Crossing Roads Safely: An Experimental Study of Age and Gender Differences in Gap Selection by Child Pedestrians

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ABSTRACT

Pedestrian crashes are among the most common causes of death and serious injury to young children in the developed world. The literature suggests that younger children may be at increased risk of crash involvement, mainly due to poor or under-developed road-crossing skills. This paper reports on a study examining the effects of age and gender on road-crossing skill amongst children aged 6-10 years (those at highest risk of crash involvement). Children were asked to make road-crossing decisions in a simulated road environment in which time gap and vehicle speed were systematically manipulated. Functional performance was also examined as part of a larger study. The results indicate that, for all age groups, gap selection was primarily based on vehicle distance and less so on time-of-arrival. The results also showed that the proportion of 'yes' responses increased as the time gap increased. Younger children (6-8 years old) were more likely than older children (9-10 years old) to indicate they would have crossed in short distance and time gaps. This suggests that many younger children may lack the skills required to make safe and appropriate gap selection of approaching traffic. Gender was not a significant predictor of road-crossing decisions. The findings from this research will play a major role in the development of countermeasures aimed to improve the safety of primary school-aged children, providing effective training aimed to improve essential skills and strategies to cross roads safely.

KEY WORDS: child, pedestrian, simulator, injury prevention, risk, behaviour.

INTRODUCTION

Crashes involving pedestrians are severe in nature and pedestrian safety is a serious community concern. Two hundred and thirty pedestrians were killed Australia-wide between January 2004 and December 2004 and over 2,500 sustained serious injuries in 2002. Children under the age of 16 years constituted a substantial proportion of these deaths (9%) and a larger proportion of serious injuries (21%) (Australian Transport Safety Bureau, 2004). Research suggests that children between the ages of 6 to 10 are at highest risk of death and injury, with an estimated minimum four times the risk of collision compared to adult pedestrians (Struik, Alexander, Cave, Fleming, Lyttle & Stone, 1988; Thomson, 1996). Further, casualty patterns also indicate that injury and fatality rates for boys in this age group typically are significantly higher than those for girls, even when exposure is taken into account (Jones & Nguyen, 1988, as cited in Connelly et al. 1998; LTSA, 2000).

Much of the literature suggests that young children are less competent in traffic than older children and adults because of poorly developed perceptual, attentional, and cognitive abilities (Connelly, Conaglen, Parsonson & Isler, 1998; Dunbar, Hill & Lewis, 2001; Whitebread & Neilson, 2000). Furthermore, young children are generally inconsistent in their road safety behaviours, and are easily distracted. The small stature of young pedestrians is another identified source of difficulty. They have greater difficulty seeing over parked cars and other obstacles, and are in turn more easily hidden by them (Demetre & Gaffin, 1994; Ledbetter, 1998). Further, the ability to identify safe and dangerous road-crossing sites increases with age among children aged 6-10 years (Tabibi & Pfeffer, 2003).

Compounding this is the fact that making the decision about when it is safe to cross the road, in relation to available gaps in the traffic, is a complex task. Judgement of whether a gap in the traffic is sufficient to safely cross requires the determination of the time-to-contact of the nearest vehicle with the planned crossing line and the assessment of whether this time-to-contact exceeds the time required to cross the road, taking into account one's own speed (Simpson, Johnston & Richardson, 2003).

However, there is evidence that children aged below 10 years have relatively poor skills at reliably setting safe distance gap thresholds, and thus do not consistently make safe crossing decisions (Connelly et al, 1998).

There is some research to suggest that children's poor skills at selecting appropriate gaps in traffic are due to the fact that distance, rather than an approaching vehicle's speed, is a primary factor in determining gap acceptance thresholds (Connelly, Isler & Parsonson, 1996, Connelly et al. 1998; Simpson et al. 2003). However, there is also some evidence that adult drivers and older pedestrians also seem to rely on distance rather than the speed of an approaching vehicle (Oxley, Ihsen, Fildes, Charlton, & Day, 2005). It is unclear whether relying on distance for making gap selections is the reason why child pedestrians are at a higher risk of death and injury than adults.

There are a handful of studies that have addressed children's road crossing judgements while walking and cycling (Connelly et al. 1998; Demetre, Lee, Grieve, Pitcairn, Thomson & Ampofo-Boateng, 1992; Lee, Young, & McLaughlin, 1984; Pitcairn and Edlmann, 2000; Plumert, Kearney, and Cremer, 2004; Simpson et al. 2003). Lee et al. (1984) developed a road-crossing task in which 5-9 year old children crossed a 'pretend road' set up parallel to an actual road. Children were instructed to cross the pretend road as if crossing the adjacent road in the face of oncoming vehicles. The findings indicated that although children were generally cautious, they sometimes accepted gaps that were too short. In addition, younger children were more likely to make a road-crossing error than older children, suggesting that younger children may overestimate their ability to walk safely through traffic gaps.

Connelly et al. (1998) devised another roadside task where children aged 5-12 years stood at the side of the road in normal traffic conditions and indicated the last possible moment that they would cross. The results showed that across the five speed categories (0-50, 51-55, 56-60, 61-65, 66kph and over) children set similar distance thresholds regardless of the speed of the vehicle. They also reported that one in three of the distance gap judgements made by children under the age of ten was unsafe, and there was some indication of a gender effect, with boys somewhat more likely to make safe decisions compared with girls at age 5-6 years and at 11-12 years.

Both Lee et al. (1984) and Connelly et al. (1998) attempted to measure children's road crossing decisions using roadside tasks. While these studies have high face validity, there are limitations in studies conducted at the roadside. For example, standing at the pretend road places the participant a road's width away from the edge of the real road, and thus may change the perspective of the child (Pitcairn & Edlemann, 2000), and therefore their judgements. Further, typically in on-road settings there is little control over the timing and location of traffic. This was a noted limitation of the Connelly et al. (1998) study. Not all children made judgements of vehicles travelling at each of the five speed groups, making it difficult to draw definitive conclusions about the roles of distance and speed in gap judgements (Plumert et al., 2004).

Three studies assessed children's road crossing decisions using simulated environments (interactive bicycle simulator: Pitcairn & Edleman, 2000; video presentation: Plumert et al. 2004; virtual reality head-mounted display: Simpson et al, 2003). In general, these studies indicated that children are poorer than adolescents and adults in making safe road crossing decisions, and both children and adults tend to base their road crossing decision on distance rather than time of arrival. Importantly, however, each study had some limitations. These include: lack of analyses amongst young children (one of the most vulnerable pedestrian groups), and technical difficulties. For example, the findings of the Plumert et al. (2004) study may have been influenced by the film format used, as it was not a perfect representation of the roadside. The need to fit the road into half a frame of the monitor resulted in the angle of the vision being much wider than normal. The effect of this change on perception is unknown.

Clearly, the ability to select safe gaps in the traffic in which to cross is crucial for safe road crossing and there is a need to understand in more detail the behaviour of children on the road, particularly the factors involved in gap selection judgement. Evidence suggests that children aged 6-10 years, particularly males, have a heightened risk of being seriously injured or killed when they cross the road.

The current study aims to investigate the influence of age and gender on road crossing ability of children in this age group in a simulated road environment, and to determine what factors may govern gap selection among children.

METHOD

Participants

Seventy-one children participated in the study, comprising 35 males and 36 females. Participants were aged between 6-10 years old (13 six year olds, 14 seven year olds, 15 eight year olds, 15 nine year olds and 14 ten year olds). Fifty schools in the Melbourne Metropolitan Area were randomly selected from the White Pages and sent a Letter of Invitation and Consent Form. On receipt of agreement from school principals, five schools were selected to participate in the study. Parents with children aged 6-10 years from each school were sent a letter of invitation and a permission slip for their child to take part in the study. For each school the returned permission slips were grouped into the five age groups and the research team randomly selected 2-3 children from each age group. Between 12 and 15 children were selected from each school to participate in the study.

Simulated Road Environment

Simulated traffic scenes that were generated from data files from a mid-range driving simulator were used in this study (Figure 1). It showed an undivided, straight two-way residential road (with visual and audio features to make the environment as realistic as possible) from the perspective of a pedestrian waiting at the kerb, with two vehicles travelling from the right-hand side (near-side lane). There was no traffic in the far-side lane.

Time gap and speed of the vehicles were systematically manipulated with five levels of time gap (3, 4, 5, 6, and 7 secs) and three levels of vehicle speed (40, 60 and 80kph) resulting in fifteen different traffic scenarios. Distance co-varied as a function of these two manipulations. Each of the 15 simulated traffic scenes was shown three times (for a total of 45 scenes). The presentations of these scenes were randomised in three sets of 45 scenes. The presentation to participants of each set was also randomised. Simulated traffic scenes were projected onto a large white screen.

Figure 1: Stimulus traffic scenarios presented in the road-crossing simulation

Responses were made on a computer keyboard on the desk in front of participants. Most of the keys were blackened and covered. Two keys (‘J’ and ‘D’) labelled ‘YES’ and ‘NO’ respectively, were available for participants to indicate whether they would ‘cross’ the road or not. The keys for numbers 1 to 9 with labels ‘very unsafe’ below the 1 key and ‘very safe’ below the 9 key, provided a nominal rating scale on which participants were asked to rate the safety of the road-crossing.

Procedure

Each participant was tested individually. Participants were seated at a desk in a darkened, quite room approximately 2m in front of the projection screen with their right index finger resting on the 'YES' key and their left index finger resting on the 'NO' key. Instructions were given verbally, and the experimenter also demonstrated the simulator task to the child, providing explanation during the demonstration. Practice trials were given until participants indicated that they fully understood the task. Participants were instructed that a buzzer would sound when the first vehicle passed the point of crossing. This 'trigger' vehicle activated a timer. Participants were instructed to look at the traffic scene as soon as they heard the buzzer and to decide whether or not they would 'cross' in front of the second vehicle (walking normally across the street), responding as quickly as possible by pressing the 'YES' or the 'NO' key. This deactivated the timer and the time interval was recorded as decision time. After this, participants were asked to rate how safe or unsafe they thought the 'crossing' would have been by pressing the appropriate key (1-9). No time limits were imposed for this response.

Walking time over a distance equivalent to the width of an average road lane (5.6m) at two walking paces was also measured. For normal walking pace, participants were asked to walk as they normally would to a designated object 5.6m away. For fast walking pace, participants were asked to walk as fast as they could, without running, to a designated object 5.6m away.

A battery of neuropsychological and behavioural assessment tools was also administered to participants as part of a larger study. Results on these assessments will be reported elsewhere. Total testing time took approximately 45 minutes (with a short break between the behavioural assessments and simulator tasks). The simulator task took approximately 15 minutes.

RESULTS

Three performance measures were analysed. These were walking times, yes/no responses and critically incorrect responses, which are described below. Safety rating responses will not be presented here, as the pattern of these results closely resembled that of the yes/no responses. Analyses of decision time results will be reported elsewhere.

Walking Times

Walking times by age group were analysed by ANOVA and the effects were explored by post hoc Tukey Tests. Table 1 shows the means, standard deviations and range (minimum and maximum) of walking times by age. There was no significant effect of age found for normal walking time, $F(4,66) = .55$, $p>0.05$. However, there was a significant effect of age found for fast walking pace, $F(4,66)$, $= 4.58$, $p<0.05$. Post-hoc Tukey tests indicated that six year olds walked at a significantly slower pace than nine year olds ($p=0.001$), and ten year olds ($p=0.013$). There were no other statistically significant differences between the groups.

Table 1 Mean walking times (normal and fast-paced) by age (with standard deviation)

	Normal-paced walking time (s)			Fast-paced walking time (s)		
	Mean (S.D.)	Minimum	Maximum	Mean (S.D.)	Minimum	Maximum
6 year olds	5.47 (2.52)	3.88	13.53	3.92 (0.81)	2.90	6.13
7 year olds	5.17 (1.19)	3.00	7.19	3.38 (0.39)	2.87	4.22
8 year olds	5.32 (0.84)	4.53	7.11	3.42 (0.56)	2.50	4.72
9 year olds	5.00 (0.92)	3.33	7.06	3.07 (0.49)	2.30	4.06
10 year olds	4.75 (1.05)	3.09	7.34	3.22 (0.42)	2.59	4.00

Table 2 shows the means, standard deviations and range (minimum and maximum) of walking times by gender. These were analysed using t-tests.

There was no significant effect of gender found for normal walking time, $t(69)=0.036$, $p>0.05$, or fast walking time $t(69)=-0.275$, $p>0.05$. There was also no significant effect of gender within each age group.

Table 2 Mean walking times (normal and fast-paced) by gender (with standard deviation)

	Normal-paced walking time (s)			Fast-paced walking time (s)		
	Mean (S.D.)	Minimum	Maximum	Mean (S.D.)	Minimum	Maximum
Males	5.14 (1.72)	3.00	13.53	3.37 (0.64)	2.47	6.13
Females	5.13 (0.98)	3.09	7.34	3.41 (0.58)	2.30	4.72

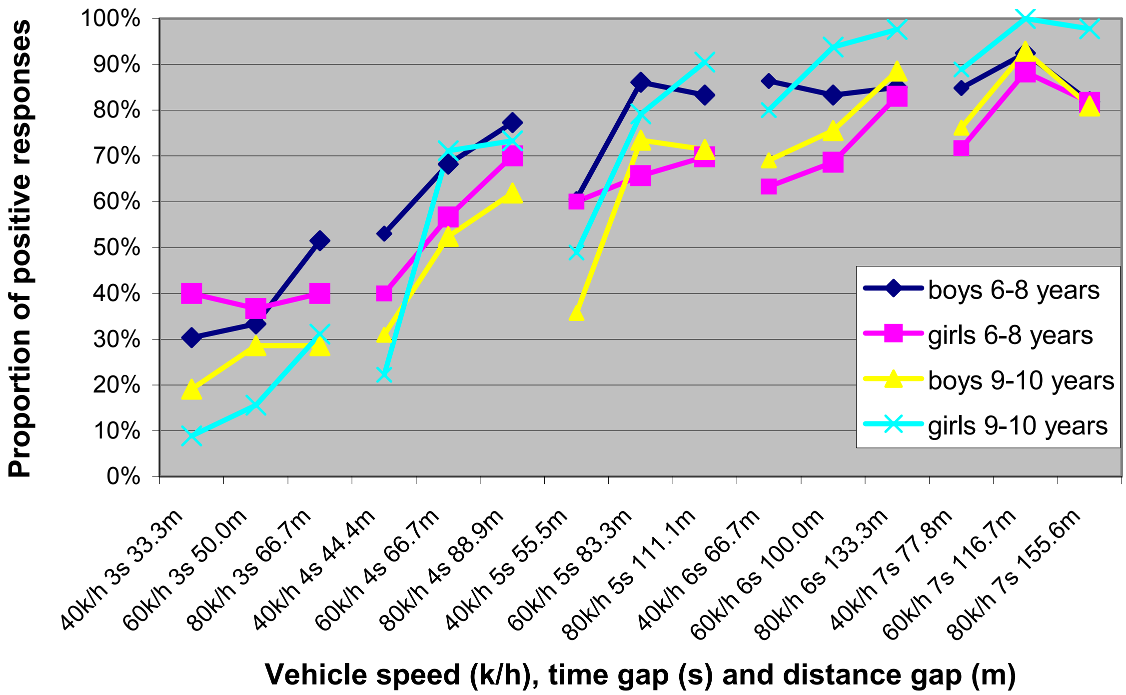
Yes/no responses

Analyses of yes/no responses were undertaken by employing hierarchical logistic regression to examine the impact on the crossing decision of the variables age group, time gap, vehicle speed, and distance gap. Children were grouped into two groups of younger children (6-8 year olds) and older children (9-10 year olds). Because distance gap co-varies in a systematic fashion when vehicle speed and time gap are manipulated, it was necessary to undertake two separate analyses. Model 1 included age group, gender, vehicle speed and time of arrival of vehicle as variables and Model 2 included age group, gender and distance gap as variables. Model 1 revealed that time gap was a strong predictor of crossing decisions $\chi^2(4) = 522.93$, $p<0.001$. Age group and vehicle speed were also predictors of crossing decisions $\chi^2(1) = 7.64$, $p<0.05$, $\chi^2(2) = 94.48$, $p<0.001$, respectively. Gender was not a predictor of road crossing decisions $\chi^2(1) = 1.21$, $p>0.05$. Model 2 revealed that distance gap was a strong predictor of road crossing decisions $\chi^2(1) = 478.09$, $p<0.001$. Again, age group was also a predictor of road-crossing decisions $\chi^2(1) = 7.35$, $p<0.05$, and gender was not a significant predictor of road crossing decisions $\chi^2(1) = 1.17$, $p>0.05$. These findings indicate that participants based their decisions on all vehicle variables (distance, time and speed) and that the different age groups responded differently to the road-crossing task.

Figure 2 shows the proportion of positive crossing responses by vehicle conditions for age group and gender. These data show that all children were less likely to indicate that they would cross when time and distance gaps were small than when they were larger. However, between 9% (for 9-10 year old girls) and 52% (for 6-8 year old boys) of participant responses indicated a ‘yes’ crossing decision in a three second time gap (for all vehicle speeds), even though most of the children required longer than three seconds to walk the distance of the carriageway even at their fastest pace.

Figure 2 also indicates that distance, not time gap, was a strong determinant of crossing decisions for all groups. Vehicle speed was also taken into account, but to a lesser extent. For instance, for the three time gap conditions of 4sec the proportion of positive responses increased for all groups as the distance gap increased. Seventy-seven per cent of responses by boys aged 6-8 years in the 80km x 4sec condition were a ‘yes’ crossing decision, compared to 53% in the 40km x 4sec condition. This difference was even more pronounced in the 9-10 year old girls, with only 22% of responses indicating a ‘yes’ crossing decision in 40km x 4sec condition, compared to 73% in the 80km x 4sec condition. In a 4sec time gap, most children would need to increase their walking speed to safely cross the road.

Figure 2:Proportion of yes responses as a function of age group, gender, vehicle speed, time gap and distance gap



Critically incorrect responses

While a 'yes' or 'no' response is an interesting measure in itself, the response needs to be put in context of whether it was a correct (safe) or incorrect (unsafe or missed opportunity) decision, allowing for walking speed. 'Correct' and 'incorrect' responses were scored, taking fast walking times into account. There were four possible responses: correct acceptance (safe), correct rejection (safe), incorrect acceptance (unsafe) and incorrect rejection (missed opportunity). The proportions of responses by age group and gender are shown in Table 3. The fastest walking speed was chosen over the normal walking speed, because, as in real life situations, a child is likely to increase their walking speed if the vehicle is quickly approaching. Of most importance is an incorrect 'yes' response, as these responses would have resulted in a collision, or the driver needing to take evasive action to avoid a collision, in a real-world situation based on the time of arrival of the vehicle exceeding the child's fastest walking speed. Of the 3,195 scenes shown to the 71 participants (each participant viewed 15 scenes three times, totalling 45 scenes per participant), 540 scenes may have resulted in a collision if the child had chosen to cross the road in a real life situation (based on the fast walking speed of the individual participant). Of these 540 scenes, there were 236 (44%) 'yes' responses made to cross the road. Forty-two participants (59%) made at least one critically incorrect decision.

Table 3: Proportion of correct and incorrect response by age and gender

	Correct acceptance	**Incorrect acceptance**	**Correct rejection**	**Incorrect rejection**
Males	940 (59.3%)	129 (8.1%)	137 (8.6%)	380 (24%)
Female	902 (58.5%)	107 (6.9%)	167 (10.8%)	365 (23.7%)
Total	***1,842 (58.9%)***	***236 (7.5%)***	***304 (9.7%)***	***745 (23.8%)***
6 year olds	295 (52%)	99 (17.5%)	56 (9.9%)	117 (20.6%)
7 year olds	341 (55.2%)	47 (7.6%)	74 (12%)	156 (25.2%)
8 year olds	434 (66.2%)	42 (6.4%)	67 (10.2%)	113 (17.2%)
9 year olds	395 (59%)	32 (4.8%)	64 (9.6%)	178 (26.6%)
10 year olds	377 (61.1%)	16 (2.6%)	43 (7%)	181 (29.3%)
Total	***1,842 (58.9%)***	***236 (7.5%)***	***304 (9.7%)***	***745 (23.8%)***

To determine what variables influenced a critically incorrect response, logistical hierarchical multiple regression modelling was employed. Included in the model were age (6, 7, 8, 9 and 10 years), gender, time of arrival and vehicle speed. The model revealed that age, time of arrival and speed were all significant predictors of crossing responses $\chi^2(4) = 119.62$, $p<0.001$, $\chi^2(1) = 415.43$, $p<0.001$, $\chi^2(1) = 6.67$, $p<0.01$, respectively. As in the analysis of yes/no responses, there was no significant effect for gender. Six year olds were 11.96 times more likely to make a critically incorrect decision than ten year olds ($p<0.001$). Six years olds made a critically incorrect decision about 1 time in 6 compared to ten year olds who made a critically incorrect decision about 1 time in 39.

DISCUSSION

The broad aim of this study was to determine what factors may govern gap selection among young children and to examine the influence of age and gender on the ability to select safe gaps in the traffic. The findings indicate that young children (6-10 year olds) generally have poor skills at reliably selecting safe gaps in traffic.

The results suggest that children primarily used distance rather than the speed of approaching vehicles in making judgements about safe crossing gaps. This is evidenced by the result that children were more likely to make a 'yes' crossing decision in a larger distance gap, despite the time gap being the same (Figure 2). This was shown in both the younger and older children, and has also been shown in other studies with child pedestrians (Connelly et al. 1998; Simpson et al. 2003), older adult pedestrians (Oxley et al., 2005) and younger drivers (De Lucia, Bleckley, Meyer & Bush, 2003). It is therefore likely that it is not age alone that determines the use of distance, speed or time of arrival in making a road-crossing decision. One suggestion for using distance as the primary factor in determining safe gaps in traffic is that pedestrians make an initial decision such as ' the further away the car is from me, the safer it is to cross.' This suggests an immediacy effect where a vehicle far away, irrespective of its travelling speed, is judged to be less threatening than one close up (Oxley et al., 2005). This may be particularly pertinent to child pedestrians, who are perhaps taught to only cross the road when the oncoming vehicle is far away. In addition, many children may only be exposed to local roads as pedestrians, where speed limits are between 40kph to 60kph. It may be that is not age, per se, that determines the use of distance in gap selection judgements, but the limited exposure of young children to vehicles travelling at higher speeds.

Further, although it appears that distance is primarily used in making road-crossing decisions, it does not mean that participants are unable to directly perceive time of arrival. It may be that participants are not paying attention to time of arrival information, and using other factors to guide their decision. It is possible that training programs could be designed to teach children to pay attention to speed and time of arrival information and not to simply rely on distance (Simpson et al, 2003).

Of most interest in this study were the analyses of critically incorrect responses. Of concern is the number of children who made a critically incorrect crossing decision, which may have resulted in a collision in a real life scenario. More than half of all children (59%) made at least one critically incorrect decision, based on their fast walking pace and time of arrival of the approaching vehicle.

Age was a strong predictor of a critically incorrect crossing decision, with six year olds almost 12 times more likely than 10 year olds to make a critically incorrect decision. This finding may be associated with slower walking speeds of younger children. Six year old children walked, on average, 0.72 seconds slower than the ten year olds in the normal walking pace trial, and 0.70 seconds slower in the fast pace walking trial. This could influence the higher proportion of critically incorrect responses found in the 6 year old group, as it takes them longer to cross the road, resulting in more 'unsafe' scenarios. Further, younger children may also over-estimate how quickly they can cross the road. This is consistent with other research that shows that children often over-estimate their abilities, and that 6-year olds who over-estimate their physical abilities are more at risk for injury (Plumert, 1995). It may be that, in the current study, the younger children were more likely to over-estimate how quickly they could cross the road compared to the older children, resulting in a higher proportion of 'yes' responses in the 6-8 year old age groups in the shorter time gaps, and higher proportion of critically incorrect decisions in the younger age groups.

Surprisingly, gender was not a predictor of road crossing decisions, or critically incorrect responses. This is an unexpected result, particularly as a number of studies suggest that boys make a higher proportion of unsafe decisions (Connelly et al., 1998) and crash statistics suggesting higher rates of death and injury amongst young boys, compared with young girls, (ATSB, 2006; LTSA, 2000). Based on a travel survey carried out in 1997/98, the LTSA in New Zealand (LTSA, 2000) found that 5-9 year old boys had almost double the risk of death or injury than girls in the same age group for each hour spent walking. This finding may, in part, be explained by the nature of the simulator environment. Research with children of varying ages has demonstrated that there is greater risk taking behaviour among boys than girls (e.g. Morrongiello & Rennie, 1998). It may be that boys and girls make similar judgements in a controlled simulator environment, but that boys are more likely to take risks when in an actual roadside setting. In addition, child pedestrian safety is more likely to be at stake when children are impulsive, distracted or delay decision making to the last moment (Connelly et al 1998). It is possible that boys are more impulsive and more easily distracted in a roadside environment than girls, yet when these distraction are removed, they make similar gap selection decisions to girls. However, this is quite concerning considering the findings of this study show that children are often making unsafe decisions in a controlled environment, without any distracting environmental factors. It is possible that children would make more unsafe decisions in an environment that contains distracting information.

In light of this, the present study may have produced gap selection judgements that may be different from those of children in normal traffic, particularly among boys. As the participants did not need to cross an actual road there was no risk in making an erroneous decision. It has been suggested by Ebbesen et al. (1977, as cited in Connelly et al, 1998) that perceived risk affects decision making, so removal of risk may have affected the outcome in this study. Further, the results may be an artefact of the impoverished two-dimensional viewing conditions of the simulator. However, these effects are likely to be minimal, as a validation study by Oxley, Fildes, Ihsen and Charlton (1997) showed that crossing decisions and perceptions of safety by younger and older adults in real world and filmed versions of traffic scenes were highly correlated. This has yet to be validated in children, and is an area for future research.

The findings of this study have practical implications for road safety countermeasures aimed at improving the safety of child pedestrians. Utilising these results, a training package is being designed that will attempt to train children on the simulator to improve their road-crossing skills. It is anticipated that the training package will improve the judgement skills of children, and thus their safety in the roadside environment. The simulator can then be used to target 'at-risk' children and provide training opportunities to these children.

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