5.3  Proportion of pedestrians waiting at the kerb, average time spent waiting, and traffic flow

<table>
<thead>
<tr>
<th></th>
<th>Younger Pedestrians</th>
<th>Older Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion waited</td>
<td>53.75%</td>
<td>85%</td>
</tr>
<tr>
<td>Average time waiting (for those who waited)</td>
<td>8.3 secs</td>
<td>18.1 secs</td>
</tr>
<tr>
<td>Traffic flow in near-side lane (cars/sec.)</td>
<td>0.23</td>
<td>0.23</td>
</tr>
<tr>
<td>Traffic flow rate for both near- and far-side lanes (cars/sec.)</td>
<td>0.47</td>
<td>0.43</td>
</tr>
</tbody>
</table>

A much greater proportion of older than younger pedestrians waited at the kerb - only about half of the younger pedestrians stopped while over four-fifths of the older pedestrians stopped at the kerb. Of those who did stop, average times spent waiting at the kerb were significantly longer (t(96)=4.36, p<0.001) for the older pedestrians than for the younger pedestrians - on average older pedestrians spent more than twice as long as younger pedestrians standing at the kerb.

Further, traffic flow information suggests that the number of passing cars both in the near-side and far-side lanes did not vary during the times that the two groups of pedestrians were standing at the kerb.

Directional Looking Behaviour

Total times spent completing the road-crossing task enhances the differences of exposure found between groups (Figure 5.5). While the patterns of looking behaviour are similar for both groups of pedestrians while standing at the kerb, great differences in time are noted.
Total time spent looking in each direction is presented in figure 5.5 for each age group. While the patterns of directional looking behaviour are similar for both groups of pedestrians while standing at the kerb, great differences in time are noted. Older pedestrians spent more than twice as long as younger pedestrians looking in each direction.

Figure 5.6 shows looking behaviours as proportions of total time spent while standing at the kerb (only for those subjects who actually waited at the kerb). Proportions were calculated to account for overall age differences in looking times.
While the pattern of directional of looking was similar for both groups of pedestrians, there was a significant main effect for direction ($F_{(2.70, 204.76)} = 95.04, p < 0.001$). No interaction effect between age and direction of looking was found.

Both groups spent most of their time looking in the direction of the near-side traffic and least time looking towards the ground ($p < 0.01$). Both far-side traffic and objects straight ahead were also looked at for substantial proportions of time by both subject groups, but less than near-side traffic ($p < 0.01$) and more than the ground ($p < 0.01$).
Table 5.4  Looking behaviours as proportion of total time spent waiting at the kerb including standard deviations

<table>
<thead>
<tr>
<th></th>
<th>Younger Pedestrians</th>
<th>Older Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearside Traffic</td>
<td>48.21% (2.03s)</td>
<td>44.13% (2.48s)</td>
</tr>
<tr>
<td>Farside Traffic</td>
<td>22.94% (1.50s)</td>
<td>22.73% (2.30s)</td>
</tr>
<tr>
<td>Ahead</td>
<td>19.84% (0.65s)</td>
<td>21.89% (1.08s)</td>
</tr>
<tr>
<td>Ground</td>
<td>0.83% (0.70s)</td>
<td>3.25% (0.75s)</td>
</tr>
<tr>
<td>Other</td>
<td>8.17% (0.98s)</td>
<td>8.01% (2.78s)</td>
</tr>
</tbody>
</table>

Standard deviation calculations showed some differences between groups for all looking behaviours while standing at the kerb. The older group of pedestrians showed slightly more variance than the younger group for all looking behaviours while standing at the kerb, particularly for looking at the far-side traffic and looking at other.

Figure 5.7 shows mean time per look in each direction while standing at the kerb for both older and younger pedestrians. Older pedestrians spent longer in each look in almost all directions while standing at the kerb, particularly when looking at other things.

![Figure 5.7 Mean time per look in each direction while waiting at the kerb](image)

---

**Figure 5.7**  Mean time per look in each direction while waiting at the kerb
Head/body Movements
The number of head/body movements while standing at the kerb was scored for each pedestrian and average number of movements and head turns per second were calculated.

Table 5.5: Average number of head/body movements and rate of head turns per second while waiting at the kerb

<table>
<thead>
<tr>
<th>Number of Head Turns At Kerb</th>
<th>Head Turns/sec. while At Kerb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>4.1</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>4.2</td>
</tr>
</tbody>
</table>

As in the pilot study, no significant difference was found in number of head turns while standing at the kerb between groups of pedestrians (Table 5.5). Further, calculation of rate of head turns per second based on the average total time spent standing at the kerb showed no significant group difference ($t(189)=1.51, p=0.07$).

Kerb Delay
Kerb delay was calculated from the average time taken between the time the back of the last vehicle passed a waiting pedestrian to when they took their first step forward to cross the road. Thus, a negative score means an individual commenced to cross before the back of the last vehicle passed the crossing line (a more efficient crossing strategy where less time is wasted waiting for the last vehicle to pass), while a positive score means an individual commenced to cross after the back of the last vehicle passed the crossing line (reflecting a less efficient crossing strategy where more time is wasted waiting for the last vehicle to pass before commencing the road cross).

Table 5.6 Average kerb delay

<table>
<thead>
<tr>
<th>Younger Pedestrians</th>
<th>-0.05 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older Pedestrians</td>
<td>+0.87 s</td>
</tr>
</tbody>
</table>

A significant difference ($t(95)=1.59, p=0.05$) was found between groups for kerb delay. Older pedestrians delayed on average just under 1 second, making their first step forward after the rear of the last vehicle had passed them. Younger pedestrians, on average commenced the road cross immediately before the rear of the last vehicle passed.

5.3.3: Road Cross
Behaviours were scored as pedestrians crossed the road. Time taken to cross to the centre of the road and the whole road, walking speeds, direction of looking, gap acceptance judgements, and crossing styles were examined.
**Time Taken to Cross the Road and Walking Speed**

Significant differences between groups were found for time taken to cross to the centre of the road ($t_{(117)}=6.6, p<0.001$) and to cross the whole road ($t_{(102)}=7.25, p<0.001$). On average, the younger pedestrians walked faster than the older pedestrians, taking 1.5 seconds less to cross to the centre of the road, and 3 seconds less than the older pedestrians to cross the whole road (Table 5.7). This was also reflected in the walking speeds (m/s). Younger pedestrians walked, on average, 0.4 of a metre further per second than older pedestrians (Table 5.7).

**Table 5.7: Average total times taken to cross the road and walking speed (to centre and whole road)**

<table>
<thead>
<tr>
<th></th>
<th>Time To Cross To Centre</th>
<th>Total Time To Cross to Other Side</th>
<th>Walking Speed - To Centre (m/s)</th>
<th>Walking Speed - Whole Road (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>3.79s</td>
<td>6.91s</td>
<td>1.478</td>
<td>1.621</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>5.34s</td>
<td>9.93s</td>
<td>1.049</td>
<td>1.128</td>
</tr>
</tbody>
</table>

**Directional Looking Behaviour**

All looking behaviours were scored for crossing the road to the centre only. Total looking times in each direction are shown in Figure 5.8 for both age groups. While the patterns of directional looking are similar for both groups, differences in time are noted. In addition, older pedestrians spent a much greater amount of time looking at the road during the road cross than did the younger pedestrians.
Figure 5.8  Total time spent in looking in each direction while crossing the road (to centre)

Figure 5.9 shows direction of looking as proportions of total time spent crossing the road. Significant differences were found in the distribution of looking direction \( F(2.32,366.99)=184.19, p<0.001 \). There was also a significant interaction for age by direction \( F(2.32,366.99)=4.27, p<0.001 \).

Figure 5.9  Direction of looking as proportion of total time spent crossing the road (to centre)

A simple effects ANOVA revealed a significant direction effect for both age groups \( F(2.32,366.99)=109.07, p<0.001 \) and \( F(2.32,366.99)=79.35, p<0.001 \) respectively. In this phase of
the task, the proportion of time looking towards far-side traffic and ahead was significantly higher than that of looking in the direction of near-side traffic and at the road (p's<0.01).

The simple effects ANOVA also revealed that younger pedestrians looked proportionately longer ahead than the older pedestrians ($F_{(1,158)}=4.54, p=0.04$), and older pedestrians looked proportionately longer at the ground ($F_{(1,158)}=18.79, p<0.001$).

Table 5.8  Direction of looking as proportion of total time spent crossing the road (to centre), including standard deviations

<table>
<thead>
<tr>
<th></th>
<th>Younger Pedestrians</th>
<th>Older Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15.75% (0.43s)</td>
<td>14.67% (1.02s)</td>
</tr>
<tr>
<td>Nearside Traffic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farside Traffic</td>
<td>33.02% (0.70s)</td>
<td>33.75% (1.02s)</td>
</tr>
<tr>
<td>Ahead</td>
<td>47.03% (0.64s)</td>
<td>40.24% (0.85s)</td>
</tr>
<tr>
<td>Ground</td>
<td>2.92% (0.55s)</td>
<td>11.17% (0.45s)</td>
</tr>
<tr>
<td>Other</td>
<td>1.28% (0.39s)</td>
<td>0.17% (0s)</td>
</tr>
</tbody>
</table>

Standard deviations showed small differences between groups for all looking behaviours. Table 5.8 illustrates that the older pedestrians showed slightly more variability in nearly all looking behaviours, particularly when looking at near-side and far-side traffic.

Figure 5.10 shows mean time per look in each direction while crossing the road (to the centre). Older pedestrians spent longer each time they looked when looking at near-side and far-side traffic and ahead than younger pedestrians, while the younger group spent longer each time they looked at the road and at other things than the older pedestrians while crossing the road.
Figure 5.10 Mean time per look in each direction of looking while crossing the road (to the centre)

Head/body Movements
The number of head/body movements was recorded for each pedestrian during the road cross (to the centre). Rate of head turns per second was then calculated based on the average time taken for each group of pedestrian to cross the road to the centre.

Table 5.9 Average number of head/body movements and rate of head turns per second while crossing the road (to centre)

<table>
<thead>
<tr>
<th></th>
<th>Number of Head Turns on Road Cross</th>
<th>Head Turns/sec. on Road Cross to Centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>2.7</td>
<td>0.71</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>3.0</td>
<td>0.56</td>
</tr>
</tbody>
</table>

No age difference was found in number of head turns. However, rate of head turns per second varied with age ($t_{(188)}=1.65, p<0.01$). Older pedestrians made less head turns per second than younger pedestrians while crossing the road (Table 5.9).

Gap Acceptance and Time-of-arrival Measures
Traffic measures were calculated for 48 younger pedestrians and 40 older pedestrians from the two sites, where oncoming near-side traffic was visible. Calculations were not possible for the remainder of the sample because traffic had either stopped at the lights or railway crossing or there was no visible approaching traffic at the time of first step forward to cross the road.
Table 5.10 Average gap acceptance measures

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>51.33 m</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>69.07 m</td>
</tr>
</tbody>
</table>

Gap acceptance data (Table 5.10) shows that younger pedestrians, on average, accepted significantly shorter gaps than older pedestrians when making their first step forward to cross the road ($t_{(32)}=2.82, p<0.05$), a difference of approximately 17.7m.

Table 5.11: Average time-of-arrival measures

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>9.4 s</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>9.9 s</td>
</tr>
</tbody>
</table>

Table 5.11 shows the average time-of-arrival measures for both groups of pedestrians. While there is little difference between the groups, comparisons of time-of-arrival measures and average crossing times to the centre, showed a difference between younger pedestrians and older pedestrians, where, on average, older pedestrians left less time between reaching the centre of the road and time-of-arrival of the first approaching near-side vehicle than younger pedestrians (4.56s vs 5.61s).

Figure 5.11 Distribution of safe/unsafe road crossings
Crossing Styles

From the distributions of individual crossing times and scoring of far-side traffic after commencement of the road cross, two major groups of crossing styles were classified. These two major groups included “non-interactive crossers” and “interactive crossers”. Non-interactive crossers included people who adopted an extra safe strategy, that is, those who waited until the road was clear in both directions then crossed in a single action, they did not stop in the centre and there was no danger. Interactive crossers included people who adopted a less safe strategy and appeared more willing to cross with closer moving traffic, they were prepared to pause, stop midway, vary their walking speed, and weave inbetween traffic.

Interactive crossers were further classified into three subgroups of interactive styles; that is, those who interacted with the near-side traffic, those who interacted with the far-side traffic and those who interacted with both directions of traffic as they crossed the road. This does not necessarily mean that people adopting either one of the interactive crossing subgroups behaved differently - it may have purely been due to the traffic circumstances at the time of crossing. This aside, based on observed behaviour these subgroups were defined as such:

1. “near-side interactive crossers” - observed to interact with the near-side traffic only. These people crossed less safely in the near-side lanes (based on crossing time in the lower or less safe 50th percentile of Figure 5.12), there were no far-side vehicles passing after commencement of the road cross, they did not stop in the middle or weave inbetween traffic, nor did they change their walking behaviour.

2. “far-side interactive crossers” - observed to interact with the far-side traffic only. They crossed more safely in the near-side lane (again, based on crossing time in the upper or more safe 50th percentile of Figure 5.12), one or more vehicles passed in the far-side lane after commencement of the road cross, they could pause in the centre, or vary their walking speed.

3. “whole-road interactive crossers” - observed to interact with both the near-side and the far-side traffic. They crossed the road less safely in the near-side lane (based on Figure 5.12), one or more vehicles passed in the far-side lane after commencement of the road cross, they could weave their way in and out of the traffic, pause in the centre, or vary their walking speed.

Table 5.13 shows proportions of ‘styles’ of crossing for both groups of pedestrians.

Table 5.13 Categories of crossing ‘styles’ for all subjects

<table>
<thead>
<tr>
<th></th>
<th>Non-Interactive</th>
<th>Near-side Interactive</th>
<th>Far-side Interactive</th>
<th>Whole-road Interactive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>48.75%</td>
<td>20%</td>
<td>20%</td>
<td>11.25%</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>26.45%</td>
<td>17.5%</td>
<td>38.75%</td>
<td>17.5%</td>
</tr>
</tbody>
</table>

While the majority of younger pedestrians did not interact with the traffic (just under half), only 26 percent of older pedestrians crossed the road non-interactively (the most safe crossing
strategy). The majority of older pedestrians interacted with the far-side traffic. Further, more older pedestrians were observed to interact with both directions of traffic than younger pedestrians (this may be conceived as the least safe strategy to adopt).

**Far-side traffic Observations**

In addition to times spent crossing the road, directional looking behaviour, head turns, and gap acceptance/time-of-arrival calculations a number of other behavioural observations related to far-side traffic were made as individuals crossed the road.

First, the time taken for pedestrians to take their first look at the far-side traffic while they were on the road was scored. Table 5.14 shows that older pedestrians took longer to direct their attention to the far-side traffic than younger pedestrians. However, when these times were taken as a proportion of crossing distance it became clear that both groups of subjects inspected the traffic in the far-side lane at approximately the same point in time.

Table 5.14 Average time taken to direct attention to farside traffic while crossing the road

<table>
<thead>
<tr>
<th></th>
<th>Time to First Look</th>
<th>First Look as prop. of crossing distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>0.79 s</td>
<td>20.9%</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>1.23 s</td>
<td>23.1%</td>
</tr>
</tbody>
</table>

Second, the proportion of looking at near-side and far-side traffic as a proportion of total looking in both directions while crossing the road was calculated (Table 5.14).

Table 5.15 Proportion of time spent looking at near- and far-side traffic as a proportion of total looking in both directions while crossing the road

<table>
<thead>
<tr>
<th></th>
<th>Prop. of Time Looking at Near-side Traffic</th>
<th>Prop. of Time Looking at Far-side Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>34.5%</td>
<td>65.4%</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>26.9%</td>
<td>73.1%</td>
</tr>
</tbody>
</table>

Both groups of pedestrians spent more of their time looking at the far-side traffic while crossing the road to the centre. This difference in directional looking was particularly pronounced for older pedestrians.
CHAPTER 6

SECOND OBSERVATIONAL STUDY - ONE-WAY ROADS

Data collected in the first observational study reflected a number of problems older pedestrians may experience in a complex road situation. In particular, apparent difficulties experienced judging the speed and distance of oncoming near-side vehicles by older pedestrians may contribute to a large number of crashes involving older pedestrians. It is possible that these judgements are effected by the complexity of the traffic situation on a two-way road.

The second observational study was conducted to gain a better understanding of how older pedestrians might behave in a less complex environment. The literature suggests that older people perform less well than younger people when the complexity of a task increases (McDowd et al., 1991; McDowd & Craik, 1988; Stelmach & Nahom, 1992). It may be that, for older people, the ability to make appropriate judgements suffers when confronted with multiple sources of information. To investigate these issues further observations in a less complex traffic environment were conducted.

6.1 SITE SELECTION

Data for the second observational study was collected at Bay Street, Port Melbourne. This site was selected on a number of criteria. First, it is a strip shopping centre with an arterial road running through and traffic conditions were such that traffic flow was moderate and vehicle speed was free; second, there is a high population of older people in the area; third, it is a 4-lane divided road with a wide median strip in the middle. Thus, pedestrians, in general, need only be concerned with the near-side traffic to safely cross to the centre of the road and can then pause before negotiating the far-side traffic. Fourth, a ramp construction similar to those found in the sites chosen for the first observational study was present.
6.2 METHOD

Observations were made between 10am and 1pm on weekdays in May, 1995 in fine weather. The observational method used in both the pilot study and the first observational study was again used in this study. Video recordings of individual road crossings of 40 younger adult pedestrians (estimated to be between 30 and 45 years old) and 40 older adult pedestrians (estimated to be aged over 65 years) were made. As in the previous studies, a random selection of participants was used. Pedestrians were filmed if they crossed the road at the chosen site, fitted into either age category, and did not show any apparent illness that may have altered their behaviour significantly. Pedestrians were filmed without their knowledge to overcome possible changes in behaviour in the face of knowing they were being observed.

6.3 RESULTS

Only two phases of the road cross identified in the pilot study were used in this study. On approach to the kerb was omitted because no significant differences were found between the groups of pedestrians. So, for this study scoring of behaviour was only performed as pedestrians waited at the kerb and while they crossed the road to the centre median strip. The same definitions used in the first observational study for these phases were used in this study. Identical behaviours as in the first observational study were scored. Results are presented in the two phases, namely, at the kerb and during the road cross.
6.3.1 At the Kerb

While standing at the kerb a number of behaviours and traffic variables were scored. These included proportions of individuals waiting at the kerb, average time spent waiting at the kerb, traffic volume, directional looking behaviour, number and rate of head turns, kerb delay, and gap acceptance measurements.

_Proportion of Individuals Waiting at the Kerb and Average Time Spent Waiting_

The number of pedestrians who waited at the kerb was scored for each group. Further, the average time spent waiting at the kerb was calculated as well as the traffic flow rate in both near-side and far-side lanes for each group of pedestrians. Table 6.1 presents these figures.

<table>
<thead>
<tr>
<th>Table 6.1 Proportion of pedestrians waiting at the kerb, average time spent waiting, and traffic flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td><strong>Proportion waited</strong></td>
</tr>
<tr>
<td><strong>Average time waiting (for those who waited)</strong></td>
</tr>
<tr>
<td><strong>Traffic flow in near-side lane (cars/sec.)</strong></td>
</tr>
</tbody>
</table>

A greater proportion of older pedestrians waited at the kerb than did younger pedestrians - only two fifths of the younger pedestrians stopped while over half of the older pedestrians stopped at the kerb. Of those who did stop, average times spent waiting at the kerb were longer (but not significantly so) for the older pedestrians than for the younger pedestrians - on average older pedestrians spent close to 3 seconds longer standing at the kerb than the younger pedestrians. Proportions of pedestrians that waited at the kerb and the times spent waiting were lower than in the first study.

Further, traffic flow information suggests that the number of passing cars in the near-side lanes did not vary greatly during the times that the two groups of pedestrians were standing at the kerb. This was slightly higher than in the first study.

_Pro directional Looking Behaviour_

Figure 6.2 shows total looking times in each direction for both age groups.
Figure 6.2  Total time spent looking in each direction while waiting at the kerb

As in the first study, total looking times in each direction enhanced the age differences. Older pedestrians spent greater times than younger pedestrians looking at the near-side traffic, ahead and at the ground.

Figure 6.3 shows looking behaviours as proportion of total time spent while standing at the kerb (only for those pedestrians who waited at the kerb).

Figure 6.3  Direction of looking as proportion of total time spent waiting at the kerb
As in the first observational study, while the patterns of direction of looking were similar for both groups of pedestrians while they waited at the kerb, the main effect of direction was found to be statistically significant ($F(2.38,85.51) = 98.26, p < 0.001$). No interaction effect for age and direction of looking was found. Both groups of pedestrians looked mostly at the near-side traffic and very little time looking towards the far-side traffic, at the ground or ahead ($p < 0.01$).

Distribution of direction of looking was very different from that found in the first study for both groups. A substantially greater amount of time was spent by both groups looking in the direction of the far-side traffic and less time looking towards the near-side traffic in the first study.

Table 6.2 Looking behaviours as proportion of total time spent waiting at the kerb including standard deviations

<table>
<thead>
<tr>
<th>Look Type</th>
<th>Younger Pedestrians</th>
<th>Older Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearside Traffic</td>
<td>66.7% (3.0s)</td>
<td>69.7% (4.2s)</td>
</tr>
<tr>
<td>Farside Traffic</td>
<td>4.8% (0.9s)</td>
<td>2.4% (0.6s)</td>
</tr>
<tr>
<td>Ahead</td>
<td>13.8% (1.6s)</td>
<td>17.7% (2.0s)</td>
</tr>
<tr>
<td>Ground</td>
<td>0.2% (0.1s)</td>
<td>7.0% (1.0s)</td>
</tr>
<tr>
<td>Other</td>
<td>14.6% (2.2s)</td>
<td>3.2% (0.7s)</td>
</tr>
</tbody>
</table>

Standard deviations showed few differences between the two groups of pedestrians for all looking behaviours (Table 6.2). Older pedestrians showed more variability than the younger group while looking towards the near-side traffic and at the ground, while the younger group showed more variability while looking at other things.

**Head/body Movements**

The number of head/body movements while standing at the kerb was scored for each pedestrian and average number of head turns per second was calculated.

Table 6.3 Average number of head/body movements and rate of head turns per second while waiting at the kerb

<table>
<thead>
<tr>
<th>Look Type</th>
<th>Number of Head Turns At Kerb</th>
<th>Head Turns/sec. while At Kerb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>1.7</td>
<td>0.30</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>2.5</td>
<td>0.29</td>
</tr>
</tbody>
</table>
As in the first study no significant difference was found in number of head turns while standing at the kerb between groups of pedestrians. Further, rate of head turns were not statistically different between younger and older pedestrians ($t_{36}=0.02, p=0.5$).

**Kerb Delay**
Kerb delay was calculated from the average time taken between the time the back of the last vehicle passed a waiting pedestrian to when they took their first step forward to cross the road (Table 6.4).

**Table 6.4 Average Kerb Delay**

<table>
<thead>
<tr>
<th></th>
<th>Younger Pedestrians</th>
<th>Older Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.11 s</td>
<td>-0.10 s</td>
</tr>
</tbody>
</table>

No significant group differences were found in kerb delay ($t_{36}=0.32, p=0.37$). On average, both groups of pedestrians made their first step forward to cross the road immediately before the rear of the last vehicle passed. This result does not concur with the findings from the first study.

6.3.2 Road Cross
Behaviours were scored as pedestrians crossed the road to the centre median strip only. Time taken to cross to the centre of the road and the whole road, walking speeds, looking behaviour, gap acceptance judgements, and crossing styles were examined.

**Time Taken to Cross the Road and Walking Speed.**
Older pedestrians took significantly more time to cross to the centre of the road than young pedestrians ($t_{66}=6.7, p<0.001$). Calculations of walking speed to the centre of the road reflected slowing in older pedestrians (Table 6.5). On average, younger pedestrians walked 0.51m further per second than older pedestrians.

**Table 6.5 Average total times taken to cross the road and walking speeds (to centre of road)**

<table>
<thead>
<tr>
<th></th>
<th>Time To Cross To Middle</th>
<th>Walking Speed - To Middle (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>5.08 s</td>
<td>1.77</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>7.16 s</td>
<td>1.26</td>
</tr>
</tbody>
</table>

Compared to the first study, subjects took longer to cross to the centre of the road (due to differences in width of roads), and subjects walked faster to the centre median strip.
**Directional Looking Behaviour**

All looking behaviours were scored for crossing the centre of the road only. Figure 6.4 shows total looking times in each direction for both age groups.

![Figure 6.4 Total time spent in looking in each direction while crossing the road (to centre)](chart)

While both groups spent a similar amount of time looking in the direction of near-side and far-side traffic, older pedestrians spent a greater amount of time than younger pedestrians looking ahead and at the ground as they crossed the road.
Figure 6.5  Direction of looking as proportion of total time spent crossing the road (to centre)

Figure 6.5 shows direction of looking as proportions of total time spent crossing the road. A significant difference was found in the distribution of looking directions ($F(2.59,202.40)=91.41, p<0.001$). Further, there was a significant interaction for age by direction of looking ($F(2.59,202.40)=4.13, p<0.001$).

In this phase of the task the proportion of time spent looking ahead was significantly higher than looking in any other direction ($p<0.01$). Subjects were also found to spend around 20% of their time looking towards the near-side traffic which was more than they spent looking at the far-side traffic ($p<0.01$).

The simple effects ANOVA revealed significant effects of direction for both younger pedestrians ($F(2.59,202.40)=47.06, p<0.001$), and for older pedestrians ($F(2.59,202.40)=48.49, p<0.001$). The older group spent a significantly greater amount of time looking towards the ground than the younger pedestrians ($F(1,78)=8.46, p<0.001$) while crossing the road.

In the first study subjects spent substantially more time looking in the direction of the far-side traffic that they did in this study.
Table 6.6  Direction of looking as proportion of total time spent crossing the road (to centre), including standard deviations

<table>
<thead>
<tr>
<th></th>
<th>Younger Pedestrians</th>
<th>Older Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearside Traffic</td>
<td>23.4% (0.9s)</td>
<td>16.1% (0.7s)</td>
</tr>
<tr>
<td>Farside Traffic</td>
<td>12.7% (0.7s)</td>
<td>7.8% (0.6s)</td>
</tr>
<tr>
<td>Ahead</td>
<td>49.6% (1.0s)</td>
<td>51.0% (3.4s)</td>
</tr>
<tr>
<td>Ground</td>
<td>12.1% (0.9s)</td>
<td>24.5% (1.7s)</td>
</tr>
<tr>
<td>Other</td>
<td>2.2% (0.3s)</td>
<td>0.6% (0.3s)</td>
</tr>
</tbody>
</table>

Few differences, again, were found between groups for standard deviation calculations. The older group showed more variability than the younger group while looking ahead and at the ground. All other looking behaviours showed similar variability in each group of pedestrians (Table 6.6).

Head/body Movements

The number of head/body movements was recorded for each pedestrian as they crossed the road (to the centre). Rate of head turns per second was then calculated based on the average time taken for each group of pedestrian to cross the road to the centre (Table 6.7).

Table 6.7  Average number of head/body movements and rate of head turns per second while crossing the road (to centre)

<table>
<thead>
<tr>
<th></th>
<th>Number of Head Turns on Road Cross</th>
<th>Head Turns/sec. on Road Cross to Centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
<td>2.8</td>
<td>0.54</td>
</tr>
<tr>
<td>Older Pedestrians</td>
<td>2.6</td>
<td>0.36</td>
</tr>
</tbody>
</table>

No significant differences were found between groups in the number and rate of head turns made during the road cross to the centre ($t_{78}=1.59, p=0.06$). This is contrary to that found in the first study, where younger pedestrians made more head turns per second than older pedestrians while crossing the road.
**Gap Acceptance and Time-of-arrival Measures**

Traffic measures were calculated for 33 younger pedestrians and 31 older pedestrians, where oncoming near-side traffic was visible. Calculations were not possible for the remainder of the sample because traffic had either stopped at the lights or there was no visible approaching traffic at the time of first step forward to cross the road.

<table>
<thead>
<tr>
<th>Table 6.8 Average gap acceptance measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
</tr>
<tr>
<td>Older Pedestrians</td>
</tr>
</tbody>
</table>

Gap acceptance data (Table 6.8) shows that younger pedestrians, on average, accepted shorter gaps than older pedestrians when making their first step forward to cross the road, a difference of approximately 14.9m. This difference, although of similar magnitude to that of the first study, was not significant ($t_{(59)}=1.47, p=0.07$).

<table>
<thead>
<tr>
<th>Table 6.9 Average time-of-arrival measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Pedestrians</td>
</tr>
<tr>
<td>Older Pedestrians</td>
</tr>
</tbody>
</table>

Table 6.9 shows the average time-of-arrival measures for both groups of pedestrians. A significant difference ($t_{(56)}=1.54, p=.05$) between the groups were found, where, on average, vehicles reached the crossing point in less time for younger pedestrians than for older pedestrians. Comparisons of time-of-arrival and individual crossing times (see Table 6.5) showed that, on average, older pedestrians left a little less time between reaching the middle of the road and time of arrival of the first approaching near-side vehicle than younger pedestrians (3.9s vs 4.7s).
Figure 6.6  Distribution of safe/unsafe road crossings

Figure 6.6 shows data points for individual pedestrians for which near-side traffic measures were calculated. Table 6.10 shows the proportions of pedestrians who engaged in near-side unsafe road crossings.

Table 6.10 Proportion of safe/unsafe road crossings

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Older Pedestrians</th>
<th>Younger Pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoption of safe</td>
<td>76.6%</td>
<td>67.7%</td>
<td>84.8%</td>
</tr>
<tr>
<td>strategy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption of unsafe</td>
<td>23.4%</td>
<td>32.3%</td>
<td>15.2%</td>
</tr>
<tr>
<td>strategy</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall, the majority of pedestrians (over 76%) adopted a near-side safe strategy, while only 23% crossed the near-side of the road unsafely. As in the first study, more younger pedestrians adopted a near-side safe strategy than older pedestrians (85% versus 68%), while more older pedestrians adopted a near-side unsafe strategy than younger pedestrians. In comparison with the first observational study, proportions of crossing strategies were similar for both older and younger adults in each environment.

Further, differences were found in distributions of individual crossing times by time-of-arrival between the two groups of pedestrians (Figure 6.7).
As in the first observational study, while the majority of pedestrians adopted a safe crossing strategy in relation to near-side traffic, differences in the distributions of individual crossing times by time-of-arrival of the nearest oncoming vehicle were apparent between the two groups of pedestrians, although these differences were not as pronounced.

Younger pedestrians generally made a narrower band of decisions about when to cross the road in relation to oncoming near-side traffic, while the younger pedestrians made a broader band of decisions.

The line of best fit of the distribution for younger pedestrians is parallel to the minimum safe time to cross indicating that both fast and slow walkers were sensitive to the time-of-arrival of the nearest vehicle.
In this environment the line of best fit of the distribution for older pedestrians diverged slightly from the minimum safe time to cross, suggesting that older pedestrians might be more sensitive to time-of-arrival of the nearest vehicle in this less complex environment than in the environment of the first study.

**Crossing Styles**

Due to the experimental definitions of classification for crossing styles, these were not included in this study. Only two groups of crossing styles could be classified, namely “non-interactive crossings” and “near-side interactive crossings”. Definitions used in the first observational study (see Section 5.3.3) were based on crossing times in both the upper and lower 50th percentiles of Figure 5.12. Classification of crossing styles in this study would show roughly 50 percent in each group.
CHAPTER 7

GENERAL DISCUSSION AND CONCLUSIONS

The purpose of this study was to investigate the road-crossing behaviour of both old and young adult pedestrians to determine whether older pedestrian behaviour differs in significant ways from that of younger pedestrians leaving them more vulnerable to accidents. The study also aimed to identify target groups and road situations for intervention and recommend countermeasures designed to reduce the frequency and severity of older pedestrian accidents.

This chapter attempts to summarise the analysis of accidents at “black-spot” sites as well as to discuss the findings of both observational studies in relation to age-related sensory, perceptual, cognitive and motor changes identified in the literature. Further, a number of recommendations for intervention are made designed to reduce the frequency and/or severity of injury. Suggestions for further research are also included.

7.1 DISCUSSION OF ACCIDENTS AT “BLACK-SPOT” SITES

The majority of all-age accidents occurred as pedestrians stepped off the kerb into the path of an oncoming near-side vehicle. Further, pedestrians were often hit as they stepped out from between parked cars. Fildes et al (1995) found that older pedestrians were more often involved in near-side crashes than younger pedestrians, however, the present results do not show any difference between age groups. Moreover, while Fildes et al. (1995) reported that “emerging” crashes (as pedestrians stepped out from between cars) accounted for only 11% of all-age pedestrian crashes and only 7% of older pedestrian crashes, the present study found a large number of “emerging” accidents. These results may be a function of the sites chosen for investigation. Each of the chosen sites had facilities for street parking for almost the entire length of the shopping centre. Many of the pedestrians crossing mid-block at these sites would necessarily need to walk out from parked cars to cross.

A large proportion of accidents also occurred in the far-side lane, however, older pedestrians were more often involved in crashes in the far-side lane than younger pedestrians. These patterns of pedestrian movements have been previously noted by the Federal Office of Road Safety (1986) and Fildes et al. (1995). The finding that a large proportion of older pedestrians adopted interactive styles of crossing might help to explain the over-involvement in crashes in the far-side lane. It might also reflect the fact that older people experience difficulty in assessing two way traffic. Carthy et al. (1995) reported that older pedestrians make judgements on the near-side traffic and commence to cross without consideration of the far-side traffic and often find themselves in a potentially dangerous situation in the centre of the road. This was investigated further in the observational studies carried out on the road itself.

7.2 DISCUSSION OF FIRST OBSERVATIONAL STUDY - TWO-WAY ROADS

The results from the first observational study highlight a number of important differences between older and younger pedestrians behaviour as they cross two-lane road. These included times spent waiting at the kerb and crossing the road, where they directed their looking, time taken to leave the kerb (kerb delay), gap acceptance judgements as they stepped off the kerb, and strategies adopted to cross the road in a safe manner. These behaviours will be discussed separately.
7.2.1 Times Spent in Completing the Road-Crossing Task

Older people spent significantly more time completing the road crossing task than did younger pedestrians. This was so while they waited at the kerb as well as in crossing the road itself. In addition, a greater proportion of older people paused at the kerb before actually crossing the road. As the risk of being involved in an accident is a function of the time exposed, these findings suggest that older pedestrians are likely to be more vulnerable than their younger counterparts.

The time at the kerb findings may be interpreted in several ways. First, they might reflect greater difficulty older people experience assessing traffic situations or making decisions, especially when time is limited due to the speed and business of the traffic. This has been previously proposed by Botwinick et al (1959) and Staplin and Lyles (1991) in their assessment of older people's decision making abilities, although their trials involved only elderly drivers. It might also be, as was argued by Stelmach and Nahom (1992), that they have increased difficulty in judging distances or processing visual information in these environments. Moreover, it could be that older pedestrians are simply more cautious or hesitant before setting out to cross the roadway.

Slower walking speeds of older people during the road cross can be explained by general slowing of behaviour with increasing age, noted in the literature. Impaired mobility has been previously related to injury risk. For the older pedestrian, postural control and changes in gait patterns may contribute to their slower walking speed (Kallman & Kallmann, 1989; Lord et al., 1990). Further, if older pedestrians find themselves in a risky situation (i.e. with fast approaching traffic while they are on the road) their impaired coordination and reaction abilities may restrict them from getting out of the way of oncoming cars quickly.

In addition, older pedestrians took longer to leave the kerb after the rear of the last near-side vehicle passed the line of crossing. It may be, as argued by Lee, Young & McLaughlin (1984), that older adults adopt a less time efficient crossing strategy than younger adults by waiting for the last vehicle to pass before commencing the road cross. This may be because of reduced reaction times, slower decision making capacity, and/or slower motor coordination, or simply greater confusion (uncertainty) on the part of the elderly.

7.2.2 Directional Looking Behaviour

Large differences in looking time were found while waiting at the kerb and during the road cross. Proportional data, however, revealed no significant differences in the direction of looking between age groups while they waited at the kerb. Group differences were found on the approach to the kerb and during the road cross, where older pedestrians spent proportionately more time than younger pedestrians looking towards the ground. This may be the result of age-related gait and balance declines and general uneasiness in walking and stepping off kerbs.

The proportional results at the kerb suggest that older subjects in this study behaved similarly to younger subjects. Both groups looked mainly at the near-side traffic and less at the far-side traffic prior to the road cross. While crossing the road, both groups of pedestrians spent a large proportion of their time looking ahead. This could be because they focussed their attention on the main goal to get to the other side of the road. Decisions of safety have presumably been made as pedestrians stepped off the kerb, and looking in the direction of traffic (particularly to near-side traffic) was conducted to check and re-check their safety.
Differences in looking behaviour while crossing the road, however, might seem to suggest that older pedestrians may not adopt the most efficient sampling strategy when attempting to cross the road. This would support Sanford and Maule’s (1980) contention that older adults experience difficulties in allocating their attention to the most appropriate source of information. Others (Rabbitt, 1982; Korteling, 1994) further argue that older people might experience a reduced ability to prioritise the appropriateness of multiple sources of information and have a reduced capacity to shift attentional emphasis accordingly. These findings, however, have not been applied to a road setting. Moreover, other studies suggest that older adults experience difficulties in actively selecting or dividing their attention between sources of information in order to make appropriate judgements (McDowd & Craik, 1977; Triggs, Fildes & Koca, 1994). The results from the present study support previous arguments.

Many crashes involving the elderly have been attributed to a neglect of, or inattentiveness to, relevant information from the road environment and from other traffic participants (McFarland, Tune & Welford, 1964; Planek & Fowler, 1971). For the older pedestrian, then, actively assessing a complex traffic situation and having to divide attention and select the most appropriate source of information might be very difficult, leaving them at higher risk of being involved in an accident.

7.2.3 Gap Acceptance and Time-of-arrival Judgements

While older pedestrians accepted longer gaps in the traffic than younger pedestrians, when combining time-of-arrival estimates with average walking speed, however, older adults were seen to behave in a less safe manner. In particular, they left less time between reaching the centre of the road and the time-of-arrival of the first oncoming vehicle.

These results might be explained by difficulty experienced judging whether gaps in the traffic are long enough to cross the road with safety. Indeed, this supports past research which showed that age differences in motion perception in critical traffic situations is an important factor in older road users’ over-involvement in accidents (Staplin & Lyles, 1991; Carthy et al., 1995). Further, the result support other studies which argue that older adults place themselves in greater danger when participating in the traffic as a result of wrongly estimating speed and distance of moving vehicles (Scialfa et al., 1991).

It might also be that older people do not compensate appropriately for their slower walking speeds. Lee, Young and McLaughlin (1984) claimed that perceiving the affordance of a gap entails combining information about the environment with information about one’s walking speed. Older adults may experience difficulty in accommodating their judgements of gaps in the traffic to slowed walking speeds.

The fact that older pedestrians may not appropriately judge the nearness of a vehicle when stepping off the kerb may account for the fact that older pedestrians are involved in a greater number of near-side crashes than younger pedestrians (Fildes et al., 1994), and the finding that more older pedestrians adopted a near-side unsafe strategy than younger pedestrians.

Motion perception ability is essential in a road situation and the ability to correctly predict the movement of a vehicle is fundamental for safe road crossing. Gap acceptance and time-of-arrival judgements involve making decisions based on motion perception skills. For pedestrians, the affordance of a gap is vital - information about the moving traffic must be combined with stored information about one’s own walking speed. Further research to clarify this ability in older pedestrians is warranted.
7.2.4 Crossing Styles/Strategies

Crossing styles were classified into two major groups of “non-interactive” and “interactive” crossers. Interactive crossers were further classified into three subgroups of “near-side interactives”, “far-side interactives”, and “whole-road interactives”. Older people were disproportionately represented in the more potentially unsafe crossing groups (e.g., far-side and whole-road interactives).

The majority of both older and younger pedestrians crossed the road in a conservative manner (i.e., with no near-side or far-side traffic close by). A greater proportion of older adults, however, crossed the road more dangerously than younger pedestrians by interacting with the far-side traffic. Further, more older pedestrians were observed to interact with both directions of traffic than younger pedestrians (conceived as the most dangerous and least safe strategy to adopt).

It might be that in a complex environment of two-way traffic, older adults experience problems in assessing both directions of traffic simultaneously and making decisions based on both sources of information. As noted above, older pedestrians appear to cross the first half of the road without considering the second half of the cross. Some older pedestrians put themselves in an extremely dangerous situation of being caught in the middle of the road with little time to take evasive action. Carthy et al. (1995) found similar patterns of crossing behaviour in their recent study of older pedestrian safety in the UK.

The adoption of unsafe crossing strategies may further explain the finding that older pedestrians are involved in a greater number of far-side crashes than younger pedestrians (Fildes et al., 1994).

7.3 DISCUSSION OF SECOND OBSERVATIONAL STUDY - ONE-WAY ROADS

Although older pedestrians adopted more cautious behaviour than younger pedestrians before they commenced the road cross, these compensatory behaviours may not necessarily be safe. The time-of-arrival estimates by crossing times, as well as crossing strategy results, seem to suggest that older people do experience problems when crossing the road in complex traffic situations or environments, compared to their younger counterparts.

The second observational study, then, was conducted in order to see whether older pedestrian behaviour was different (more safe) in a less complex situation. Particular interest was in their ability to judge suitable gaps in the traffic in which to cross the road safely in these less complex traffic environments. In other words, was the often inappropriate or unsafe behaviour observed in the first study because of the complexity of the task or because they could not make these judgements? As in the first observational study a number of differences were found between the road crossing behaviour of younger and older adult pedestrians.

7.3.1 Times Spent in Completing the Road-crossing Task

Time spent waiting at the kerb was less for both groups of pedestrians than in the first study, and especially so for the older group. While older pedestrians again spent, on average, longer waiting times at the kerb than the younger pedestrians, the differences were not as large as in the first study. Further, while the proportion of people who did stop at the kerb was less for both groups of pedestrians than in the previous study, a greater proportion of more older people waited at the kerb once more.
Older pedestrians again walked slower than younger pedestrians in this study. While both groups took longer to cross to the centre due to differences in road width in this study, both groups walked faster to the centre of the road than in the first study. This could be due to the lack of far-side traffic. In the previous two-way environment, pedestrians could vary their walking speed, pause in the centre, weave in traffic, etc. Presumably, when the road is divided pedestrians need only be concerned with the near-side traffic. They can then base their judgements solely on the near-side traffic, reducing the need to vary (slow) walking speed to adjust for far-side traffic.

No differences in kerb delay were found in this study, suggesting that in a less complex environment older pedestrians experience less difficulty in decision making and assessing the traffic.

7.3.2 Directional Looking Behaviour

As in the first study, there were large differences in total time spent looking because of differences in looking exposure. Distributions of direction of looking for both groups, however, were notably different from the first observational study, particularly for looking in the direction of near-side and far-side traffic. As in the first study, both groups of pedestrians spent most of their time looking towards the near-side traffic while waiting at the kerb, however, in this study both groups spent a much greater proportion of their time looking in the direction of the near-side traffic. Little time was spent looking in the direction of far-side traffic for both pedestrians, presumably because the road was divided and pedestrians could cross to the centre without needing to take far-side traffic into consideration.

During the road cross, too, distributions of direction of looking were different from the main study. Both groups of pedestrians spent the majority of their time looking ahead, and relatively little time looking at the traffic. Little time, also, was spent looking towards the far-side traffic. Older pedestrians spent less time looking towards either direction of traffic and more time looking at the ground than did the younger pedestrians. Presumably they were able to give more attention to not tripping because of lower attentional demands.

7.3.3 Gap Acceptance and Time-of-arrival Judgements

Average gaps accepted were longer for both groups of pedestrians than in the first observational study, presumably because of differences in road width and number of lanes. However, younger pedestrians still accepted shorter gaps than older pedestrians when making their first step forward to cross the road.

Figure 7.1 shows the distribution of crossing times by time-of-arrival estimates for both studies and reveals some interesting trends.

On the two-way road (more complex environment), younger pedestrians, especially the slower younger walkers, tended to over-compensate (top left figure) while slower older adults under-compensated (bottom left figure). This was apparent by the lines of best fit of the scatter diagram diverging and converging to the theoretically safe outcome.

On one-way road, though, (less complex environments), the lines of best fit for both young and older pedestrians (top and bottom right hand figures) are quite similar and almost parallel with the theoretical safe line.
In short, older pedestrians acted much more like younger ones and were able to make more safe judgements generally in less complex crossing situations. They were "better calibrated" in these more simpler settings.

The few instances where individuals were below the theoretical safe line are potentially very interesting as they could represent those at most risk of a collision. As there were no crashes observed, it can be assumed that the drivers of the approaching vehicles took some avoidance action to prevent a collision.

![Two-way road and One-way road diagrams]

**Figure 7.1 Distribution of individual crossing times by time-of-arrival estimates - one-way and two-way roads**

### 7.4 PERCEPTUAL AND COGNITIVE ISSUES

The elderly are often thought to precipitate their own accidents because they behave incompetently or irresponsibly when crossing the road. Efficient pedestrian participation in traffic requires a combination of well developed skills, which allow the individual to assess complex traffic situations, and to choose and execute appropriate responses. Despite the vitality of many older persons, the effects of age-related deficits predict that the ability to perform these complex tasks becomes more difficult (van Wolffelaar et al., 1991).

Findings from this study give supporting evidence that older people are slower than younger pedestrians when crossing roads. In general, older pedestrians experience deficits not only in their physical abilities but also in their information processing and decision making capacities. Older pedestrians may perceive and process information and execute actions slower than younger pedestrians. This strongly suggests that perceptual and cognitive deficits associated with the ageing process contribute to many of the crashes in which older pedestrians are involved in.
Initial observations in the pilot phase noted general uneasiness, hesitancy, appearance to be able to concentrate on only a few things at one time and faltering among older pedestrians. Younger pedestrians, on the other hand, generally appeared to execute smooth, fast actions when crossing the road, and appeared to take in information about the traffic environment with ease.

Waiting at the kerb, standing further back, seemingly concentrating on traffic, and generally displaying greater caution are more common among older pedestrians than younger pedestrians. While these behaviours indicate greater caution in road crossing behaviour, the results from this research confirm that these behaviours may not necessarily result in greater safety. Indeed, instead of adopting a more conservative or hesitant type of crossing, by waiting for both directions of traffic to clear and cross the road in one action, the crossing time and time-of-arrival results showed that older pedestrians behave in a more unsafe manner than younger pedestrians once they have made the decision to cross the road. Older pedestrians leave less time between the time they take to cross to the centre and time-of-arrival at the crossing path of near-side oncoming vehicles, thus under-compensating for their slower walking speed.

Past studies postulate that some road accidents among older adults may be related to difficulties in judging the speed of vehicles (Scialfa et al., 1991; Sheppard & Pattinson, 1986). The results of these studies appear to support this contention - older adults place themselves in greater danger when crossing the road as a result of wrongly estimating speed and distance of moving vehicles, under-compensating for slower walking speed, and/or a general insensitivity to time of arrival estimates which may be compounded by attention and mobility difficulties.

This is particularly the case in complex traffic situations. A combination of a complex traffic environment, fast speeds, and declining abilities to make appropriate judgements along with a failure to accommodate or modify behaviour quickly to avoid a potentially dangerous situation are several interacting sources of threat to the older pedestrian.

It seems that the most critical processes affecting safety for older pedestrians include deficits in a number of areas. These are discussed below.

7.4.1 Ability to make appropriate gap acceptance and time-of-arrival judgements

Veridical motion perception is essential in a road situation and the ability to correctly predict the movement of a vehicle is fundamental for safe road crossing. Data obtained from the observational studies suggest that older adults experience difficulties in judging both the speed and distance of vehicles, and this is consistent with past research (Wounters & Welleman, 1988; Scialfa et al., 1991; Carthy et al., 1995).

7.4.2 Ability to react quickly

Diminished motor skills may leave the older pedestrian more at risk of an accident because they are less able to react quickly and take evasive action in a dangerous situation. The results demonstrate that age-related slowing may affect safe road crossing. Older pedestrians take longer to execute actions, leaving them exposed for longer times to dangerous situations.

Motor control is of prime importance when faced with traffic emergencies where actions must be executed quickly. Increased reaction time means that the older pedestrian has a shorter
interval than a younger pedestrian in which to respond to a stimulus, and to correct a misguided action - a slowed reaction time may be vital in determining the outcome.

7.4.3 Ability to focus attention on important sources of information

Appropriate looking behaviour is essential to enable older pedestrians to make judgements about safe gaps in traffic for crossing the road, taking their slower walking speeds into account. Older pedestrians spent much longer assessing the traffic. While the proportional data of directional looking behaviour showed few age differences, older pedestrians spent much longer looking at sources of information. It may be that older pedestrians are impaired because, compared to younger adults, they take in less information and have less of the relevant information available to process and integrate to reach a decision.

In a traffic situation it is important to attend selectively to information about oncoming vehicles and potential hazards. While not related to the road setting, previous studies have found that older adults are less able to perform attentional selection tasks as well as tasks requiring the division of attention. This is possibly due to difficulties in appropriately allocating attentional resources to the most important stimuli (Maule & Sanford, 1980) as well as difficulty in ignoring irrelevant stimuli (Madden, Connelly & Pierce, 1994).

Numerous investigators have proposed that age-related differences in performance might be explained in terms of working memory (Welford, 1958; Salthouse, 1990). For pedestrians, a crucial component of safe traffic participation is monitoring changes in the traffic situation and a regularly updating memory system for each of the sources of information is essential. The elderly pedestrian, then, may be impaired because, compared to younger adults, they have a reduced ability to retain information in memory while simultaneously processing the same or other information thus having less of the relevant information available when it must be integrated or evaluated to reach a decision.

7.4.4 Ability to process information efficiently in complex environments

The complexity of many traffic situations demand quick and accurate judgements and decision may place overwhelming demands on cognitive processes of elderly pedestrians resulting in higher risk of accidents than for younger pedestrians. Behavioural differences found between the two environments of these studies show that the older pedestrians experience difficulties in complex traffic resulting in unsafe road crossing. In the less complex environment older pedestrians road crossing behaviour was more safe and more like that of younger adults.

Many studies have suggested that older adults are particularly impaired relative to younger adults in complex situations (Fildes et al., 1994; Sheppard & Pattinson, 1986). In Sheppard and Pattinson's (1986) interview study many of the older pedestrians said that the accident had occurred at a complex place to cross and that they were confused.

7.5 IMPLICATIONS FOR COUNTERMEASURES

The findings from these two studies point to a number of specific behavioural differences or problems that older people experience when crossing the road.

- Older people took twice as long to assess the traffic and to cross the road than younger adults
They spent more time looking at the ground when approaching the kerb and when crossing the road than younger pedestrians

While they spent more time deciding when to cross, older pedestrians often found themselves caught out in the traffic and less able to cope

They were more likely to become confused crossing the road in complex traffic situations where decisions involve the integration of many source of information

They were slower to react to approaching traffic

Slower older pedestrians were particularly at risk and seemed more confused than the more fit elderly pedestrians

They did not compensate adequately for their slower walking speeds

They failed to check and re-check traffic once they had commenced the road cross

They were more likely to interact with traffic once they had commenced the road cross

In less complex traffic environments, their road crossing behaviour was more safe and more like that of younger adults.

These findings have implications for behavioural countermeasures aimed at improving the safety of older pedestrians. Suggested countermeasures are listed below under the headings of publicity, training packages, enforcement and traffic engineering. While they are discussed separately, it may be noted that countermeasures are likely to be most effective when linked appropriately and implemented in an integrated way.

7.5.1 Publicity

It has been argued that behavioural factors play an increasing larger role in traffic safety and that intervention programs are desperately needed to change behaviour by increasing awareness of pedestrian safety issues. These findings confirm the need for awareness campaigns to encourage older pedestrians to be aware of safe road crossing practices as well as difficulties they may face when crossing the road. Further, driver and other road user awareness of the right of pedestrians to a share of the traffic environment should be stressed also.

These results point to the need to give older pedestrians specific information on dangers and how to avoid them such as where to cross the road, who has right of way, and safe walking practices. Messages emerging from this study that might be given to older pedestrians in future publicity campaigns include:

i) the need to cross at signalised pedestrian crossings wherever possible and not mid-block,

ii) avoid crossing in complex environments such as shopping centres as these locations pose particular dangers for them,

vi) if unable to avoid crossing in these complex situations, then adopt a more conservative strategy in crossing roads, that is, wait until traffic has cleared in both directions before crossing,
vii) plan trips in advance to reduce the number of roads crossed,

iv) increased awareness of current road laws would be beneficial,

v) be consistently aware that age-related changes may put them at higher risk of an accident.

7.5.2 Training Packages

Although some behaviour training programs have been implemented, many believe they have limited success, particularly in the case of elderly people (FORS, 1987). Behaviour intervention programs specifically designed for older people may encounter difficulties, especially in getting older people to respond to educational campaigns to improve their safety. It is difficult with habits developed over many years to change that behaviour. Older people may be resistant to change, insisting that they have been performing tasks as crossing the road for many years and may believe there is no need to learn new strategies (Carthy et al., 1995).

Despite these difficulties, findings from past studies have indicated that with practice the performance of older adults can be improved considerably (Triggs, Fildes & Koca, 1994; Fisk & Rogers, 1991). Specialised training programs aimed at learning and practising the appropriate skills needed for safe road participation may have potential for reducing age-related pedestrian accidents.

The “Walk With Care” program for the elderly has been implemented by VicRoads for a number of years in Victoria. This is an elderly pedestrian education and advocacy program established in conjunction with local government, local agencies and community groups. While the program promotes safe walking practices and modification of the environment to increase the safety behaviour of elderly pedestrians the issues it has targeted have not been specific. Further, no evaluation of the program has been completed. A rigorous program could address more specific behavioural issues shown to pose particular dangers for older people raised in this study.

For instance, improved training and education programs for the elderly might focus on judging speed and distance of approaching vehicles, making appropriate decisions in complex environments, attending to relevant sources of information, and crossing the road as one task and not in two stages. Effective looking strategies might also be included although more work is still required to identify critical sensory inputs associated with crossing the road.

7.5.3 Enforcement

Enforcement can be an effective way to reduce the frequency and severity of pedestrian crashes. While there are currently few laws aimed at pedestrian safety, there are legal and enforcement opportunities that could be considered. These include reduction of speeds in high pedestrian areas, enforcement of not crossing near signalised crossings, and restrictions on street parking in strip shopping centres. Further, older pedestrians (and drivers, too) need to be made aware of road laws that affect them while on the road.

• Reduction of speeds in high pedestrian areas

The creation of a slow speed environment would enhance both pedestrian safety and reduce the severity of injury if an accident does occur. Slowed traffic would assist older people in coping better with traffic environments (particularly complex ones), giving them more time to process information about the traffic and make appropriate and safe decisions. McLean,
Anderson, Farmer, Lee & Brooks (1994) estimated the likely effect of reduced travel speeds on the incidence of fatal pedestrian collisions. They argued that a reduction of speed limit from 60km/h to 50km/h can result in a large decrease in impact speed, reductions in the number of collisions, and reduced risk of fatal injury.

Reduction of speeds in high pedestrian areas (especially those heavily frequented by older people) could be achieved through setting and enforcing local speed limits, that is, reduce speed limits from 60km/h to 40km/h or 50km/h in strip shopping centres. Further speed reduction in these environments can be achieved by the introduction of speed humps, narrowing of the road, and introduction of a coordinated traffic control system.

- **Enforcement of crossing in appropriate places**

Crossing at mid-block areas poses problems for the older pedestrian. While pedestrians should be encouraged to cross at signalised pedestrian crossings, enforcement may improve safety if it is directed at pedestrians crossing near but not at signalised crossings. Currently, the law states that pedestrians should not cross the road under 20 metres from a signalised crossing. Perhaps there may be scope for innovative laws preventing mid-block road crossing in strip shopping centres in association with more frequent formal crossings.

- **Awareness of current road laws**

For laws to be enforced successfully, road users need to be aware of current laws. A recent study, however, reported that few older pedestrians (and drivers) were aware of road laws and the rights of pedestrians on roads (Fildes et al., 1994).

- **Reduced or restricted roadside parallel parking**

The design of parking areas in shopping areas, particularly at strip shopping centres, often has little regard for access by pedestrians. Parallel parking poses particular problems for pedestrians who must often weave their way past cars and step out from between parked cars to assess the traffic. The summary of accident histories at strip shopping centres found that a large proportion of accidents to both younger and older pedestrians happened as pedestrians stepped out from between parked cars, and all of these sites had parallel parking. Provision of off-street parking at shopping centres along with restrictions on street parking would be beneficial to pedestrians for clearer visibility and to reduce traffic complexity and dangers associated with reversing cars.

7.5.4 Traffic Engineering

Traffic engineering countermeasures have been very popular and successful in the last few decades and many countermeasures aimed at pedestrian safety have previously been suggested and implemented. Perhaps a continued emphasis on providing traffic engineering countermeasures in areas where there is a high population of elderly pedestrians should be stressed.

- **Provision of median refuges and kerb extensions**

The walking speeds of older pedestrians are, on average, slower than younger pedestrians leaving them more exposed to potential dangerous situations. The time during which a pedestrian is exposed to traffic when crossing the road would be greatly reduced by the use of kerb extensions and pedestrian refuges in the centre of the road.
The second study clearly showed that older pedestrians perform better in a less complex environment, where they can cross the road in two stages. The importance of medians in providing a refuge on which pedestrians could pause whilst crossing has been noted in past studies (Federal Office of Road Safety, 1987; Safety for Seniors Working Group, 1986). Provision of a median refuge would provide a relatively safe place between the two directions of traffic so that crossing decisions would be less difficult for the older pedestrian.

Provision of kerb extensions means that problems associated with weaving from between parked cars would be reduced, and that waiting pedestrians are more clearly visible to drivers. Pedestrians could stand and assess the traffic with a clear view not obstructed by parked cars. Indeed, observations for the pilot study were made in an environment without kerb extensions and pedestrians were observed to lean or step out from between cars to assess the traffic. Observations for these studies were made at sites where kerb extensions were constructed. They made the task of assessing the traffic a much easier task which posed less danger for pedestrians.

- ** Provision of pedestrian crossings

Older adults should be encouraged to cross at recognised and controlled crossings. Provision of an increased number of formal crossings positioned such that people do not need to walk far to the crossing in busy strip shopping centres that are frequented by older people is desirable. Further, crossing phases should take slower walking speeds of older pedestrians and be of sufficient duration to allow safe crossings. This has been called for in past studies (Safety for Seniors Working Group, 1986; Federal Office of Road Safety, 1987; Fildes et al., 1994). Raised crossings may act as speed humps with additional safety benefits.

- ** Provision of barrier fencing

Fildes et al., (1994) found that while the majority of older road users had a greater tendency to cross at formal pedestrian crossings, a sizeable proportion of older people cross the road mid-block and therefore increase their risk of being struck by a vehicle. Prevention of these crossings at dangerous locations may be minimised by the use of barrier fencing or other forms of restraint.

- ** Separation of pedestrians and traffic

From the safety viewpoint separation of pedestrians and vehicles is highly desirable. Overpasses and underpasses have been suggested and implemented as an intervention, however, studies have shown that pedestrians, especially older pedestrians, are reluctant to use these facilities because of the physical effort involved (Safety for Seniors Working Group, 1989). Many European cities are adopting the practice of physically separating pedestrians and vehicle by greater use of ring roads around busy locations. While not always possible, this solution should not be overlooked for high black-spot locations.

7.6 THE NEED FOR FURTHER RESEARCH

Due to a paucity of earlier detailed research in this area, this study set out to establish whether older pedestrians experience particular problems crossing the road and whether their behaviour differs in significant ways from that of younger pedestrians. It has provided a detailed investigation of the behaviour of both older and younger adults as they cross the road and the
findings point to a number of specific areas in which age-related performance declines may contribute to many of older pedestrian accidents.

The observational study results suggested that older people may have greater difficulty judging the speed of on-coming vehicles and what constitutes an acceptable gap in which to cross the road safely. Moreover, there was a hint that older people (especially the slower walkers) may not be totally efficient in attending to critical cues while crossing the road. More research is warranted in these areas to help guide future initiatives aimed at improving older pedestrian safety.

On-road measures generally have the advantage of high face validity in road experimentation because behaviours are studied as they occur naturally in everyday settings. However, within a natural setting behaviour is taking place under a large number of conditions, and any one of these conditions may affect behaviour. By conducting a series of controlled laboratory experiments a better understanding of the underlying processes involved in safe road crossing would be achieved. A more detailed examination of critical processes that underlie deficits in performance in traffic situations would be beneficial, particularly those processes that may put older pedestrians at higher risk of being involved in an accident.

This is a significant road safety issue and greater knowledge of many of the issues raised in this study will provide road authorities and safety researchers with a better understanding of the reasons for older pedestrians' over-involvement in crashes. Detailed investigation of these issues would necessarily lead to improved countermeasure design, and ultimately to reduce the number and frequency of accidents involving older pedestrians. Measurements of performance would be linked back to on-road risky behaviours to ensure that practically-based countermeasures can be developed. More comprehensive training packages aimed at specific problems older people can be developed, along with campaigns aimed to increase awareness of relevant issues to older pedestrian safety.
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