Original Article

Choosing a safe place to cross the road: the relationship between attention and identification of safe and dangerous road-crossing sites

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Abstract

Background Safe pedestrian behaviour relies on cognitive skills, including the ability to focus attention on the traffic environment and ignore irrelevant stimuli. An important pedestrian skill that young children find difficult is the ability to find a safe place to cross the road. The aim of this study was to examine the relationship between attention and children's ability to identify safe and dangerous road-crossing sites.

Methods Participants were 95 children (aged 6.5 years, 8.6 years and 10.4 years) and 33 adults. Ability to identify safe and dangerous road-crossing sites was assessed using computer presentations of five safe and five dangerous sites. Attention was assessed using the Stroop test for resistance to interference. Correlations were calculated between Stroop test measures and pedestrian task measures (accuracy and speed of identifying safe and dangerous road-crossing sites) for each age group separately.

Results The ability to identify safe and dangerous road-crossing sites and the ability to resist interference increased with age. Significant correlations were observed between identification of safe and dangerous road-crossing sites and performance on the Stroop test for children but not for adults.

Discussion The results indicated that attention is required for identifying road-crossing sites quickly and accurately, especially for younger children. Road safety training programmes for children may need to take into account the development of children's attention.

Keywords
pedestrian, child safety, attentional development, Stroop test

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Introduction

One of the most important causes of death, injury and long-term disability among children is accidents. Road accidents form two-thirds of fatal accidents to children aged 5–14 years, the rate of road accidents rising from 3 years of age and peaking at age 12 years. In the UK in 1997, 3424 children aged 5–7 years and 6312 children aged 12–15 years were killed or injured (DETR 1999). The proportion of accidents among children is much higher than that among adults considering that children are not exposed to traffic as much as adults (Routledge *et al*. 1974). Even when exposure rate is taken into account, the number of road accidents affecting 5- to 9-year-olds is four times higher than that of adults (Thomson 1996a), leading to the conclusion that children are less competent in traffic than adults.

Finding a safe place to cross the road is an important pedestrian skill that young children find difficult (Ampofo-Boateng *et al.* 1993). According to Thomson (1996b), young children do not know the factors that make some road-crossing locations dangerous. Traffic situations present very complex stimuli that require consideration of several factors (e.g. lines of sight of both pedestrians and drivers, traffic speed, driver's intentions, etc.). The more complex a situation, the less the probability of noticing the factors that make a situation dangerous. Hill *et al.* (2000) found that 4- to 9-year-old children have difficulty paying attention to the features that make a road-crossing situation dangerous, that is they have difficulty paying attention to relevant information and ignoring irrelevant information. Negotiating traffic requires cognitive and perceptual skills. Studies of the development of appropriate skills include investigations of children's use of peripheral vision (David *et al.* 1986), estimations of vehicle approach times (Hoffman *et al.* 1980) and auditory perception (Pfeffer & Barnecutt 1996). Given the complex nature of the task, the development of attention is also important. Demetre *et al.* (1992) asserted that attention is important for judging safe traffic gaps, particularly among 5-year olds. Pfeffer and Barnecutt (1996) suggested that attention is important for judging the sounds of approaching traffic. Dunbar *et al.* (1999) found that 4- to 10-year-old children who were better at attention switching were more likely to show awareness of traffic when crossing a road, and children who maintained concentration when challenged by a distracting event crossed the road in a 'less reckless' manner.

In addition, clinical studies have indicated that attention is implicated in accident incidence. Zuckerman and Duby (1985) noted a higher rate of accidents among children with attention deficit disorders. Van der Molen (1981) reported that complete lack of attention was implicated in 62% of accidents involving boys under 10 years and in 50% of accidents involving girls under 10 years.

The aim of this study was to investigate the role of attention in selection of safe road-crossing sites. Although Thomson *et al.* (1992) have argued that roadside tasks are important in the analysis of children's road-crossing ability, using real traffic environments presents problems for the researcher regarding control and testing of variables. Researchers have used a variety of techniques to overcome this problem, including table-top road models (Ampofo-Boateng & Thomson 1991), film presentation (Pitcairn & Edelman 2000) and com- 1
puter animation (Foot *et al.* 1999). Comparable results have been found for such experimental materials and real traffic environments for training road-crossing skills (Ampofo-Boateng *et al.* 1993) and for analysis of abilities (Foot *et al.* 1999). The technique used in this paper is a computer animation displaying a selection of road-crossing sites varying in complexity in order to investigate the variables influencing children's ability to select safe road-crossing sites.

Materials and methods

Participants

A total of 128 participants, 95 children and 33 adults in four age groups as follows: 32 children from Year 2 (16 boys and 16 girls, mean age 6.5 years), 31 children from Year 4 (16 boys and 15 girls, mean age 8.6 years), 32 children from Year 6 (15 boys and 17 girls, mean age 10.4 years) and 33 adult students (14 males and 19 females, mean age 27.3 years).

Measuring recognition of safe road-crossing sites

A computer task was designed to measure the skills required by pedestrians to identify a safe place to cross the road. The task was based on previous research on pedestrian skills (e.g. Vinje 1981; 2
Ampofo-Boateng & Thomson 1991). County Council Road Safety Education Officers were consulted during the development of the task. The computer task used animated street scenes and was designed to be interactive and user-friendly for children.

The recognition task featured the image of a boy standing at the edge of a road facing towards the

Table 1. Road-crossing sites with irrelevant information

Crossing site	Irrelevant information added	Safe or dangerous identification
Straight road	Fixed landscape (unanimated)	Safe
Zebra crossing	Fixed landscape (unanimated)	Safe
Blind bend	Children playing in park (animated)	Dangerous
Pelican crossing (with green man)	Cat walking in rain (animated)	Safe
Roundabout	Fixed landscape (unanimated)	Dangerous
Traffic island	Fixed landscape (unanimated)	Safe
Traffic lights on red	Dog barking (animated)	Safe
Parked cars	Road construction (animated)	Dangerous
Road-crossing patrol	Aeroplane (animated)	Safe
Brow of a hill	Fixed landscape (unanimated)	Dangerous
Junction	Cyclist (animated)	Dangerous

road. Eleven road-crossing sites were represented separately, including one practice trial, five 'safe' crossing sites and five 'unsafe' crossing sites (see Table 1). Two conditions were designed using the 11 road-crossing sites in each condition: recognition task without irrelevant information and recognition task with irrelevant information. For the recognition task without irrelevant information, all distracting visual and auditory information was removed from the scene (such as houses, trees, cars) allowing the participant to focus on the road site. For the recognition task with irrelevant information, unanimated distractions were included (such as shops, a bus station and lamp posts) as well as animated distractions. Table 1 outlines the irrelevant information incorporated into specific road-crossing sites.

Road-crossing sites were presented in random order with a 2-s interval between trials. Trials were not time limited. The experimenter started the practice trial, then all subsequent trials were started by the participant pressing one of the two keys (green to indicate a safe crossing site and red to indicate a dangerous crossing site) from a response-key box connected to the computer. Accuracy (correct or incorrect identification of a safe road-crossing site with a maximum possible score of 10) and identification time (in ms) were recorded.

Measuring attention

The 50-word version of the Stroop colour word test (Stroop 1935) was used to measure attention. The Stroop test measures ability to resist the interference of dominant information. The Stroop test is divided into three parts, two with congruent information and one with incongruent information. The congruent section comprises two parts. One part requires the participant to read a list of colour names typed in black ink as quickly as possible. The other part requires the participant to name the colours displayed by coloured ink XXXs as quickly as possible. The incongruent part requires the participant to name as quickly as possible the colour of ink in which a colour name is printed. This is the interference test as the colour names are printed in different coloured inks (e.g. the name blue printed in red ink). The task is a measure of ability to focus attention on a relevant stimulus (ink colour) and ignore an irrelevant stimulus (word meaning). The measure used was the time taken to respond to each part.

Procedure

All children of the required age group present in school on the day of the study with consent to participate took part in the investigation. Adults were student volunteers. To reduce the possible effects of memory of one condition of the pedestrian task affecting responses to the second condition, the attention test was presented between the two pedestrian task conditions. The order of presentation of the two pedestrian task conditions (with and without irrelevant information) was counterbalanced.

For the computer-based tasks, participants were seated in front of a computer monitor and asked to place their hand on the response box. All participants used their dominant hand to press the appropriate response key. The task was explained to participants before starting the practice trial on the computer. Responses to the Stroop test were tape-recorded (with the participant's consent). Depending on the participants' speed of performance, the computer-based task took ≈10 min to complete and the Stroop test took ≈5–10 min to administer.

Results

The results are presented as follows. Age, gender and condition effects for the computer-based pedestrian task; age, gender and condition effects on the attention task; the relationship between attention and the computer-based pedestrian tasks.

Identification of road-crossing sites

Table 2 presents the rate of correct responses for the two conditions by age and gender. A factorial ANOVA with repeated measures on one factor was computed to examine age, gender and condition effects. A significant age effect was found with F (3, 120) = 5.6, $P < 0.001$. The number of correctly identified safe and dangerous road-crossing sites increased with age. No significant effect of condition and gender was found, and there were no significant interactions. The presence of irrelevant information did not affect ability to recognize safe and dangerous road-crossing sites. Post hoc analysis using Tukey HSD found a significant difference between the responses of Year 2 children and Year 6 children ($P < 0.001$) and between Year 2 children and adults ($P < 0.02$). No significant differences were found between Year 4 and Year 6 children or between Year 6 children and adults.

Table 3 presents the response time for identifying a road-crossing site as safe or dangerous. A factorial ANOVA with repeated measures on one factor was computed to examine age, gender and condition effects on the amount of time spent on deciding whether a road-crossing site was safe or dangerous. A significant age group effect was found (F (3, 120) = 5.294, $P < 0.002$) with identification time decreasing with age. A significant condition effect was also found (F 1, 120 = 8.455, $P < 0.004$) showing a significantly longer identification time for the condition with irrelevant information. No significant gender effect was found, and there were no significant interactions. The significantly longer identification time for the pedestrian task with irrelevant information was evident for all age groups. A post hoc analysis using Tukey HSD indicated a significant difference in identification time between Year 2 children and that of Year 6 children and adults ($P < 0.02$, $P < 0.001$ respectively). No significant difference was found between Year 4

Table 2. Mean correct responses for safe and dangerous road-crossing sites by age, gender and condition

		Recognition task without irrelevant information		Recognition task with irrelevant information	
Age group	**Gender**	**Mean**	**SD**	**Mean**	**SD**
Year 2	All	6.2	1.2	6.2	1.2
	Male	6.4	1.3	6.2	1.5
	Female	5.9	1.2	6.3	0.08
Year 4	All	6.6	1.2	6.6	1.4
	Male	7	1.4	7.1	1.5
	Female	6.2	0.08	6	1.2
Year 6	All	7.3	1.4	7.4	1.5
	Male	7.4	1.4	7.6	1.4
	Female	7.2	1.4	7.2	1.5
Adult	All	7.1	1.2	7	1.4
	Male	6.8	1	6.9	1.2
	Female	7.4	1.3	7.2	1.5

Table 3. Response time (in ms) for identification of safe and dangerous road-crossing sites

		Without irrelevant information		With irrelevant information	
Age group	**Gender**	**Mean**	**SD**	**Mean**	**SD**
Year 2	All	4038.2	2924.1	4217.6	2863.8
	Male	3732	1883.5	3905	1891.2
	Female	4344.4	3731.4	4530.2	3628.2
Year 4	All	2753	1386	3577.8	2593.6
	Male	2546.2	1137.2	2975.3	1253.4
	Female	2973.5	1621.6	4220.5	3445.9
Year 6	All	2636.7	1221.1	3115.0	1271
	Male	2691.7	1364.7	3370.2	1461
	Female	2588.2	1119.8	2889.9	1073.2
Adult	All	2173	682	2765.6	1860.8
	Male	2045.5	472.8	3176.2	2556.8
	Female	2267.5	803.3	2463.1	1098.6

and Year 2 children or between Year 6 children and adults.

We were also interested in the relationship between identification time and identification accuracy, that is whether correct identification of safe and dangerous road-crossing sites was related to the speed at which such identification was made. No linear or non-linear relationship was observed for children or adults (for children: $r = 0.02$, $P > 0.05$ and $r = 0.20$, $P > 0.05$; for adults: $r = 0.02$, $P > 0.05$ and $r = 0.39$, $P > 0.05$). Correctly identifying a road-crossing site as safe or dangerous was not related to time spent on the task.

Age, gender and condition differences in attention

Age differences in performance on the Stroop test were analysed for response time (Fig. 1).

Analysis of variance for response times indicated that response time decreased with age (F (3, 120) = 45.9, $P < 0.001$), response times were slower for the interference condition (F 1, 120 = 820.25, $P < 0.001$), and there were no significant differences in response time between males and females. A significant interaction between age and condition was observed in that interference was less for adults than for children [F (3, 120) = 24.03, $P < 0.001$].

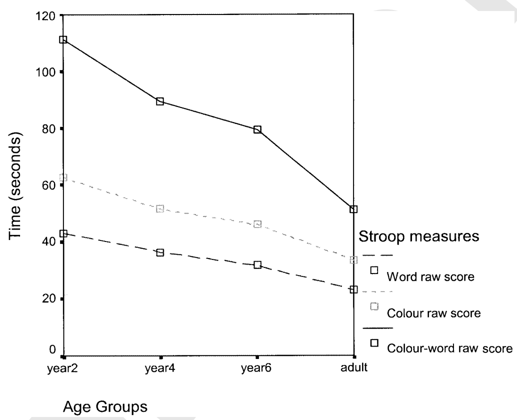

Figure 1. Stroop effect on different age groups using response time.

The relationship between attention and recognition of where to cross

Spearman correlations were calculated to determine the relationship between the Stroop effect and the number of correct identifications of safe and dangerous road-crossing sites, also between the Stroop test results and the time taken to identify crossing sites as safe or dangerous, separately for each age group. The interference measure of the Stroop test was calculated by taking the time taken to name the colour of XXXs (congruent) from the time taken to name the colour of colour words (incongruent) (Stroop 1935). In order to simplify the correlations, the two pedestrian task conditions were combined, and the mean score for the two conditions was used (Table 4).

Significant negative correlations were found between the accuracy of identifying safe and dangerous road-crossing sites and the speed of reading words in the Stroop test for Year 2 children, indicating that, as speed of processing increased, accurate identification also increased. Also, a marginally significant correlation was found between the interference measure of the Stroop test and accuracy for Year 2 children, indicating that, as interference increased, correct identification of safe and dangerous road-crossing sites decreased. How-

Table 4. Correlations between Stroop measures and accuracy scores and identification time separately for each age group

	Identification time				**Accuracy**			
	Y2	**Y4**	**Y6**	**Adult**	**Y2**	**Y4**	**Y6**	**Adult**
Word raw score†	−0.14	0.31*, P=0.04	0.14	0.09	−0.35*, P=0.02	−0.00	−0.03	−0.21
Colour raw score‡	0.01	0.24	0.08	0.23	−0.26	0.16	−0.34*, P=0.02	−0.25
Interference raw score§	−0.25	0.31*, P=0.04	−0.10	0	−0.28*, P=0.055	0.06	0.17	−0.07

†Time taken to read the words printed in black ink (congruent part).
‡Time taken to say the colour of XXXs (congruent part).
§Interference raw score=Colour word raw score–colour raw score.
*$P \leq 0.05$.

ever, there was no significant correlation between interference measures and accuracy for Year 4 and Year 6 children and adults. Furthermore, there was a significant positive correlation between the time taken to identify road-crossing sites and the interference measure and reading time of the Stroop test for Year 4 children, indicating that, as interference increased, the speed of identification decreased and faster processing was related to quicker identification respectively. Year 6 children's accuracy was related to speed of naming the colour of XXXs, indicating that, as speed of processing increased, accuracy also increased.

Discussion

The results indicate that the ability to identify safe and dangerous road-crossing sites increased with age and the ability to resist interference from irrelevant stimuli also increased with age. In addition, for Year 2 children, accurate identification was related to speed of processing and marginally to resistance to interference ability. Identification time for Year 4 children was related to the ability to resist interference and to the speed of processing. For Year 6 children, accurate identification was related to the speed of processing.

Regarding children's ability to recognize safe and dangerous road-crossing sites, as expected, younger children were less able to identify safe and dangerous road-crossing sites, supporting previous research by Ampofo-Boateng and Thomson (1991). Their identification time was longer than that of older children and adults. However, the non-significant difference between Year 4 and Year 6 children suggests that this increase does not appear to progress in a linear incremental fashion. A non-significant difference between the results of Year 6 children and adults was also noted. Previous researchers (e.g. Ampofo-Boateng & Thomson 1991; Demetre & Gaffin 1994) have compared children of different ages when examining their ability to identify safe and dangerous road-crossing sites; however, these authors did not use an adult comparison group. In the present study, an adult comparison group was included with the expectation that adults' performance at identifying safe and dangerous road-crossing sites would be much better than that of children. However, this expectation was not fully supported. Some of the road-crossing sites may have been too difficult even for adults to determine. The sites producing the most errors from adults and children were the junction, blind bend and brow of a hill. Alternatively, the findings of David *et al*. (1986) that sometimes children's road-crossing judgements may be less risky than the road-crossing judgements of adults may explain our results. Further research is needed comparing adults with children on a range of pedestrian sites before firm conclusions can be made.

The lack of gender differences in the ability to identify a road-crossing site as safe or dangerous is also consistent with previous research (e.g. Ampofo-Boateng & Thomson 1991). There were also no gender differences evident in the amount of time spent on deciding whether a site is safe or dangerous. Gender differences in accident rates (Chapman & O'Reilly 1999) cannot be explained by differences in identification of road-crossing sites.

In general, irrelevant information did not affect the ability of children and adults to identify safe and dangerous crossing sites but did affect the time taken to do so. This is consistent with the research literature on attention that irrelevant information decreases the speed of processing (Dempster & Corkill 1999). This decrease in speed would be more deleterious in a rapidly changing environment such as a traffic situation. It would also put younger children, who are generally slower than adults when negotiating traffic environments, in greater danger. The unanimated distractions used (adding more visual information) may not have been sufficiently demanding for the participants. For future research, an increase in irrelevant information may highlight the vulnerability of children to interference more, as it is argued that children would be more sensitive to distractions than adults when the amount of irrelevant information increases (Dempster & Corkill 1999). However, the amount of time taken to decide whether a road site is safe or dangerous did not affect accuracy. Distractions may be more important for other aspects of the road-crossing task not reported here, such as deciding when to cross the road.

Regarding the attention task, the ability to resist interference increased with age, but no gender differences were found. This is consistent with the study by Comalli *et al.* (1962). Our results confirm that speed of processing was important for all children in order to identify safe road-crossing sites quickly and accurately, although selective attention seemed to be important for Year 2 and Year 4 children. Children at 6–9 years with high sensitivity to interference were less accurate and slower at identifying road-crossing sites. Previous researchers such as Dunbar *et al.* (1999) found a relationship between attention and road-crossing behaviour. In their research, children who took less time to switch attention were more likely to show evidence of being aware of traffic, and children who were less distracted were less reckless in their road-crossing behaviour. Our results indicate that attention is required for identifying road-crossing sites quickly and accurately, especially for younger children. Therefore, it is suggested that, in designing road-safety training programmes for children, these aspects of cognition should also be addressed. The correlation between the measure of attention used (resistance to interference) and the road-safety measure used was low. We believe that this relationship is a conservative estimate of the importance of attention in developing pedestrian skills. Presenting participants with a computer-based task under controlled conditions facilitates the focusing of attention to the task in hand. The real pedestrian environment does not facilitate the focusing of attention; on the contrary, it is more likely to provide interfering and distracting stimuli. It is expected that the correlation between judgement of safe road-crossing sites and resistance to interference should be much higher in the natural environment. For future research, the computer-based test can be modified to produce more tasking demands on attention.

Foot *et al.* (1999) suggested that computer-based tasks may be useful for training in pedestrian skills. Relevant attention skills may also be trained in this way. The advantages of such tasks are that they allow control of variables, can be used to develop specific skills and are attractive to children. We have conducted preliminary studies on using computer animations to teach children how to identify safe and dangerous road-crossing sites with encouraging results. Further research is needed to determine which aspects of attention are most important for safe pedestrian behaviour and the type of distractions that are most deleterious for child and adult pedestrians.

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