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Finding a Safe Place to Cross the Road: The Effect of Distractors and the Role of Attention in Children's Identification of Safe and Dangerous Road-Crossing Sites

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Negotiating traffic requires the ability to focus attention on the traffic environment and ignore distracting stimuli. The aims of this study were (1) to examine the effect of distractors on children's ability to identify safe and dangerous road-crossing sites and (2) to examine the relationship between identification of safe/dangerous sites and attention (selective attention, attention switching, sustained attention and divided attention). Participants were 88 children (aged between 6 and 11 years) and 29 adults. Ability to identify safe and dangerous road-crossing sites was assessed using computer presentations of sites with and without visual and auditory distractions. Measures of attention were examined using the Test of Everyday Attention (child and adult versions). The ability to identify safe and dangerous road-crossing sites and performance on the attention tests were found to improve with increasing age. Correct identification of safe/dangerous road-crossing sites was related to selective attention and divided attention for children but not for adults. Road safety training should take into account the development of these skills. Copyright © 2007 John Wiley & Sons, Ltd.

Key words: pedestrian; child safety; attention development

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INTRODUCTION

'Of all the systems with which people have to deal everyday, road traffic systems are the most complex and the most dangerous' (World Health Organization, 2004, p.1.). Pedestrians are a particularly vulnerable group of road users, especially child pedestrians who have a proportionately higher casualty rate than adult

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pedestrians (Chapman & O'Reilly, 1999). Negotiating traffic requires cognitive and perceptual skills that may differ at each step in the pedestrian task (Vinje, 1981; Thomson, 1996). For example, the essential pedestrian task of detecting the presence of traffic involves visual search, focussing of attention on relevant information, counteracting distractions, auditory localization and co-ordinating visual and auditory information (Thomson, 1996). Given the complex nature of the pedestrian task the development of attention will be important for all aspects of road-crossing judgements.

Attentional skills can be broken down into a number of distinct functional systems that operate co-operatively (Posner & Peterson, 1990). The most widely recognized attentional processes are selective attention (the ability to attend to relevant stimuli and ignore a powerful competing distractor), sustained attention (maintaining vigilance to respond in the absence of external cues), the capacity to switch attention (the ability to engage, move and disengage attention in space) and divide attention (the ability to allocate attention efficiently to different tasks) (Manly, Robertson, Anderson & Nimmo-Smith, 1999; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994). These attention skills are believed to have different functional, psychophysiological and neuroanatomical bases (van Hover, 1974; Manly *et al.*, 2001; Posner & Peterson, 1990; Stuss, 1992) that continue to mature into early adolescence (Cooley & Morris, 1990).

Relevant developmental theories of information processing explain age differences in children's attention by improvements in information-processing speed (Kail, 1991) and improvements in mechanisms of attentional control such as the ability to inhibit irrelevant information (Dempster, 1992; Harnishfeger, 1995). These two theoretical perspectives are not considered to be mutually exclusive by several researchers (e.g. Hommel, Li & Li, 2004). Experimental studies have found that different attention skills develop at different ages with focussed attention reaching adult levels during mid childhood, and other aspects of attention continuing to progress into adolescence (Cooley & Morris, 1990). Pearson and Lane (1991) found switching attention to develop between 8 and 11 years. Sustained attention has been found to increase in the preschool age ranges and a large increase in auditory sustained attention has been found at age 8–9 years (Levy & Hobbes, 1979; Ruff & Lawson, 1990). Developmental studies of selective attention have suggested that children below 8 years of age are less able to attend to relevant information and ignore irrelevant information than are older children and adults (Miller & Weiss, 1981; Welsh, Pennington, & Groisser, 1991; Trick & Enns, 1998).

Studies of children's accidents have examined the contribution of different attention processes. For example, the ability to allocate attention to different aspects of a perceptually complex road environment (divide attention) may be an important skill that develops with age. In this respect, Malek, Guyer and Lescohier (1990) refer to children's difficulties in dividing attention in their discussion of the causes of child pedestrian injury. Dunbar, Hill and Lewis (2001) found that children who were 'less reckless' at crossing a road were those who were able to maintain concentration when challenged by a distracting event, suggesting that sustaining attention and inhibiting interference may be important for pedestrians. Also, switching attention from one task to another, or from one location to another, may be essential for pedestrians, for example when vehicles are approaching in different directions. Dunbar, Lewis, and Hill (1999) found that children who were better at switching attention were more likely to show awareness of traffic when crossing a road. Other aspects of attention found to be important for children's pedestrian behaviour include the ability to resist

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interference (Tabibi & Pfeffer, 2003a, 2003b) and selective attention (Hill, Lewis & Dunbar, 2000). Selective attention to features of the environment relevant to *where* to cross a road as well as *when* to cross a road are likely to be necessary to effective pedestrian behaviour.

The focus of the current study is on children's ability to identify safe and dangerous road-crossing sites, a vital aspect of the pedestrian's interaction with the traffic system that young children find difficult. In this regard, Ampofo-Boateng and Thomson (1991) found that children under 9 years were not able to recognize dangerous crossing sites. Also, Demetre (1997) suggested that the ability to appreciate the dangers of selecting a crossing point with limited visibility develops from about 7–8 years. Following our earlier studies (e.g. Tabibi & Pfeffer, 2003a), the technique used in this paper is a computer graphics presentation of a selection of road-crossing sites varying in complexity. Although real traffic environments present the most ecologically valid test of children's pedestrian abilities, they also present problems for the researcher regarding control and testing of variables as well as safety of the research participants. Computer animations (Foot, Tolmie, Thomson, McLaren, & Whelan, 1999) have been used to overcome these problems. Comparable results have been found for analysis of children's abilities (Foot *et al.*, 1999). Also, the UK Department for Transport has promoted the use of computer presentations as part of child pedestrian training (Department for Transport, 2002; Thomson *et al.*, 2005).

The aims of this study were to examine age differences in children's ability to identify safe and dangerous road-crossing sites related to age differences in attention. Integrating the results of research literature on attention and on road safety awareness led to the choice of three age groups of children (6–7 years, 8–9 years and 10–11 years) for comparison with an adult group. We predicted age differences in identification of safe and dangerous road-crossing sites and age differences in attention. For this study we were interested in several aspects of attention. First, the effect of distractors on identification of road-crossing sites was examined (speed of processing as well as accuracy). Also, the location of distractors was investigated following Humphrey's (1982) finding that children's ability to ignore distractions is affected by the location and type of distraction. In addition, the relationship between ability to identify safe and dangerous road-crossing sites and measures of selective attention, attention switching, sustained attention and divided attention was investigated.

METHOD

Participants

A total of 117 participants, 88 children and 29 adults in four age groups as follows: 29 children aged 6–7 years (14 males and 15 females, mean age 6.4 years, S.D. = 0.47), 30 children aged 8–9 years (14 males and 16 females, mean age 8.3 years, S.D. = 0.45), 29 children aged 10–11 years (15 males and 14 females, mean age 10.4 years, S.D.= 0.48) and 29 adults (10 males and 19 females, mean age 23.3 years, S.D. = 9.3).

Measuring identification of safe and dangerous road-crossing sites

The skills required by pedestrians to identify a safe place to cross the road were assessed by a computer-presented task showing street scenes. The task was based

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on previous research on pedestrian skills (e.g. Vinje, 1981; Ampofo-Boateng & Thomson, 1991) and was designed in consultation with Lincolnshire County Council Road Safety Education Officers.

The task featured the image of a boy standing at the edge of a road facing towards the road. Ten road-crossing sites were presented separately; five 'safe' sites and five 'unsafe' sites (see Table 1). The 'safe' scenes included designated road-crossing sites (such as light controlled crossings, pedestrian refuge, road-crossing patrol, etc.) and the 'unsafe' scenes included sites where views of oncoming vehicles would be restricted or complex (such as 'blind' bends and complex junctions). Decisions about which sites to include in each group were made in consultation with the Road Safety Education Officers. Three conditions were designed using a total of 10 road-crossing sites in each condition, without distractors, with on-screen auditory–visual distractors (On-screen A–V) and with off-screen auditory distractors (Off-screen A). For the 'Without Distractors' condition, still images of road-crossing sites were presented with no additional animations. The on-screen distractors included vision and sound such as an aeroplane moving across the top of the screen with appropriate sound effects relayed through the built-in computer monitor speakers. The auditory–visual distractors were the only moving features within each of the scenes. The off-screen distractors were sounds such as a boy shouting, cats fighting, a train moving. The off-screen distractors were presented through small speakers located 30 in to the left or right of the computer monitor. The technical demands of including a visual element to the off-screen distractors were in excess of the space available in a school setting. Therefore off-screen distractors were auditory only (presented in a different mode as well as different location). Choice of distractor for each road-crossing site depended on the space available within the image to include a visual animation (for example, the aeroplane was included in

Table 1. Road-crossing sites and distractors

Crossing site		Distractor Image	Type	Position
'Zebra' crossing	Safe	Set 1: Cats meowing	Auditory	Off-screen
		Set 2: Aeroplane	Auditory-visual	On-screen
Blind bend	Unsafe	Set 1: A boy shouting	Auditory	Off-screen
		Set 2: Dog barking	Auditory–visual	On-screen
'Pelican' crossing on green man	Safe	Set 1: A cat walking in the rain	Auditory–visual	On-screen
		Set 2: Cats fighting	Auditory	Off-screen
Roundabout	Unsafe	Set 1: Sound of a horse	Auditory	Off-screen
		Set 2: Children playing in park	Auditory–visual	On-screen
Traffic island	Safe	Set 1: Marching sound	Auditory	Off-screen
		Set 2: Road construction	Auditory–visual	On-screen
Traffic light on red	Safe	Set 1: Dog barking	Auditory–visual	On screen
		Set 2: Marching sound	Auditory	Off-screen
Between parked cars	Unsafe	Set 1: Road construction	Auditory–visual	On-screen
		Set 2: Cats meowing	Auditory	Off-screen
Road-crossing patrol person	Safe	Set 1: Aeroplane	Auditory–visual	On-screen
		Set 2: Sound of a train	Auditory	Off screen
Brow of a hill	Unsafe	Set 1: Children playing in park	Auditory–visual	On-screen
		Set 2: Sound of sea birds	Auditory	Off-screen
Complex junction	Unsafe	Set 1: Man riding a bicycle	Auditory–visual	On-screen
		Set 2: A boy shouting	Auditory	Off-screen

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images where sufficient skyline was available). Two sets of road-crossing sites were used for the distractor conditions, this was to enable an even distribution of on-screen and off-screen distractors across safe and unsafe road-crossing sites. The sets differed in order of image presentation and in the combination of distractors assigned to each image (see Table 1). Each set comprised of 10 images plus one practice trial.

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 two keys on a response-key box connected to the computer. A green key was used to indicate a safe crossing site and a red key to indicate an unsafe crossing site.

Dependent variables were accuracy and identification time. Accuracy was measured by the percentage of correct identifications of road-crossing sites as safe or unsafe. Identification time was recorded in milliseconds.

Measuring attention

Four subtests of the Test of Everyday Attention for Children (TEA-Ch) (Manly *et al.*, 1999) and four compatible subtests of the adult Everyday Attention Test (TEA) (Robertson *et al.*, 1994, Version A) were used to measure selective attention, sustained attention, attention switching and divided attention.

Selective attention (children): 'Sky Search'. Twenty identical pairs of spaceships (the target) were distributed among 108 non-identical pairs of spaceships (distractors) on an A2 sheet. Participants were expected to find and circle the identical pairs of spaceships quickly and accurately. Motor speed is also measured by circling all spaceships as quickly as possible on a separate sheet.

Selective attention (adults): 'Telephone Search'. Participants were asked to find specific symbols located next to telephone numbers on a simulated telephone directory page. Twenty targets were distributed among 126 distractors. Unlike the children's version, this subtest does not include a measure of motor speed.

Dependent variables were accuracy and time. Accuracy was measured by the number of targets found (maximum score = 20). Time per target was measured by the time taken to complete the search task divided by the number of targets found. For children, attention was measured by the search time per target minus the motor skills time per target.

Sustained attention (children): 'Score!' A series of tones presented on an audiotape produced at different time intervals from 500 to 5000 ms. There were 10 strings of tones excluding two practice strings. Participants count the number of tones for each string.

Sustained attention (adults): 'Elevator Counting'. A series of tones presented on an audiotape (7 strings of tones and two practice strings). As for the children's version, participants count the number of tones on each string.

The dependent variable accuracy was measured by the number of correct tone strings (for children, maximum score = 10; for adults, maximum score = 7).

Attention switching (children): 'Creature Counting'. Ten A4 cards depicting a chain of creatures on each card with arrows pointing up or down interspersed among the creatures. Participants should count up or down the chain depending on the direction of the arrows. The direction of the arrows requires the child to switch the way the task is performed.

Attention switching (adults): 'Visual Elevator'. Ten A4 cards picturing a series of elevators on each card with arrows pointing up or down distributed among the

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elevators. Participants should count up or down the elevators following the direction of the arrows.

The dependent variables were accuracy and time. Accuracy was measured by the number of correct trials (cards) attempted with a maximum of 10 (7 for children). Time was measured by the total time taken on correct trials divided by the number of arrows.

Divided attention (children): 'Sky Search Dual Task'. The ability to allocate attention efficiently to different tasks was measured by asking children to do the Sky Search and Score! subtests simultaneously.

Divided attention (adults): 'Telephone Search while Counting'. Participants were required to perform both the Telephone Search task and the Elevator task simultaneously.

A decrement score was calculated to find the difference between scores on the search task when performing the counting task and scores on the search task when not performing the counting task (the selective attention scores). For a full description of the method of calculation see Manly *et al.* (1999) and Robertson *et al.* (1994).

Procedure

All children of the required age group in school on the day of data collection with consent to participate took part in the investigation. The pedestrian task and attention tests were administered in two sessions. In the first session, three subtests of TEA-Ch (Sky Search, Score! And Sky Search Dual Task) were administered. In the second session the Creature Counting subtest of TEA-Ch and the pedestrian task were administered. Each session took about 20 min. Half the children in each age group completed Set One of the pedestrian task and half completed Set Two. All tests were administered in a quiet room in the school.

For adults the attention tests and the pedestrian task were administered in one session. The pedestrian task was completed first followed by the attention tests. For the pedestrian task the conditions were counterbalanced and half the adults completed Set One and half completed Set Two. Testing took place in a Psychology laboratory and was completed in about 35–40 min.

RESULTS

The results are presented as follows. Age and condition effects for the computer-based pedestrian task are presented first, followed by age effects on the attention tests, then finally the relationship between attention and the computer-based pedestrian task.

The effect of distractions on identification of road-crossing sites

Table 2 presents the percentage of correct responses for all age groups in identifying safe and unsafe road-crossing sites. A factorial ANOVA with repeated measures on one factor was computed to examine age, gender and condition effects. Although gender was also included in the analysis, there were no significant gender effects for any of the measures. A significant age effect was found ($F_{3,107} = 5.57$, $p < 0.001$). The percentage of correct responses increased with age up to age 10–11 years; however, there was no difference between the mean

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Table 2. Percentage correct identifications of safe and unsafe road-crossing sites by condition and age

Age group	Without distractions		With off-screen auditory distractions		With on-screen auditory–visual distractions	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
6–7 years	65.4	12.6	58.3	20.5	61.7	13.7
8–9 years	68.6	13.0	65.4	20.5	60.1	18.5
10–11 years	77.5	12.1	73.7	15.8	69.6	18.6
Adult	77.5	13.2	74.7	20.2	68.2	22.9

Table 3. Response times (in milliseconds) for identification of safe and unsafe road-crossing sites by age and condition

Age group	Without distractions		With off-screen auditory distractions		With on-screen auditory-visual distractions	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
6–7 years	2639.8	1260.2	5007.1	4238.4	4462.0	2554.2
8–9 years	2509.1	1310.5	3755.4	2276.2	3112.0	1124.5
10–11 years	2429.8	841.2	3572.6	1809.3	3235.7	1462.9
Adult	1529.4	640.3	1621.9	770.5	1701.3	712.3

percentage correct response for 10–11 year-olds and adults. A significant condition effect was also found ($F_{2,214} = 7.32$, $p < 0.001$) showing that the presence of distractors had an adverse effect. Pairwise comparisons of the results for conditions using Bonferroni adjustment indicated that, overall, the percentage of correct responses in the Without Distractors condition was higher than in both the On-screen A–V ($p = 0.04$) and Off-screen A conditions ($p = 0.001$). However, there was no significant difference between the two distractor conditions. Further comparisons of the two distractor conditions with the Without Distractors condition for each age group separately found significantly more correct responses in the Without Distractors condition than in the On-screen A–V condition for the 8–9 year-olds ($p = 0.02$), 10–11 year-olds ($p = 0.01$) and for the adults ($p = 0.01$). Although the Off-screen A distractors appeared to have the most deleterious effect for the youngest age group, this did not reach statistical significance ($p = 0.07$). No significant difference was found between the Off-screen A distractors condition and the Without Distractors condition or between the two distractor conditions for any of the age groups.

Table 3 presents the time taken to identify safe and unsafe road-crossing sites by age, gender and condition. 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 time taken to identify safe and unsafe road-crossing sites decreasing with age ($F_{3,107} = 11.89$, $p < 0.001$). There were no significant effects of gender. A significant effect of condition was found ($F_{2,214} = 23.75$, $p < 0.001$), such that identification time was longer when distractors were present. In addition, there was a significant interaction between condition and age group ($F_{6,214} = 3.41$, $p < 0.003$): the effect of distractions was greater for younger children than for adults. Pairwise comparisons of the conditions using Bonferroni adjustment indicated that, for all age groups combined, there was a significant difference between the Without Distractors condition and the Off-screen A

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distractors condition (p = 0.001), between the Without Distractors condition and the On-screen A–V distractors condition (p = 0.001) and between the Off-screen A and On-screen A–V distractors conditions (p = 0.03). Identification time was longer with Off-screen A distractors than with On-screen A–V distractors.

Age differences in attention

Table 4 presents the means and standard deviations of the raw scores for the children's attention tests and compatible adult attention tests. Table 4 also presents the means and standard deviations of the raw scores for the remaining adults' attention test results.

Analysis of variance was used to compare the three age groups of children and the children and adults for compatible measures (attention tests from the adult version of TEA that were compatible with tests from the children's version of TEA-Ch). For all attention measures, significant differences between age groups were found (see Table 4 for F values).

Post hoc analyses were carried out using Tukey HSD. For selective attention ('Sky Search') accuracy, 6–7 year-old children's scores were significantly lower than the scores for all other age groups. There were no significant differences between any of the other age groups on this test. For the time measure of selective attention ('Sky Search' time), 6–7 year-old children were significantly slower than 8–9 year-old and 10–11 year-old children. Also, 8–9 year-old children were significantly slower than 10–11 year-old children. For the attention score (incorporating an allowance for motor skills), 6–7 year-old children were significantly poorer than 8–9 year-old and 10–11 year-old children but there was no significant difference between 8–9 year-old and 10–11 year-old children.

For sustained attention ('Score!' number correct) 6–7 year-old children were significantly poorer than 10–11 year-old children but there were no significant differences between 8–9 year-old and 6–7 year-old children or between 8–9 year-

Table 4. Age group comparisons for subtests of the test of everyday attention (TEA-Ch And TEA)

Attention skills	6–7 years		8–9 years		10–11 years		Adult		F	df	P
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.			
Selective attention											
Number correct	16.10	3.05	18.70	1.50	18.20	2.20	18.70	1.85	8.7	3, 111	<0.001
Time	10.10	3.70	7.10	2.20	5.04	0.96	2.94	0.59	28.19[a]	2, 83	<0.001
Attention score (children only)	7.80	3.40	4.90	1.60	3.60	0.84	Na	na	25.8[a]	2, 80	<0.001
Sustained attention											
Number correct	8.00	1.50	8.70	1.20	8.90	1.30	6.65	0.93	3.43[a]	2, 83	<0.05
Switching attention											
Number correct	4.70	1.40	4.70	1.50	5.10	1.30	7.93	1.84	28.7	3, 108	<0.001
Time	6.00	1.30	4.80	0.74	3.70	0.60	3.37	0.67	49.1	3, 104	<0.001
Divided attention											
Decrement score	7.20	6.10	1.80	3.20	3.02	3.40	0.59	1.24	15.6	3, 111	<0.001

[a]Comparisons for children only (adult group not included).

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old and 10–11 year-old children. For switching attention ('Creature Counting' number correct) all groups of children were significantly less accurate than adults but there were no significant differences between the three age groups of children. For the time measure of switching attention, 6–7 year-old children were significantly slower than all other age groups, also 8–9 year-old children were significantly slower than 10–11 year-old children and adults but 10–11 year-old children were not significantly different to adults. For divided attention 6–7 year-old children were significantly poorer than 8–9 year-old children, 10–11 year-old children and adults. There were no other significant age differences for this measure.

The relationship between attention measures and identification of safe and dangerous road-crossing sites

As significant differences between road-crossing task conditions were evident, correlations were calculated with attention test results for each condition separately. The raw scores of all the attention tasks were converted to age-scaled scores to make the children's scores compatible with those of adults. The higher scaled scores on all tests indicate better performance (Robertson *et al.*, 1994; Manly *et al.*, 1999). Scaled scores of both TEA-Ch and TEA had a mean of 10 and a standard deviation of 3 (Robertson *et al.*, 1994; Manly *et al.*, 1999). These scaled scores were consistent across children and adult groups. To assess the normality of data, the one-sample Kolmogorov–Smirnov Z-test was conducted. For those results with skewed data, square roots were computed (Tabachnick & Fidel, 1996) and used for the correlations.

Significant correlations between attention measures and identification of road crossing sites scores are presented in Table 5. Few significant correlations between attention measures and identification of road crossing sites were found.

Table 5. Significant correlations between attention test measures and pedestrian test measures

Age group	Measures	Correlation
6–7 years	On-screen A–V distractions condition: identification of road crossing sites and selective attention	$r_{27} = 0.47, p < 0.001$
	Off-screen A distractions condition: identification of road crossing sites and divided attention	$r_{28} = 0.37, p < 0.02$
8–9 years	Without distractions condition: identification of road crossing sites and divided attention	$r_{29} = 0.39, p < 0.02$
	On-screen A–V distractions condition: time to identify road crossing sites and selective attention (time scaled score)	$r_{29} = -0.46, p < 0.01$
	On-screen A–V distractions condition: time to identify road crossing sites and divided attention	$r_{28} = 0.37, p < 0.02$
10–11 years	On-screen A–V distractions condition: time to identify road crossing sites and selective attention (time scaled score)	$r_{28} = -0.387, p < 0.02$
	On-screen A–V distractions condition: time to identify road crossing sites and selective attention (time scaled score)	$r_{28} = -0.43, p < 0.02$

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No significant correlations were found for sustained attention and divided attention for any of the age groups. No significant correlations were observed for adults.

For selective attention, children aged 6–7 years with poor ability in selective attention correctly identified fewer safe/dangerous road-crossing sites in the On-screen A–V distractions condition. For the 8–9 year-olds and the 10–11 year-olds, children with poor selective attention spent longer time identifying the crossing sites (in the On-screen A–V distractions condition for 8–9 year-olds and in both the On-screen A–V and Off-screen A distractors conditions for 10–11 year-olds). For divided attention, children aged 6–7 years with high ability to divide their attention were better able to identify safe/dangerous road-crossing sites in the Off-screen A distractions condition. Children aged 8–9 years with high ability to divide their attention (better attentional capacity) were better able to identify safe and dangerous road-crossing sites in the Without Distractions condition. Also, 8–9 year-olds with high ability to divide their attention took longer time to identify the crossing sites.

DISCUSSION

As expected, the results indicated that the ability to identify safe and dangerous road-crossing sites increased with age up to age 10–11 years. No significant difference was found between the older children and adults. This finding supports previous research by Ampofo-Boateng and Thomson (1991). However, a difference between adults and 10–11 year-olds in terms of time taken to identify safe and dangerous crossing sites was evident, with 10–11 year-olds taking much longer than adults in all conditions. So, although 10–11 year-olds appear to have reached adult levels of ability at identifying safe and dangerous crossing sites, they take longer to do so than adults.

Distractors affected correct identification of road-crossing sites for 8–9 year-olds, 10–11 year-olds and adults when the distractor was on-screen auditory–visual. However, contrary to expectations, distractors did not significantly affect the accuracy of the 6–7 year-old children's judgements. It is possible that the younger children's responses were not affected by distractors because of the type of road crossing sites used in this experiment, particularly the 'safe' road-crossing sites. 'Safe' road crossing sites made up half of the test items and most of these sites were designated crossings. Previous researchers (Ampofo-Boateng & Thomson, 1991) have found that young children have most difficulty in identifying 'dangerous' sites. That is, young children are more likely to say that a dangerous site is safe than they are to say a 'safe' crossing site is dangerous.

Overall, the time taken to identify safe crossing sites decreased with age, suggesting development in cognitive efficiency and supporting Kail's (1991) account of development involving increase in processing speed. Also, time taken to identify safe crossing sites was affected by distractors; identification time was longer with distractors and more so with off-screen auditory distractors compared to on-screen auditory–visual distractors. Considering the results for correct responses and identification time together, the without-distractors condition produced the most accurate and fastest responses for all age groups. Interestingly, the 8–9 year old and 10–11 year-old children's responses to the on-screen distractions were less accurate but faster than their responses to the off-screen distractions. These older children appeared to trading accuracy against speed when making judgements about road-crossing sites.

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The nature of the distractors used in this experiment needs further comment. The on-screen distractors were both visual and auditory, whereas the off-screen distractors were only auditory. The off-screen distractors would be easier to ignore as they draw on one sensory modality rather than two and were located away from the main task. Previous research by Humphrey (1982) found that distractions external to and easily discriminable from the task had less effect on children's performance than distractions embedded in the task. Our results for correct responses support this for all but the youngest children. However, the results for identification time showed the greatest effect for off-screen auditory distractors. This may be because participants were not told to expect distractors, so they were not likely to attempt to focus on the main task and inhibit their responses to the distractor. The off-screen auditory distractors may have caused participants to glance away from the screen, decreasing speed of information processing. The distractions used in this experiment were limited and to some extent, artificial. Also, the comparison between distractors involved modality as well as location. In the real traffic environment complex visual and auditory distractions are abundant and pedestrians may also be managing internal distractions from thoughts and emotions. Further research is needed comparing a wider range of distractor variables before firm conclusions can be reached about the ability of participants to ignore different types of distractors.

Consistent with previous studies (Manly *et al.*, 2001), a developmental change was evident in selective attention, sustained attention, switching attention and divided attention. Children aged 6–7 years were significantly poorer than 8–9 year-old, 10–11 year-old children and adults on all attention test measures. Significant differences between 8–9 year-old children and 10–11 year-old children were only observed for two attention measures (switching attention: 'Creature Counting' and selective attention: 'Sky Search' time). All children were significantly poorer than adults at 'Creature Counting' accuracy (one of the switching attention measures). Regarding selective attention, Welsh *et al.*, (1991) found that efficiency of visual selective attention develops at around 6 years of age. The current study suggests that selective attention is developed by 8–9 years, consistent with Miller and Weiss (1981) and Trick and Enns (1998). The switching attention test used as part of TEA-Ch test (Manley *et al.*, 1999) provides quite a limited switch in attention (the participant is expected to follow a change in direction of arrows). However, the results obtained using this test support the findings of Gale and Lynn (1972) and Pearson and Lane (1991) that the efficiency of switching attention develops late in childhood.

Regarding the relationship between the simulated pedestrian task results and the attention test results, the only attention measures found to be related to the identification of safe and dangerous road-crossing sites were selective attention and divided attention. Sustained attention and attention switching were not related to the pedestrian task for any of the age groups. Sustained attention may be more important for making decisions about *when* to cross the road rather than *where* to cross the road (e.g. remaining vigilant when standing at the roadside, waiting for a gap in the flow of traffic) as found by Dunbar *et al.* (2001). Similarly, attention switching may be more important for deciding *when* to cross than for identifying *where* to cross (e.g. switching attention to vehicles moving in different directions) as found by Dunbar *et al.* (1999). Further studies using a more pronounced attention switch than provided by TEA-Ch may be needed to determine the role of attention switching in a range of pedestrian decisions.

The ability of 6–7 year-old children to identify safe and dangerous road-crossing sites was significantly related to both selective attention and divided

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attention. Children with high ability to select relevant information and ignore irrelevant information, and those with a higher ability to divide their attention between two tasks, were more accurate in identifying the crossing sites. Interestingly, selective attention was associated with accuracy scores in the condition with on-screen auditory–visual distractors, while divided attention was associated with accuracy scores in the condition with off-screen auditory distractors. The ability of 8–9 year-olds to identify safe and dangerous road-crossing sites was related to divided attention in the without distractors condition and the time taken to identify the crossing sites was related to selective attention in the on-screen auditory–visual distractors condition. For 10–11 year-old children, the time taken to identify safe and dangerous road-crossing sites was related to the time aspect of selective attention for both the on-screen auditory–visual distractors and off-screen auditory distractors conditions. From these results, the most consistent finding is the relationship between selective attention and performance in the on-screen auditory–visual distractors condition. Selective attention is deployed for distractors embedded in the task, supporting Ruff and Rothbart's (1996) discussion of attention development. No relationships between attention test measures and the identification of safe and dangerous crossing sites was observed for adults, supporting previous results (Tabibi & Pfeffer, 2003a).

Among the limitations of the results are the relatively few significant correlations between the pedestrian task and the attention tests. Further research is needed to confirm the results and establish the strength of the relationship between these attention measures and the pedestrian task. Also, our results have provided an estimation of the role of attention and distractions on a controlled pedestrian decision-making task. The procedure used and the controlled experimental conditions are likely to facilitate the focusing of attention to the immediate task. The real pedestrian environment does not facilitate the focusing of attention, therefore the role of attention may be much more pronounced than reported in our results. In the On-screen auditory–visual task, the only moving object in the scene was the distractor whereas in the real pedestrian environment there are many moving features. In addition, the real pedestrian environment provides strong distractions, sometimes distractions that are personal to the child (such as conversations with friends while crossing the road) and thus more difficult to ignore. Identifying safe and dangerous road-crossing sites is only one aspect of the road-crossing task that may be affected by differences in attentional skill. Other aspects, such as making decisions about speed and direction of traffic, as well as making judgements about safe traffic gaps, may be strongly affected. It is recommended that children's attention capabilities be given full consideration when developing pedestrian education programmes for children and their careers.

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