# Neuropsychological Functions and Pedestrian Behaviour in Children with and without ADHD

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## Author's Declaration

This thesis is the result of the author's original research. It has been compiled by the author and has not been previously submitted for examination which has led to the award of a degree.



Signed:

Date:

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## List of Abbreviations

| | |
|---|---|
| ADHD | Attention Deficit Hyperactivity Disorder |
| ANOVA | Analysis of Variance |
| ANCOVA | Analysis of Covariance |
| APA | American Psychiatric Association |
| BADS | Behavioural Assessment of Dysexecutive Syndrome |
| BPVS | British Picture Vocabulary Scale |
| BSE | Between Search Errors |
| CAMHS | Child and Adolescent Mental Health Service |
| CANTAB | Cambridge Neuropsychological Testing Automated Battery |
| CBQ | Child Behaviour Questionnaire |
| CGT | Cambridge Gambling Task |
| CNT | Contingency Naming Task |
| CPT | Continuous performance test |
| CU | Conceptual Understanding |
| DBRS | Disruptive Behaviour Rating Scale |
| DEX | Dexamfetamine |
| DfT | Department for Transport |
| D-KEFS | Delis-Kaplan Executive Function System |
| DMtS | Delayed Match to Sample Task |
| DSM | Diagnostic and Statistical Manual of Mental Disorders |
| EF | Executive Functioning |
| FASD | Foetal Alcohol Spectrum Disorder |

| | |
|---|---|
| FSM | Free school meals |
| IR | Immediate release |
| LEA | Local Education Authority |
| MANOVA | Multivariate Analysis of Variance |
| MPH | Methylphenidate |
| MR | Modified release |
| NEPSY | NEuroPSYchological Assessment |
| NHS | National Health Service |
| NICE | National Institute for Clinical Excellence |
| NRES | National Research Ethics Service |
| OCD | Obsessive Compulsive Disorder |
| ODD | Oppositional Defiant Disorder |
| PFC | Prefrontal Cortex |
| R&D | Research and Development |
| RCT | Randomised controlled trial |
| SCRN | Scottish Children's Research Network |
| SD | Standard Deviation |
| SDQ | Strengths and Difficulties Questionnaire |
| SES | Socioeconomic status |
| SIGN | Scottish Intercollegiate Guidelines Network |
| SIMD | Scottish Index of Multiple Deprivations |
| SSRT | Stop Signal Reaction Time |
| SST | Stop Signal Task |
| STM | Short Term Memory |

| | |
|---|---|
| SWM | Spatial Working Memory |
| TBI | Traumatic brain injury |
| ToM | Theory of Mind |
| TTC | Time to contact |
| UN | United Nations |

**Abstract**

This thesis examines the development of pedestrian skill level and the extent to which cognitive functioning underpins this amongst children with and without Attention Deficit Hyperactivity Disorder (ADHD). Three studies are reported, the first of which is an examination of the development of three pedestrian skills (safe place finding, visual gap timing and predicting road user intentions) and four aspects of cognitive function amongst typically developing children aged 5 to 12 years. Results from the first study revealed clear age related improvement in both pedestrian skill level and cognitive function. Inhibitory control, spatial working memory as well as non-executive delayed short term memory (but not risk taking) predicted children's pedestrian skill level. The second study examined developmental differences in pedestrian skill level and cognitive function by comparing the abilities of medication naive children with ADHD and matched controls aged 5-12 years on the same three tasks assessing pedestrian skill level and three aspects of cognitive function. Findings from the second study revealed significant between group differences in both cognitive function and pedestrian skill level such that children with ADHD performed markedly less well than controls. Whilst inhibitory control, spatial working memory and delayed short term memory predicted pedestrian skill level for control children, these relationships were for the most part, absent amongst children with ADHD. The final study was a longitudinal follow up study of a subset of the children with and without ADHD who took part in study 2. In study 3 the same tasks were administered to children at a mean time of 14 months following their participation in study 2, by which point all of the children

with ADHD were being treated with stimulant medication. The findings of study 3 revealed medication had normalised the performance of children with ADHD on tasks assessing inhibitory control and non-executive delayed short term memory but had no impact on spatial working memory. Medication had also normalised performance on two of the three tasks assessing pedestrian skill level and improved most measures of performance on a third. These results have implications for clinicians and educators working with children with ADHD and highlight scope for future research to develop and trial interventions which take account of the relationship between cognitive function and pedestrian skill level amongst both typically developing children and the more vulnerable group of children with ADHD.

# Chapter 1

# General Introduction

## 1.1 The Problem of Child Pedestrian Injuries

Accidental injuries have become the leading cause of death and serious injury in the developed world (Patel & Sandell, 2013), one of the most common types of which are road accidents. Indeed, road accidents account for almost 1.3 million deaths globally each year with almost 50 million people seriously injured or permanently disabled (UN Road Safety Fund, 2011). Road traffic injury is also the number one cause of death for young people specifically (UN Road Safety Fund, 2011) with pedestrian accidents being one of the most common types (World Health Organisation, 2013). This places considerable strain on health services and makes traffic accidents, particularly those involving children, an international public health concern (World Health Organisation, 2004).

When involved in an accident, pedestrians are almost 20 times as likely to be killed as drivers and children are amongst the most at risk (World Health Organisation, 2013). Given most early experience of traffic is acquired from the perspective of a pedestrian (as children engage in extracurricular pursuits, exercise and walk to and from school), it follows most road accidents in which children are killed or seriously injured feature children as pedestrians (Transport Scotland, 2010a, 2015). Therefore, while unintentional injury is the leading cause of pediatric mortality, killing more children aged 1 – 18 than the next 20 causes of death combined (US National Centre for Injury Prevention and Control, 2010) child pedestrian accidents pose one of the most significant threats.

In Scotland, in 2013, there were 464 child pedestrian casualties compared with 110 children injured as cyclists and 414 injured as passengers in cars (Transport Scotland, 2015). Child pedestrians are also disproportionately vulnerable to serious injury or death compared with pedestrians who are adults (Rodriguez & Brown, 1990; Singh & Yu, 1996). Child pedestrian casualty rates in Scotland (2009) were between 3 and 4 times higher than the corresponding rates for pedestrian casualties amongst adults (Transport Scotland, 2010a, 2015). This is in spite of children's lower exposure to traffic (and associated risk) and likely reflects the different ways in which children and adults use the road (Downswell, Towner, Simpson & Jarvis, 1996).

Almost 15 years ago, Roberts (2002) predicted that by 2020 road traffic accidents would have moved from 9th to 3rd place in the world ranking of the burden of disease, with child pedestrian accidents accounting for a disproportionately large part of this burden. In the years prior to the publication of this thesis, the UK Department for Transport reported a 4% rise in overall road fatalities and 5% rise in the number of children seriously injured (Department for Transport, 2015). Pedestrian fatalities specifically rose by 12% in this period, accounting for three quarters of the overall increase between 2013 and 2014 (Department for Transport, 2015). This suggests Roberts' 2002 prediction will likely be realised. This reflects an ongoing problem which appears to be growing.

Although the human cost of pedestrian accidents is immeasurable, high accident rates also place an accordingly high financial burden on society. Each road fatality costs the taxpayer over £1.5 million and every serious accident costs more than £170 thousand (Road Casualties Scotland, 2007). Yet pedestrian accident trends appear remarkably similar year on year and indeed from one country to the next (Sengoelge, Hasselberg & Laflamme, 2010) which suggests not enough is being done to address the problem. The alarming consistency in pedestrian accident rates was acknowledged over 20 years ago by Thomson (1996) who highlighted such consistency suggests accidents do not happen 'by accident', but rather that constant factors are at work which in turn means accidents may be predictable and also to some extent preventable.

It is when we consider this, that the need and scope to act to reduce them becomes most salient. Yet the process approach to childhood injury described by Peterson, Farmer and Mori (1987) highlights the complexity of attempting to do so, because injuries are not simply physical states, but rather the end result of a series of complex interactions between the child, the environment and the child's perception and understanding of it. Indeed, the complex psychological processes required for the accurate perception, processing and integration of environmental information which pedestrians must use in order to undertake a safe road crossing is substantial (Barton & Morrongiello, 2011). However, it is only fairly recently that research has begun to acknowledge that pedestrian skill level is an important and psychologically complex factor which may contribute towards pedestrian accident rates and only very recently indeed that psychologists have moved to study the cognitive underpinnings of safe pedestrian behaviour empirically.

**1.2 Changing Views and Approaches to Intervention**

Traditional approaches to studying child pedestrian safety largely focused on describing accident trends and pedestrian casualty rates statistically (Rivara & Barber, 1985; Rivara & Mueller, 1987). Early correlational studies highlighted factors which appeared to predispose some groups (such as children and the elderly) to pedestrian injury more than others. Dougherty, Pless and Wolkins (1990) for example argued that children from low income families were more likely to be injured than those from more affluent backgrounds. Some studies reported differences in accident involvement between ethnic groups (Agran, Winn & Anderson, 1996; Onwuachi-Saunders & Hawkins, 1993) while others suggested children with family illness (Backett & Johnston, 1959) and those who are looked after or accommodated by the state (Pless, Peckham & Power, 1989) are more vulnerable. These studies did little to aid our understanding of the causal processes which underpin pedestrian safety, which resulted in limited improvement in accident outcomes.

Traditional road safety education interventions primarily took the form of classroom-based programmes requiring children to engage in the rote learning of the rules of the road or comprised periodic school visits from police and road safety officers (Ampofo-Boateng and Thomson, 1990; Thomson, 1991). Enduring accident rates suggest traditional rule-based approaches such as the Green Cross Code are largely ineffective**.** Sengoelge et al. (2010) argue the reasons for this ought to be afforded far greater attention though a number of possible accounts have been forwarded.

One such reason may be the assumptions of parents and educators that if materials deal with road safety in any way at all, then they will allow children to become safe, responsible and competent road users (Thomson, 1991, Thomson et al., 1996). Thomson (2007) argues this may reflect the inaccurate and common assumption that safe road use is a relatively straightforward task. In reality however, interacting safely with traffic requires the development and coordination of a wide range of complex perceptuo-cognitive and motor skills, as well as a range of broader cognitive abilities and psychological skills. Indeed, for even typically developing, healthy children, many of these skills do not begin to approach adult levels of competence until around 11 years of age (Thomson, 1991) and even then are not always used effectively or consistently until mid-adolescence (Tolmie et al., 2006).

Another likely reason past attempts to intervene have been ineffective is the inappropriate focus on increasing knowledge rather than improving skill level (Thomson et al., 1996). Given safe pedestrian behaviour is underpinned by a range of perceptual, cognitive and motor skills, it follows that we cannot assume learning rules (such as stop, look and listen) will translate into safer child pedestrian behaviour by the roadside. Safe interaction with traffic requires the development of these skills rather than the acquisition of declarative knowledge, thus it has been argued we ought to focus on enhancing children's performance of these skills directly. This necessitates a practical approach within an appropriate and realistic environment (Thomson, 1996).

Accordingly, practical training approaches have been shown to be surprisingly effective in this regard. The Kerbcraft programme developed by Thomson and colleagues (Thomson & Whelan, 1997; Thomson, Dickson, McBrearty, McLean, Motion & Docherty, 2002, Thomson, Whelan, Stephenson, Dickson, McBrearty, McLean, Motion & Docherty, 2008) is a comprehensive practical roadside training programme designed for 5-7 year old children which aims to improve skill level on a range of key pedestrian skills through practical roadside training rather than classroom based learning. It targets skills including recognising safe places to cross roads as well as crossing near parked cars and junctions which are targeted in a progressive manner over a 3 to 12 month period. Roadside training is conducted by community volunteers recruited via schools (often parents and grandparents) who are themselves trained in the workings of the programme.

The effectiveness of the Kerbcraft programme is well documented. Some studies have shown practical training using the Kerbcraft programme to be effective in boosting skill level among even very young children. For example, Thomson and Whelan (1997) demonstrated children as young as 5 years old were amenable to training and the differences in performance at pre and post-test on three key pedestrian skills were significant and in some cases, dramatic. Moreover, these improvements were enduring, as evidenced by superior performance relative to untrained children at follow-up tests 2 months later. Whelan, Towner, Errington and Powell (2008) suggest the benefits may be even more long lasting. Whelan et al.

demonstrated a replication of the original Kerbcraft project leads to a significantly higher number of safe crossing routes amongst trained children of all ages some 4 months later.  The Kerbcraft programme's effectiveness is such that it has been adopted by 98 local authorities throughout the UK.  Kerbcraft in England has been funded by the Department for Transport and Kerbcraft in Scotland by the Scottish Government.  It has also been supported by the Welsh Assembly (Whelan et al., 2008).

Thomson and colleagues then extended the Kerbcraft approach using computer simulated traffic environments so that skills which are difficult to study and train at the roadside could also be targeted (Tolmie, Thomson, Foot, Whelan, Morrison & Sarvary, 2002; Tolmie, Thomson, Foot, Whelan, Sarvary & Morrison, 2004).  Skills such as visual gap timing, predicting the intentions of other road users and the use of designated crossings are examples of skills which require specific traffic conditions which may not occur by chance at the roadside or may not exist in the vicinity of schools.

Tolmie et al. (2002) and Thomson, Tolmie, Foot, Whelan, Morrison & Sarvary (2005) demonstrated this virtual reality approach was effective in improving crossing speeds and reduce the number of opportunities children missed by targeting children's visual timing skills and negotiation of traffic gaps, as well as children's conceptual understanding of the decisions required to complete such tasks safely. The crossing times of trained children became better aligned with the actual time needed; they accepted smaller traffic gaps without increasing the number of risky crossings; they showed better conceptual understanding of potential risk factors relating to crossing judgments and were able to cross more promptly and more safely. These broad improvements were found to be significant across all age groups (encompassing children aged 7-11 years). Moreover, these improvements were still present some 8 months later during retest, providing a strong empirical basis for both the scope and long term effectiveness of this kind of virtual, though practical approach. This resulted in the production of a software training resource (Crossroads) which combines virtual reality with a practical training approach similar to Kerbcraft (Tolmie, Thomson, Foot, Whelan, Morrison & Sarvary, 2004). Crossroads was also subsequently adopted by the UK Department for Transport as a government-sponsored training resource.

A range of pedestrian skills have been shown to be amiable to improvement using this kind of practical, skill focused approach. These include training children about safe place finding (Ampofo-Boateng & Thomson, 1991; Thomson et al., 1992, Ampofo-Boateng et al., 1993); visual and auditory attention (Whitebread & Neilson, 2000); perception of road user intentions (Foot et al., 2006); crossing near parked vehicles (Rothengatter, 1984; Thomson & Whelan, 1997); crossing at junctions (Rothengatter, 1984; Thomson & Whelan, 1997); using designated crossings (Tolmie et al., 2002) and visual gap timing (Lee et al., 1984; Thomson et al., 2005).

Beyond improving outcomes for children, practical approaches to pedestrian skill training provide a strong evidence base for the skill based nature of pedestrians' safe interaction with the traffic environment and have also provided insights into how skill levels develop naturally across childhood from the data collected at pre-test in these studies. This approach to studying children's pedestrian behaviour and skill level has resulted in an increase in the number of studies which have attempted to describe the developmental trends characterising child pedestrian behaviour across childhood.

### 1.3 Age Trends in Child Pedestrian Behaviour

A number of studies have demonstrated that pedestrian skills develop gradually. The ability to select safe routes (or crossing strategies) for example appears very poor in younger children aged 5 (Ampofo-Boateng & Thomson, 1991). By age 9 children begin to show some improvement in ability in this regard but it is not until around age 11 years that children begin to perform safely.

For example, Ampofo-Boateng and Thomson (1991) studied crossing routes in children aged 5-11 years old. This study required children to construct the safest route they could between a start and end point by the roadside over 48 trials. Clear developmental differences in terms of the safety of responding were observed between children at ages 5, 7, 9 and 11 years. Ampofo-Boateng and Thomson report younger children (aged 7 and under) fail to recognise dangers in the environment and assume that the most direct route is the safest, even if this required children to cross the road diagonally. It is only once children reach age 11 that they begin to display adult levels of competence. These differences represent the gradual acquisition of pedestrian skill across early to middle childhood and have been consistently shown to develop in this way (Thomson, Ampofo-Boateng, Pitcairn, Grieve, Lee &

Demetre, 1992; Ampofo-Boateng, Thomson, Grieve, Pitcairn, Lee & Demetre, 1993; Thomson and Whelan, 1997). Other skills too appear to follow similar trends.

Lee, Young & McLaughlin (1984) for example demonstrate similar age-related development in relation to the ability to select safe gaps between cars in a flow of traffic. Demetre et al. (1992) used a pretend road paradigm to further study the development of this skill. This study also reports gap timing ability improves significantly between the ages of 7, 9 and 11 years respectively. Even by age 9 children have high starting delays whereby they squander significantly more time before initiating a cross compared with adults (Schwebel, Gaines & Severson, 2008). Similar findings have been reported by studies investigating this skill using computer simulation (Thomson et al, 2005) and some have argued the development of this skill is more protracted than others. Connelly, Conaglen, Parsonson and Isler (1998) for example examined the strategies children use to assess whether gaps are sufficiently large to cross through, reporting two thirds of children (even up to the age of 12 years old) use distance alone (and not speed) to make judgements about the safety of gaps.

Velde, van der Kamp, Barela and Savelsbergh (2005) compared performance of children aged 5-7 to children aged 10-12 and a group of adults on a simulated visual (gap) timing task. The findings show children aged 5-7 squandered much more time when it was safe to cross compared with older children and adults. Tapiro, Meir, Parmet and Oron-Gilad (2013) add to this literature through findings of an eye tracking study which demonstrate younger children aged 7-13 spend significantly less gaze time searching peripheral areas where traffic would enter their view compared with adults. This suggests although improvement does take place across childhood, even by age 13 children are significantly less safe in their performance on a gap timing task in terms of their visual search strategy compared with adults

Children’s ability to predict the intentions of other road users is a further skill which follows a similar developmental trajectory (Tolmie, Thomon, Foot, Whelan, Sarvary and Morrison, 2002). This skill relates to children’s ability to ‘read’ the intentions of other road users which is an important skill given the social dynamic of safe road use. This skill requires children to accurately predict the likely future actions of drivers based on perception of the traffic environment relative to environmental cues that may be indicative of others’ intentions and the rules of the road. Younger children aged 7 are significantly less able to accurately extrapolate and successfully predict the future action of drivers compared with both older children aged 11 (Foot et al., 2006) and adults (Tolmie et al., 2006).

Over the last few decades, researchers have begun to study the psychological underpinnings of pedestrian behaviour and have identified a range of cognitive and perceptual factors which appear to be linked with a corresponding range of pedestrian skills. Oxley, Fildes, Ihsen, Charlton and Day (1997) suggest age differences in cognitive abilities may play a substantial role in explaining pedestrian road accidents.

Whitebread and Neilson (1998) for example make a case for the importance of metacognition in explaining the development of child pedestrian skill level. They define metacognition as one's awareness and control of one's own cognitive processes. Whitebread & Neilson considered metacognition in relation to the development of children's roadside visual search strategy. They report strategic awareness (being aware of selecting a processing strategy) and strategic control (monitoring and adapting that strategy) as being significant factors in explaining variance in the construction and implementation of effective searches across all age groups (5, 7 and 11 year old children).

In a follow up study, Whitebread and Neilson (2000) further investigated the contribution of visual search strategy to the development of pedestrian skill level in 5-11 year old children. Whitebread and Neilson first tasked participants with separate photographs depicting both safe and unsafe crossing locations which produced an accuracy score. Children were also asked to provide verbal justifications for selections which produced a justification score representing conceptual understanding of the task at hand. The findings demonstrate linear increases in both in the ability to distinguish safe from unsafe locations and in terms of the quality of justifications between the ages of 4/5, 7/8 and 10/11 years of age.

Whitebread and Neilson also studied children's visual search strategies in relation to a traffic detection task. In the moments before participants decided whether it was safe to cross, clear developmental differences were revealed in relation to the number of times children looked in all directions and the duration of time spent looking.

Older children spent less time looking in a particular direction compared with younger children, instead making more short glances in both directions which represents a more appropriate strategy. The authors note there was some overlap between age groups and variation in responding appears to exist within age groups, which suggests factors other than age and visual search are important.

Tolmie et al. (1998) similarly highlight the importance of visual search strategy in relation to the ability of child pedestrians to identify relevant from irrelevant information in the traffic environment. Tolmie and colleagues (1998) studied crossing routes in children aged 5-11 years old. In this study children were instructed to construct the safest route they could between a designated start and end point by the roadside over 48 trials. Significant age trends were revealed which demonstrate a gradual but incremental increase in visual search strategy with age. Younger children's approach to visual search appears to be significantly less focused compared to that of older children. It appears with age children become more strategic and subsequently more effective in their visual search of the roadside. Other studies have reported similar trends in relation to selective attention, which also appears linked with the safety of children's pedestrian behaviour. Dunbar, Hill and Lewis (2001) for example report age differences in attention switching whereby older children were less distracted and switched more quickly than younger children. Those with better attention switching ability were more aware of traffic when making crossing decisions by the roadside. Those with better concentration were more able to maintain focus. In a recent review paper, Barton (2006) concludes gains in the safety of children's pedestrian behaviour are at least a partial reflection of the development of selective attention in middle childhood.

These findings suggest children's developing pedestrian skill level may reflect the concomitant development of a range of underlying cognitive functions which likely underpin and may help drive age-related improvements in pedestrian skill level during childhood. These past studies have laid a foundation upon which more recent research has been conducted and a number of recent studies have begun to study the role of a particular subset of cognitive functions in relation to children's pedestrian behaviour.

### 1.4 Executive Functions

A growing body of recent evidence suggests a collection of cognitive abilities known as executive functions are important in driving improvement in child pedestrian skill level. Executive Functioning (EF) is an umbrella term used to describe a collection of higher order cognitive functions which allow humans to maintain an appropriate problem-solving set for attainment of a future goal (Luria, 1996). Others have described these as general purpose control mechanisms which modulate human cognition (Miyake et al., 2000), or more simply as mental control processes which underpin self-control (Denckla, 1996; Lezak, 1995; Pennington & Ozonoff, 1996). These abilities are related to the functioning of the frontal lobe (Aron, Robbins & Poldrack, 2004). They allow us to perceive and interact with the external environment and are essential in allowing us to maintain and process sensory information (Diamond, 2009). They are also essential in order to plan and engage in goal-directed behaviour (Gioia, Isquith & Guy, 2001). In this thesis the term cognitive function will be used to refer to both higher order 'executive' functions as well as more basic functions without a prominent executive component. EF will be used to refer to higher order functions alone and non-executive will be used to refer to more basic cognitive processes. Cognitive functions, both executive and non-executive, which are associated with brain regions are referred to collectively as neuropsychological functions.

Executive functions include processes such as response inhibition, working memory, cognitive flexibility (attention set shifting), planning and risk taking (Miyake et al., 2000, Diamond, 2013). Together these processes form the cognitive basis of problem solving and underpin our ability to respond to new or challenging situations. Research into EF first arose from clinical observations of changes in the cognitive abilities of patients who had suffered traumatic brain injury. For example, localised damage to the prefrontal cortex (PFC) results in working memory impairment (Owen, Downes, Sahakian, Polkey & Robbins, 1990). Disinhibition, problems with attention switching and planning have similarly been associated with damage to the PFC (Owen et al., 1990, 1991; Braun, Weber, Mergner & Schulte-Monting, 1992). Similar findings have been reported in animal studies (e.g. Goldman-Rakic, 1996).

It has been argued by some that EF is a unitary set of operations (Duncan, Johnson, Swales & Freer, 1997) perhaps understandably given the evolution of this concept following the proposal of a central executive within the popular Baddeley and Hitch (1974) model of working memory and Norman and Shallice's (1986) supervisory attentional system. The original Baddeley and Hitch (1974) model of working memory proposes a phonological loop which is responsible for the manipulation of speech based information and a visuo-spatial sketch pad responsible for the manipulation of visual information. The model also contains a central executive which is responsible for managing the above two slave systems and determines what information is attended to and which slave system should be used. These components are interconnected and interdependent. Aspects of EF also share a common neurological location in the frontal lobes (Duncan, Emslie, Williams, Johnson & Freer, 1996) which may further underpin the original view that EF was unitary.

For some time however, it has been argued that there are multiple and separable functions of the frontal lobe, evidence for which stems from both clinical observations and experimental studies of executive function alike (Stuss & Benson 1986). Patients with traumatic brain injury (TBI) often display impaired performance on some aspects of EF, while performing similarly to control participants in respect of others. Children suffering TBI have been shown to experience difficulties associated with damage to the prefrontal regions with specific deficits having been reported in respect of planning, cognitive flexibility and inhibitory control (Ylvisaker, Szekeres, & Hartwick, 1992, Scheibel & Levin, 1997). Injury to different regions of the frontal lobes therefore has been shown to result in different patterns of performance on neuropsychological tasks (Levin & Kraus, 1994). In light of these observations, current theoretical understanding of the organisation and diversity (rather than unity) of these functions suggests they are related but separable abilities which can be studied and indeed used independently of one another.

Miyake et al. (2000) for example examined individual differences in three components of EF, namely mental set shifting between tasks and mental states, information updating and inhibitory control in order to determine the extent to which these functions are separable. Mental set shifting (or attention switching) has been described as the ability to shift back and forth between tasks, operations, rules or mental sets (Monsell, 1996). Updating refers to the ability to update and monitor working memory representations (Miyake et al., 2000). Working memory is the ability to temporarily hold and manipulate information in mind and is necessary for complex cognitive tasks including language comprehension, learning and reasoning (Baddeley, 1992) whilst inhibition (or inhibitory control) refers to the ability to deliberately inhibit an automatic or proponent response (Miyake et al., 2000). Miyake and colleagues report performance on tasks assessing these functions were moderately correlated (and shared underlying commonality) but were also clearly distinguishable amongst adults.

That being said, the unity versus diversity of EF has also received research attention in the developmental literature and the structure of EF and the relatedness of its components amongst children has been subject to even more debate. The three factor structure of EF has been contested and the number of factors which best define this construct in childhood have been disputed by several researchers. On the one hand Brydges, Reid, Fox and Anderson (2012) argue EF is essentially a unitary construct in childhood. This argument has received moderate support from empirical studies of cognitive development. Davidson, Amso, Anderson and Diamond (2006) for example studied the independence of working memory, inhibitory control and cognitive flexibility in a sample of children aged 4 to 13 years and adults. Performance on tasks assessing inhibitory control and working memory was found to be highly correlated in childhood in terms of reaction time but accuracy was correlated to a much lesser extent. On the other hand, some have argued EF in childhood is best defined as a two factor construct having identified the updating of working memory and inhibition as definable factors in children (St-Clair Thompson & Gathercole, 2006). Others however emphasise a three factor structure of EF in children, similar to that reported in adults (Lehto, Juurarvi, Kooistra & Pulkkinen, 2003; Wu, Chan, Leung, Liu, Leung & Ng, 2011), identifying attention switching (or shifting), working memory or 'updating' (of working memory representations) and inhibition, comparable to that reported in adults (e.g. Miyake et al., 2000).

Modern neuropsychological evidence from patients with psychological and developmental disorders seems to confirm the diversity of EF in childhood. Studies comparing profiles of cognitive impairment between different developmentally disordered populations provide strong evidence for the notion of diversity of EF in childhood further still (Gioia, Isquith, Kenworthy & Barton, 2002). A range of specific impairments in EF have been reported in patients with Autism Spectrum Disorders (Geurts, Vertiw, Oosterlaan, Roeyers & Dargent, 2004; Happe, Booth, Charlton & Hughes, 2006; Hill 2004; Ozonoff, South & Provencal, 2005; Pennington & Ozonoff, 1996), Tourette Syndrome (Bornstein, 1990) and Attention Deficit

Hyperactivity Disorder or ADHD (Barkley, 1997; Rhodes, Coghill & Matthews, 2005; Pennington & Ozonoff, 1996), which will be shortly discussed in more detail.

A favoured approach to studying these abilities makes use of tests which assess performance of components of EF with reliable neurological correlates. These executive functions, as well as those with neurological correlates without a prominent executive component, are collectively referred to as neuropsychological functions. Imaging studies consistently link performance on tasks assessing a range of cognitive functions to activation of specific frontal lobe regions (Fuster, 1995). The development of reliable neuropsychological tests such as the NEuroPSYchological Assessment (NEPSY; Korkman, Kirk & Kemp, 1998), the Behavioural Assessment of Dysexecutive Syndrome (BADS; Wilson, Alderman, Burgess, Emslie & Evans, 1996), Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan & Kramer, 2001) and the Cambridge Neuropsychological Testing Automated Battery (CANTAB; Owen, Downes, Sahakian, Polkey, & Robbins, 1990) has allowed researchers to study the development of these functions separately across the lifespan which has provided strong evidence that at least to some extent, aspects of both executive and non-executive neuropsychological functions can be assessed and studied independently.

Studies investigating the development of cognition in childhood suggest aspects of functioning develop at different rates (Anderson, 2002). On the one hand aspects of attention and inhibitory control develop markedly during early childhood. The control and inhibition of impulsive actions appears to develop dramatically up to age

6 years of age (Diamond & Taylor, 1996) and appears relatively well developed by age 9 (Anderson, Anderson & Lajoie, 1996). On the other hand, the ability to switch responding according to rapid rule changes (attention set shifting) is thought to develop around 3-4 years of age (Espy, 1997). Working memory appears to develop gradually between the ages of 4 and 7 (Luciana & Nelson, 1998) but appears to continue to develop into adolescence with studies reporting significant differences between children aged 8-10 and 11-14 years (DeLuca et al., 2003).

These findings demonstrate early to mid-childhood is an important time for the development of EF. The simultaneous development of children's pedestrian skill level during this period has led to some to hypothesise that their development may not only be concurrent but may also be interrelated (Barton & Morrongiello, 2011).

## 1.5 The relationship between Executive Function and Child Pedestrian Skill Level

EF allows us to maintain and manipulate information about potential actions and responses by allowing us to integrate sensory being maintained in mind with information about the environment in order to identify an appropriate course of action (Willcutt, Doyle, Nigg, Faraone & Pennington, 2005). Others have described EF as being essential for goal directed behaviour (Luria, 1996). These descriptions exemplify the importance of EF in a road setting and a number of studies have attempted to demonstrate this empirically. An early study by Pless, Taylor, and Arsenault (1995) for example found that children injured as pedestrians or cyclists were significantly less inhibited even when compared to children injured in other settings, which suggests EF may be particularly important in a road safety context.

Dunbar et al. (2001) then reported both sustained attention and attention switching develop significantly between the ages of 4 and 10, correlate with the safety of children's roadside behaviour. Attention switching ability on an abstract computer task correlated with more frequent looking behaviour by the roadside. Those who performed poorly on the computer task were also more likely to make road crossings in an uncontrolled manner.

Similarly, Tabibi and Pfeffer (2003) examined the role of inhibition on children's ability to identify a safe place to cross the road. Through 10 computer simulated road scenes, participants were asked to identify safe from dangerous road crossing sites. The authors demonstrate that both safe place finding ability and inhibitory control improves between the ages of 6, 8 and 10 years old and that scores on these measures were significantly correlated across all age groups. The authors also recruited a control group of adults and correlates which exist between performance on these tasks in childhood however disappear by adulthood. It is likely that children rely more heavily on cognitive abilities in order to make safe decisions about where is safe to cross whereas adults can make these decisions based on other factors such as experience.

Barton and Schwebel (2007) also reported that poorer inhibitory control was related to children engaging in more risky pedestrian behaviours when selecting gaps between cars in a flow of traffic. Using the inhibitory control scale of the child behaviour questionnaire (Rothbart, Ahadi, Hershey & Fisher, 2001) and a pretend road, Barton and Schwebel showed children with greater inhibitory control were much more conservative in their crossings. They chose larger gaps, waited longer before attempting to cross and made fewer tight fits compared with children with poorer inhibitory control.

Barton and Morrongiello (2011) demonstrate executive functions beyond inhibition are also important for safe pedestrian behaviour. Barton and Morrongiello used a Stroop task to provide a composite measure of attention, inhibition, working memory and monitoring (Wright, Waterman, Prescott & Murdoch-Eaton, 2003). The parent version of the Behaviour Rating Inventory of Executive Function questionnaire (BRIEF; Gioia, Isquith, Guy & Kenworthy, 2000) was also used to provide a parent rated measure of inhibition and of monitoring. The Contingency Naming Task (CNT; Anderson, Anderson Northam & Taylor, 2000), a paper-based measure of speed and accuracy in cognitive performance, was used to provide a further measure (of working memory, selective attention and shifting). The authors compared performance on these measures of EF to children's ability to select safe gaps between cars in a flow of traffic on a visual gap timing task. The findings demonstrated that some aspects of EF correlate with children's performance on the visual timing task whereby children with greater inhibitory control (assessed by parent ratings on the BRIEF) and children with superior cognitive efficiency (assessed with the CNT) had higher safety margins on the gap timing task. Those with superior monitoring ability (also assessed by parent ratings on the BRIEF) also had higher safety margins and crossed in shorter times.

The study by Barton and Morrongiello provides one of the most comprehensive investigations of the relationship between EF and child pedestrian skill level to date and would certainly appear to suggest EF and child pedestrian skill level are positively related. That said there are some methodological limitations to this study in respect of the measures of EF used and the limited age range of participants. The Stroop task for example was reported as a measure of inhibition but was originally designed as a measure of selective attention (Miyake et al., 2000) and requires the concurrent use of working memory (Engle, 2002). The CNT task requires WM, selective attention and shifting; functions with distinct developmental trajectories (Diamond, 2002; Welsh, 2002). In addition, studies have shown scores on the parent rated BRIEF appear to be poorly correlated with scores on performance based measures of EF (Mcauley, Chen, Good, Schachar & Crosbie, 2010, Toplack, Bucciarelli, Jain & Tannock, 2008). These issues mean a number of important questions remain unanswered because it is difficult to pinpoint which aspects of EF are associated with visual gap timing ability. That said, Kovesdi and Barton (2013) report more conclusively that working memory is significantly related to children's pedestrian skill level. Using the Corsi Block Task which is largely accepted as a non-verbal WM task as a measure of working memory and a change blindness paradigm to assess pedestrian visual search performance in children aged 6-9 years old, Kovesdi and Barton report WM task accuracy was related to pedestrian visual search ability whereby superior non-verbal WM accuracy significantly predicted pedestrian visual search even when controlling for children's age and visual acuity.

Unfortunately, as outlined above, no other studies have adopted specific measures of EF.

Therefore, although several studies have implicated aspects of EF with pedestrian skill level, few appear to have measured EF or child pedestrian skill level comprehensively and the contribution of more basic aspects of cognition such as holding information in memory over time appears to have been overlooked. It would appear that relationships do seem to exist between EF and child pedestrian skill level but the specific contribution of individual aspects of EF to the range of skills known to be important for safe road use is not yet fully understood. Preliminary findings in this field however have led some to suggest that these relationships might explain the vulnerability of children who have problems with EF in a road safety context. In particular, some have argued this may be a key reason that explains why children with developmental disorders and in particular children with ADHD, are at such high risk of pedestrian injury (Jerome et al., 2006, Transport Scotland, 2010b, Department for Transport, 2007).

### 1.6 Attention-Deficit/Hyperactivity Disorder

Attention-Deficit/Hyperactivity Disorder (ADHD) is a diagnosis contained within the Diagnostic and Statistical Manual of Mental Disorders (DSM) of the American Psychiatric Association (APA), now in its 5$^{th}$ edition (DSM-V; APA, 2013). Much of the literature reported in this thesis is based on samples of children with ADHD who received a diagnosis using the revised 4$^{th}$ edition of the DSM (DSM-IV-TR; APA, 2000). The DSM criteria for ADHD were changed in the 5$^{th}$ edition of the manual, but these changes focus on additions which facilitate application across the lifespan and allow for wider comorbid diagnoses. A copy of the current DSM-V diagnostic criteria is provided in Appendix 1.

ADHD is one of the most frequently diagnosed and frequently studied psychological disorders in the pediatric population (NHS Choices, 2016; Roland, Lesesne, Abramowitz, 2002; Shue & Douglas, 1992; Woo & Keatinge, 2008). With a significant gender imbalance, ADHD is much more common in males (Barkley, 1997) and has been said to have a prevalence rate of between 8 and 10% in school-aged children (American Academy of Pediatrics, 2000). UK estimates are more conservative and range from 1.4% (Russell, Rodgers, Ukoumunne & Ford, 2014) to between 3 and 9% (NICE, 2008). The number of prescriptions issued to treat ADHD in Scotland from 2009/10 to 2010/11 grew by 3.8 % in one year alone, rising from 75,768 to 78,679 (NHS Scotland, 2011) suggesting the prevalence and treatment of the disorder is increasing. These trends are persistent and both medication uptake and rates of diagnosis in Scotland steadily increase year on year (Stead & Lloyd, 2008).

ADHD is characterised by pervasive symptoms of inattention, hyperactivity and impulsivity, which must be present in two or more contexts of a child's functioning (typically at home and school) with symptoms present for at least 6 months (DSM-V, APA, 2013). ADHD is associated with an array of cognitive impairments with those diagnosed displaying delay aversion (Snouga-Barke, 1994), difficulties with temporal processing (Smith, Taylor, Warner, Newman & Rubia, 2002, Toplack &

Tannock, 2005) and impairment in various aspects of cognitive functioning including EF (Kempton et al., 1999; Rhodes, Coghill & Matthews, 2004, 2005). The literature demonstrating cognitive impairment in ADHD is vast and will now be discussed in more detail.

**1.7 Cognition in ADHD**

Early study of the cognitive profile of individuals with ADHD highlighted impairment in attention (e.g. Douglas, 1972), traditionally described as the ability to withdraw from some things in order to deal more effectively with others (James, 1890). Studies began investigating the ability of those with ADHD to focus, sustain and switch attention with varying results (e.g. Pearson, Lane & Swanson, 1991; Swanson, Posner, Potkin, Bonforte, Youpa, Fiore, Cantwell & Crinella, 1991; van der Meere, Shalev, Borger & Gross-Tsur, 1995). A number of researchers however have highlighted a lack of consensus about attentional impairment in ADHD (Sergeant & van der Meere, 1990; van der Meere, 2002) and more recent evidence much more conclusively suggests that cognitive impairment in ADHD is more broad than had initially been thought.

Delay aversion for example, has been linked with ADHD for some time and led Sonuga-Barke and colleagues to propose a delay aversion theory of ADHD (Sonuga-Barke, Taylor, Sembi & Smith, 1992a; Sonuga-Barke et al., 1992b). A large number of studies have shown children with ADHD show preference for smaller immediate rewards (or rewards that come sooner) over larger rewards which come later (Bitsakou, Psychogiou, Thompson, & Sonuga-Barke, 2009; Castellanos, Sonuga-

Barke, Tannock, & Milham, 2006; Hoerger & Mace, 2006; Sonuga-Barke, Taylor, Sembi, & Smith, 1992a, Sonuga-Barke et al., 1992b). A review by Luman, Oosterlaan and Sergeant (2005) concludes that this finding is robust and this tendency is one of the most salient motivational markers of the ADHD population. Some have argued this aversion to delay is a result of children with ADHD differing in their response to reinforcement (Haenlein & Caul, 1987) which causes them to discount the value of the larger reward available following delay (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001). Others however argue those with ADHD have difficulty inhibiting the temptation posed by the immediate reward because of underlying difficulties with inhibitory control (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Bitsakou, Psychogiou, Thompson, & Sonuga-Barke, 2008) which suggests aversion to delay might be a secondary deficit resulting from underlying difficulties with higher order aspects of cognitive control. In light of these arguments, Sonuga-Barke (2002) revised his earlier delay aversion theory of ADHD to take account of EF deficit through a dual model pathway which recognises underlying difficulties with inhibitory control whilst maintaining that delay aversion is a distinct characteristic of the cognitive profile of ADHD.

It has also been argued that children (Barkley, Koplowitz, Anderson & McMurray, 1997; Smith, Taylor, Rogers, Newman & Rubia, 2002; Toplak & Tannock, 2005) and adolescents (Rubia, Tayloy, Taylor & Sergeant, 1997) with ADHD are impaired in respect of temporal information processing. Impairment has been shown via duration discrimination (Radonovich & Mostofsky, 2004), duration reproduction and time estimation tasks (Meaux & Chelonis, 2003; Rommelse, Oosterlaan, Buitelaar, Farone & Sergeant, 2007). Although these findings have been demonstrated quite consistently (Smith, Taylor, Rogers, Newman & Rubia, 2002; Yang, Chan, Zou, Jing, Mai & Li, 2007) a wide number of studies here too suggest this difficulty may also be a result of underlying difficulties with aspects of higher order cognition. For example, aspects of attention have been linked with the prospective perception of time amongst children (Zakay, 1992) and those with poor inhibitory control have been shown to be particularly impaired on time reproduction tasks (Barkley, Edwards, Laneri, Fletcher & Metevia, 2001; Fraisse, 1963; Gerbing, Ahadi, & Patton, 1987) which some have argued is what leads children with ADHD to underestimate duration relative to typically developing children (Levine & Spivack, 1959; Seigman, 1961). Thus a number of cognitive impairments in the ADHD population appear to be a result of or at least related to impairment in higher order aspects of cognition and EF. This likely accounts for the large proportion of the ADHD literature addressing this impairment.

The study of higher order cognitive functions in ADHD became a focus of research over 20 years ago. Initial accounts described and placed primacy on a deficit in inhibitory control (Douglas, 1983; Schachar, Tannock, Marriott & Logan, 1995). Over time, research began to demonstrate these impairments were wider and extended to other aspects of EF such as working memory (Karatekin & Asarnow, 1998), attention set shifting, or switching (Kempton et al., 1999; Pearson, Lane & Swanson, 1991), planning (Kempton et al., 1999) and risk taking (Garon, Moore & Waschbusch, 2006). In 1997, Russel Barkley proposed his widely held theory of ADHD which proposes that problems with inhibitory control are central to the

ADHD disorder and that this is the core cognitive deficit from which other cognitive impairments arise. This conceptualisation of ADHD has spurred a substantial literature (Castellanos, Sonuga-Barke, Milham & Tannock, 2006) which has provided consistent empirical evidence that children with ADHD are impaired in respect of a range of aspects of EF including working memory, planning, inhibitory control and attention set shifting (e.g. Kempton et al., 1999; Martinussen & Tannock, 2006; Rhodes et al., 2005; Schoemaker et al, 2012; Skogan et al., 2014; Strand et al., 2012; Thorell & Wahlstedt, 2006; Toplak, Bucciarelli, Jain & Tannock, 2008). A meta-analysis of over 80 studies (including data from more than 6700 participants), concluded those with ADHD are impaired in respect of a range of aspects of EF including inhibitory control, attention set shifting as well as verbal and spatial working memory though the authors note that there is much more evidence of impairment in spatial rather than verbal working memory (Willcutt, Doyle, Nigg, Faraone & Pennington, 2005).

Admittedly, there is some inconsistency in the literature as to whether children with ADHD are more impaired on spatial or verbal working memory tasks. On the one hand, there have been a number of studies which have reported impairment in verbal working memory in ADHD (e.g. Pennington & Ozonoff, 1996; Rapport, Alderson, Kofler, Sarver, Bolder & Sims, 2008) and many more via working memory tasks that could be encoded verbally or visually (Martinussen, Hayden, Hogg-Johnson & Tannock, 2005). However, a meta-analysis of 26 studies of working memory impairment in ADHD reported much larger effect sizes for impairment in spatial working memory than for verbal (Martinussen, et al., 2005), which suggests there is a stronger spatial deficit; a conclusion supported by another more recent review (Kasper, Alderson & Hudec, 2012). Taken together the literature suggests children with ADHD may be impaired on a range of aspects of EF including perhaps most notably inhibitory control and working memory, particularly in the spatial domain. Yet alongside these studies which have demonstrated impairment in relation to higher order (executive) aspects of cognition, researchers have also begun to argue the ADHD population might also be impaired in respect of more basic (non-executive) aspects of cognitive function as well.

A study by Quinlan and Brown (2003) for example demonstrated that both adolescents and adults with ADHD performed less well on a task assessing short term (non-executive) verbal memory whereby those with ADHD performed significantly less well on the Logical Memory subtest of the revised Wechsler Memory Scale (Wechsler, 1987) compared with controls, even when controlling for IQ.

Kempton et al. (1999) demonstrated similar findings. Kempton and colleagues reported children with ADHD aged 6-12 years were impaired on spatial recognition memory and delayed short term visual memory. Rhodes et al. (2004, 2005) reported similar findings, providing evidence of impairment in a range of cognitive functions (both with and without prominent executive components). Indeed, the studies by Rhodes and colleagues reported delayed short term visual memory was most impaired aspect of cognition amongst children with ADHD even when compared with inhibitory control, attention shifting and planning. This finding has been replicated by both the same authors (Rhodes, Park, Seth & Coghill, 2012) and has also reported by a number of others (Andersen, Egeland & Merete, 2013; Dovis, Van der Oord, Wiers & Prins, 2013; Krauel et al., 2007). The literature therefore appears to demonstrate that cognitive impairment in ADHD extends beyond higher order, executive aspects of cognition and generalises to more basic, non-executive aspects of cognition as well, most notably delayed short term memory.

### 1.8 ADHD and Vulnerability to Injury

ADHD can result in a range of significant health implications (Rowland, Lesesne & Abramowitz, 2002) as well as a tendency for children with the disorder to perform less well at school (Antonini, Kingery, Narad, Langberg, Tamm & Epstein, 2013; Barry, Lyman & Klinger, 2002; Loe & Feldman, 2007). These traditional difficulties are accompanied by problems surrounding the health and safety of both individuals with ADHD and others around them (Meaux & Chelonis, 2003). For example, it has been well documented that adults with ADHD engage in more risk taking and a range of health threatening behaviours compared to typically developing individuals including smoking (Lambert & Hartsough, 1998), alcohol and substance misuse (Barkley, 1998), unprotected sex (Barkley, 1998) and risky driving behaviours resulting in injury or damage (Barkley, 1996). As a result, it is perhaps unsurprising that children with ADHD are significantly more likely to suffer an accidental injury or death compared with controls (Brehaut, Miller, Raina & McGrail, 2002; Davidson, 1987). Estimates suggest that children with ADHD are twice as likely to suffer accidental injuries compared to healthy children (Rowe, Maughan & Goodman, 2004; Schwebel, Speltz, Jones and Bardina, 2002) and this increases to three times as likely when considering serious injuries alone (Merrill et al., 2009).

Corresponding differences in hospital admissions between children with and without ADHD are well documented. Children and teenagers with ADHD use both health and mental health services significantly more frequently than their undiagnosed peers (Rowland, Lesesne & Abramowitz, 2002). For example, DiScala, Lescohier, Barthel & Guohua (1998) found children with ADHD in the US suffered more instances of head trauma, were hospitalised for longer periods and sustained more serious unintentional injuries than did controls. Schwebel et al. (2002) report preschool boys with behavioural disorders like ADHD are twice as likely to suffer accidental injury than are control children, a trend which also appears true for adults with ADHD (Merrill, Lyon, Baker & Gren, 2009). Bruce, Kirkland and Waschbusch (2007) argue that we need to develop more effective ways to reduce rates of injury in the ADHD population. Bruce and colleagues compared medical records of children with ADHD; children with ADHD and comorbid conduct problems; children with conduct problems alone and typically developing controls. Bruce et al. reported children with ADHD were at greatest risk of accidental injury compared with all other groups. More recent evidence from Schewebel et al., (2011) also seems to support the notion that ADHD is a more significant a predictor of child injury or death compared to children with other psychological disorders, through a comparative study of children with ADHD and children with conduct problems.

Correspondingly, children’s unsupervised exposure to traffic appears to be increasing, which is likely underwritten by the expectation that typically developing children usually begin to display the cognitive and psychological competence needed to interact with traffic safely around mid-childhood. Yet for those with ADHD it may be that these competences are impaired. This notion is well aligned with impairment across a range of aspects of functioning in the ADHD population which have been well described (see Barkley, 1998 for a commentary). The findings of the above reviewed studies suggest it is likely this impairment extends to the road safety competence of those with ADHD also, although few previous studies have examined this.

Indeed, most study of ADHD in a traffic context has been correlational. Wazana (1997) for example examined predictors of accidental injury in childhood and reported hyperactivity was especially predictive of child pedestrian injuries over and above injuries in other domains. Wazana argues that there is strong evidence to support the existence of tangible and identifiable risk-factors for child accidental injuries and highlights a particular role of hyperactivity in relation to pedestrian injury specifically. This observation has been echoed by government's recognition of the vulnerability of children with behavioural disorders like ADHD to pedestrian injury (Transport Scotland, 2010b, Department for Transport, 2007) but the evidence base for the vulnerability of children with ADHD in the traffic context is limited although inferences can be drawn from the literature relating to adults with ADHD.

Weiss, Hechtman, Perlman, Hopkins & Wener (1979) reported that those with ADHD symptoms in childhood were significantly more likely to have serious car accidents as adults. More recent findings of a simulator study by Wheafer, Camarillo, Fillmore, Milich & Marczinski (2008) go further and report the driving performance of un-medicated ADHD drivers to be similar to alcohol-intoxicated control drivers.

A meta-analytic review paper by Jerome, Segal and Habinski (2006) concluded drivers with ADHD are at increased risk of unintentional injury because of difficulties with cognitive functions. A number of empirical papers provide evidence of this. Fried, Petty, Surman, Reimer, Aleardi, Martin, Coughlin and Biederman (2006) for example report a trend of slower processing speeds on subtests of the WAIS-III (Wechsler, 1997) in high risk drivers with ADHD. Cox, Merkel, Moore, Thorndike, Muller and Kovatchev (2006) report adolescent drivers with ADHD frequently speed and make inappropriate use of brakes whilst driving on a simulator but note stimulant medication can significantly improve such performance. Jerome and colleagues conclude that impairments in executive functions result in inattention and distractibility, poor risk perception and an impaired ability to deploy appropriate skills which impairs the ability to make accurate judgments in the traffic environment and suggest EF impairment is likely what underlies both the riskier behaviour of drivers with ADHD. Recently, studies have begun to investigate pedestrian skill level and the contribution of cognitive impairment to injury risk amongst children with ADHD as well.

### 1.9 ADHD and Pedestrian Behaviour

Given the difficulties adults with ADHD have with driving (Thompson, Molina, Pelham & Gnagy, 2007, Sadek, 2013) and the difficulties even typically developing children experience in relation to interacting with traffic as pedestrians; it follows that children with ADHD will likely struggle further still. Indeed, some have argued children with ADHD are almost 5% more likely to be injured as cyclists and 10% more likely to be seriously injured as pedestrians compared to controls (DiScala et al., 1998). A recent study by Nikolas et al., (2016) confirms this and reports aspects of EF may underpin risky cycling behaviour in children with ADHD. Yet very few studies have examined pedestrian skill level in children with ADHD and only one has attempted to examine the cognitive factors which may underpin this. That said, a specific threat of pedestrian injury to developmentally-disordered children has been recognised by both the Scottish and UK governments. Both have identified children with attentional problems and hyperactivity as priority groups within their respective road safety strategies (Department for Transport, 2007; House of Commons Transport Committee, 2008; Transport Scotland, 2010b). This recognition seems supported by an emerging empirical evidence base which has also begun to demonstrate empirically that children with ADHD are even more vulnerable as pedestrians compared with their already vulnerable peers.

It has been argued for some time that the most fundamental difficulty of hyperactive children is in the ability to 'stop, look and listen' (Douglas, 1972) and that children who are at greatest risk of accident involvement tend to be hyperactive (Christoffel, et al., 1986) and impulsive (Matheny, 1987). This has led some to hypothesise that the well documented impairment in cognitive functioning amongst children with ADHD could be causal in explaining the particular vulnerability of this group of children to pedestrian accidents (Oxley et al., 1997) and studies have begun to examine the pedestrian behaviour of children with ADHD in more detail. One study for example, showed children with ADHD were significantly poorer in their ability to select gaps large enough to cross through safely in a flow of oncoming traffic compared with healthy control children when crossing in a virtual reality simulator (Clancy, Rucklidge and Owen, 2006). Clancy et al. compared performance of 24 children with ADHD (who had suspended medication for testing) to control children matched on chronological age and gender. Following confirmation of ADHD with standard diagnostic measures (Schedule for Affective Disorders & Schizophrenia for School-Age Children-Present & Lifetime Version [K-SADS-PL; Kaufman, Birmaher, Brent, Rao & Ryan, 1996] and Connors parent and teacher rating scales [Connors, 1969]), participants completed 42 virtual reality road crossings. Findings revealed children with ADHD had slower walking speeds, made poor use of gaps between cars, had significantly lower safety margins and were hit by vehicles twice as often as control children. These differences demonstrate the risk of serious injury faced by children with ADHD in a pedestrian context is significantly greater than that facing their typically developing peers across a range of performance measures.

Although these findings reveal a great deal about the ability of children with ADHD to complete safe road crossings, they relate only to adolescents aged 13-17. A range of studies have shown significant age differences amongst much younger typically developing children in the performance of this skill (e.g. Thomson et al., 1991) and so the skill level of children with ADHD below this age remains unknown. The study by Clancy and colleagues also fails to provide an account of the reasons for the poor performance of the ADHD group. Clancy and colleagues argue future interventions targeting children with ADHD should investigate the role of cognitive impairment for this group which they suggest might reasonably be expected to be causal. They specifically highlight the need for research to examine disorder-related cognitive impairments and their impact on the pedestrian skill level of this group but only one study to date has attempted to do so.

Stavrinos, Biasini, Fine, Hidgens, Khatri, Mrug & Schwebel (2011) report the only previous study to investigate the role of cognitive impairment in relation to pedestrian skill level in children with ADHD. Like Clancy and colleagues, this study also used virtual reality simulation to examine the performance of children with ADHD on a gap timing task. Unlike the study by Clancy and colleagues, this study went further and attempted to identify factors which underpin the relationship between ADHD and unsafe pedestrian behaviour.

Stavrinos and colleagues recruited 39 children with ADHD (combined subtype) and 39 age and gender matched controls. The ADHD group were asked to suspend medication for 24 hours before testing and participants aged 7 to 10 years completed 15 road crossings on a virtual reality simulator. Children completed the executive domain of the NEPSY (Korkman, Kirk & Kemp, 1998) and the Connors Continuous Performance Test (CPT; Connors, 2000). Their parents completed the oppositionality subscale of the Disruptive Behaviour Rating Scale (DBRS; Erford, 1997) as measures of cognitive functioning. Findings suggest that although preliminary kerbside behaviour (attention to traffic, looking behaviour & the time before initiating a crossing) were similar between those with and without ADHD, children with ADHD crossed when vehicles were closer, chose smaller traffic gaps and left less time to spare between their crossing and the passing of cars compared with controls.

Stavrinos et al., also report significant between group differences in relation to EF, attention and oppositionality whereby a diagnosis of ADHD predicted a significant proportion of between group variance on all three of these measures. In turn, the authors report executive dysfunction fully mediated the relationship between ADHD and the safety of crossings amongst those with ADHD.

Whilst these findings provide strong evidence that problems with cognition amongst children with ADHD at least partly explains the vulnerability of children with ADHD to pedestrian road injury, the study by Stavrinos and colleagues, like the study by Barton and Morrongiello (2011) described earlier, used a composite measure of EF meaning it is unclear which components of EF are important. In addition, like Clancy and colleagues (2006), Stavrinos et al. recruited a relatively narrow age-range of participants and did not control for IQ or general ability as is a standard expectation for studies examining differences between children with ADHD and controls (e.g. Coghill, Hayward, Rhodes, Grimmer & Matthews, 2014, Kempton et al., 1999, Rhodes et al., 2004, 2006, Rhodes, Riby, Matthews & Coghill, 2010). In addition, this study recruited a sample of children with ADHD who had been treated with stimulant medication which represents a further limitation because studies have shown treatment with stimulant medication significantly improves a variety of aspects of cognition (Kempton et al., 1999; Mehta et al., 2000). Studies have also shown significant improvement in ADHD symptomology remains even when participants were tested some 12 months after pharmacological treatment had been suspended (Aggarwal & Lilystone, 2000; Huang, Wang & Chen, 2012). Thus while these studies strongly suggest EF may explain the relationship between ADHD and unsafe pedestrian behaviour, there are a number of important questions still to be answered, which will be discussed in more detail shortly.

In summary a small but growing body of research has emerged in recent years which demonstrates clear differences in pedestrian skill level between children with ADHD compared with controls (Clancy et al., 2006). One study to date has examined the relationship between EF and pedestrian skill level in the ADHD population which demonstrates difficulties with EF appear to underpin the disproportionate vulnerability of this group (Stavrinos et al., 2011). There are however, a number of important questions in this field which remain unanswered. The contribution of specific aspect of EF is still not known. The full contribution of EF and other basic aspects of cognition identified as being impaired in ADHD to a broader range of pedestrian skills is also unclear. In recent years studies have also begun to investigate the impact of stimulant medication on the EF of children with ADHD, which appears to improve some but not all aspects of cognition (see Coghill et al., 2014 for a review). The impact (if any) this has on the pedestrian skill level of children with ADHD however, has never been previously studied.

**1.10 Treatment of ADHD**

The first line treatment for both moderate and severe cases of ADHD is pharmacological intervention (NICE, 2008; SIGN, 2009) most commonly through the use of stimulant medications such as the indirect dopamine agonist methylphenidate (MPH). Pharmacological intervention has been a primary approach to treatment for decades (Safer & Malever, 2000). MPH has been marketed as Ritalin since the 1950s (Diller, 1996) and remains the most commonly prescribed (Barkley & Cox, 2007) and most frequently studied (Greenhill, Halperin & Abikoff, 1999) stimulant drug used to treat the symptoms of ADHD today. A range of longitudinal studies have shown MPH in the treatment of ADHD to be safe and effective in terms of associated improvements in a range of areas of functioning (Greenhill, 2001). Very few studies though have considered the impact of pharmacological intervention in terms of the safety of children with ADHD. Medication use is an obvious factor to be considered in relation to the ADHD child's readiness to safely navigate the traffic environment given the impact it has been shown to have on aspects of cognitive function (Kempton et al., 1999; Rhodes et al., 2005), previously linked with pedestrian behaviour (Barton & Morrongiello, 2011; Stavrinos et al., 2011).

Indeed, there is strong evidence which suggests MPH improves aspects of cognitive function in those with ADHD. Kempton et al., (1999) reported stimulant medication improved performance on short term memory and spatial working memory, set-shifting and planning tasks. It appears a single dose of MPH improves short term visual memory but not working memory, but chronic administration improves both short term visual and pattern recognition memory (Rhodes et al., 2004). Similar administration effects have been reported in respect of inhibitory control (Coghill, Rhodes & Matthews, 2007). Some have argued MPH is comparatively less effective in improving attention set-shifting, inhibition and planning task performance (O'Driscoll, Dépatie, Holahan, Savion-Lemieux, Barr, Jolicoeur & Douglas, 2005; Rhodes et al., 2005) but the effectiveness of MPH appears at least to some extent, to depend on whether children are assessed after acute or chronic administration (Coghill, et al., 2007). A meta-analytic review of 36 studies examining the effects of medication on cognition in ADHD reported MPH has a positive impact on working memory, non-executive short term memory and inhibitory control (Coghill, Seth, Pedroso, Usala, Currie & Gagliano, 2014). This literature will be discussed further in chapter 15.

In light of the effects of medication on cognitive functioning in ADHD and the recent evidence suggesting cognitive functioning plays an important role in allowing children to interact safely with the traffic environment (Barton & Morrongiello, 2011; Stavrinos et al., 2011), it may be reasonably expected that medication may impact on the pedestrian behaviour of children with ADHD but no empirical research has ever investigated this explicitly.

Marcus, Wan, Zhang & Olfson (2008) studied US medical records to explore the relationship between use of stimulants and accidental injuries in the ADHD population and reported no significant effect of medication in terms of protecting against accidental injuries amongst children with ADHD. However, as the authors themselves highlight, stimulant use is often inconsistent in children with ADHD, an issue other research has identified (Marcus, Wan, Kemner & Olfson, 2005, and

Marcus and colleagues did not control for whether children were taking medication at the time they became involved in an accident. Other studies have controlled for this and a considerable literature has argued an encouraging case for the effectiveness of medication in improving the safety of drivers with ADHD (Barkley & Cox, 2007; Cox, Humphrey, Merkel, Penberthy & Kovatche, 2004; Cox, Lawrence, Kovatchev & Steward, 2000; Cox, Merkel, Moore, Thorndike, Muller & Kovatchev, 2006; Jerome & Segal, 2001) and some have implicated inhibitory control in the MPH-driving performance relationship (Barkley, Murphy, O'Connell and Connor, 2005). These studies, which will be discussed in more detail in chapter 15, consistently report that medication improves driving performance in the ADHD population but it is impossible to conclude whether these effects extend to the safety of pedestrian behaviour amongst children with the disorder. Further investigation in this regard is would appear worthwhile and will be a focus of the present thesis.

### 1.11 Summary

Unintentional injuries have become the leading cause of death in the developed world. Traffic accidents account for the largest proportion of these but it is pedestrian accidents specifically which are the most common type of accident resulting in serious injury or death amongst children. The reasons for this have traditionally not been well understood.

Early work focused on describing accident rates and focused on identifying demographic factors which predisposed some groups of children to pedestrian injury more than others which resulted in longstanding and ineffective attempts to improve outcomes via public awareness campaigns and knowledge enhancement approaches. Child pedestrian accident rates remained largely unchanged. As research begun to explore more effective approaches to improving outcomes for children, the skill based nature of safe interaction with the traffic environment begun to emerge and researchers started to take seriously the psychological complexity of the pedestrian's interaction with traffic. Over time, a number of key skills have been identified and typical developmental age trends for some of these skills have been described. Less well understood are the factors which underpin the development of these skills both amongst typically developing children and amongst groups who appear even more vulnerable such as children with ADHD. This limits the scope of targeted intervention.

Only recently research has begun to explore the psychological underpinnings of pedestrian skill level and evidence is beginning to suggests that cognitive functions (and in particular executive functions) may play an important role, though the evidence base is limited and the specific components of cognition which are important remain largely unknown. The potential importance of cognitive function in pedestrian decision making has also been underscored by the emergent vulnerability of children with ADHD to traffic accidents. Studies suggest this group is particularly vulnerable and that this vulnerability would appear to be related to the profile of cognitive impairment associated with the ADHD disorder.

In view of these trends, there is a strong case for a better understanding of the relationship between cognitive abilities and pedestrian vulnerability and how this changes across childhood. The role that these factors might play in explaining the disproportionate vulnerability of children with ADHD is also unclear and requires more detailed investigation. Such understanding would seem to be a necessary precursor to establishing how future interventions can be better structured and designed to promote pedestrian skill development amongst all children.

### 1.12 The Present Research

In broad terms, this thesis aims explore the development of pedestrian skill level across childhood and to investigate the role of EF in its development amongst both typically developing children and children with ADHD.

Very few previous studies have investigated cognitive function in relation to child pedestrian skill level in detail. Two recent studies have reported that EF and child pedestrian skill level are positively related (Barton & Morrongiello, 2011, Stavrinos et al., 2011) but these studies have adopted a narrow focus, investigating the size of gaps children are willing to cross through in a flow of traffic alone. This scarcely does justice to the range of pedestrian skills investigated in recent years (Thomson, 2016). In addition, these studies have focused on a narrow age range. Barton and Morrongiello (2011) recruited typical children aged 6-9 years and Stavrinos et al. (2011), children with ADHD aged 7-10 years. This makes it difficult to explore developmental trends in any depth. The measures of cognitive function used by these studies reflects a further limitation as they have been composite measures implicating multiple cognitive functions which make it unclear which cognitive abilities are important.

The first main aim of the present thesis is to address these limitations and extend the findings of these previous studies by investigating the relationship between cognitive function and child pedestrian skill level more comprehensively. This thesis will:

1. Investigate changes in the development of pedestrian skill level and EF in children between the ages of 5 and 12 years of age. This age range was selected to allow for a fuller developmental trajectory of child pedestrian skill acquisition to be investigated. Past research has shown very young children aged 5 show very little pedestrian competence but by age 12, children are beginning to exhibit near adult levels of performance.

2. Investigate a wider range of pedestrian skills using a broader range of measures of performance whilst also taking account of conceptual understanding of each skill. Three skills will be addressed. The first skill will be children's safe place finding ability (the ability to identify dangerous crossing locations and construct safe routes across the road which avoid them). This is a skill which has been described as one of the most crucial of all for safe pedestrian-traffic interaction (Tabibi & Pfeffer, 2003). The second skill to be investigated is that of visual timing and gap selection (the ability to identify and utilise gaps between cars in a flow of traffic which are sufficiently large enough thorough which to cross safely). This is a skill which is paramount, particularly for older children who begin to use the road autonomously or in locations where designated crossings are not available.

The third skill which will be investigated is the perception of other road users' intentions (the ability to accurately predict the intentions and future actions of others). This is another crucial skill essential for safe road use which takes account of the social interactive nature of the traffic environment. In addition, the perceived difficulty of the performance of these skills will also be considered. In the driving literature, this is a critical variable and studies have shown a predictor of both speeding and other driving violations is perceived behavioural control (Paris & Broucke, 2007). Past research has also shown adolescent pedestrians overestimate their own ability compared with adults and that such confidence does not concord with skill level (Tolmie et al., 2006). Tolmie and colleagues showed this effect is more pronounced amongst adolescents than 11 year olds, but little is known about this effect in younger pedestrians.

3. Investigate the relationship between pedestrian skill level and the development of cognitive function. Past research has shown many pedestrian skills have a protracted development across childhood, less well known is how this compares to the development of aspects of cognition which have been previously linked with pedestrian skill level. Separable measures of cognitive function will be used via neuropsychological tasks to investigate the development of these functions and their relationship to performance of the pedestrian skills described above. The first measure of cognitive function selected is a measure of inhibitory control. This is an aspect of EF which has been previously linked with pedestrian skill level in respect of visual gap timing ability (Barton & Morrongiello, 2011) but has never been studied in

relation to other pedestrian skills. The second is a measure of spatial working memory which has been linked with children's ability to find a safe crossing route (Barton, Ulrich and Lyday, 2010), but once more never considered in respect of other skills. The third is a measure of risk taking on a gambling task. Risk taking has been long since claimed to be a causal factor to pedestrian accidents and in a study by Hoffrage, Weber, Hertwig and Chase (2003) children who took risks on a laboratory task were found to make more risky crossings by the roadside. A fourth measure of short term visual memory without a prominent executive component which involves the holding of information in mind over time. It has been argued for some time to be a central ability which underpins safe pedestrian behaviour (Vinje,1981) but never studied in relation to skill level empirically.

Recent studies have also highlighted that children with ADHD are even more vulnerable as pedestrians compared to the already vulnerable typically developing child population. A wide body of literature has shown children with ADHD are impaired in respect of a number of aspects of cognitive functioning (Kempton et al., 1999, Rhodes et al., 2004, 2005). Studies have also shown this appears to impact on a range of negative and health threatening behaviours in the ADHD population which in turn suggests this group would be a particularly appropriate population in which to examine the relationship between cognitive function and pedestrian skill development. One study to date has addressed this. The findings suggest problems with neuropsychological function amongst those with ADHD may account for the vulnerability of this group, but Stavrinos and colleagues (2011) do not specify what tasks or component skills are included in their measure of neuropsychological function and consider performance in respect of only one pedestrian skill.

A second main aim of this thesis is therefore to examine differences in pedestrian skill level between children with and without ADHD in respect of a more broad range of pedestrian skills that those addressed by previous studies. It will also use separate neuropsychological tasks to measure aspects of cognitive function to determine which functions explain the vulnerability of the ADHD population.

A third main aim of the thesis is to retest children with ADHD following titration onto stimulant medication. A number of previous studies have shown medication has a positive impact on aspects of cognition in children with ADHD as well as on the performance of adult drivers with the disorder, yet no research has considered its impact on pedestrian skill level. This thesis aims to investigate the impact of medication on both the cognitive functioning and pedestrian skill level of children with ADHD. This could provide important additional insights into the relationship between cognitive function and pedestrian skill level and approaches to improving outcomes for this vulnerable group.

These three objectives are addressed through two main phases of research reported in parts A and B of this thesis. Part A focuses on typically developing children aged 5-12 years and comprises 4 studies, the first 3 of which systematically examine the development of three key pedestrian skills. The fourth examines the development of cognitive function and the relationship between these factors. Part B focuses on children with ADHD and compares the development of these same skills (and their relationship to cognitive function) amongst medication naive children with ADHD also aged 5- 12 years to typically developing controls. The final study also reported in part B considers the development of pedestrian skill level in children with and without ADHD over the course of approximately one year, through a longitudinal follow up study, by which time all of the children with ADHD who were retested had been treated with stimulant medication.

# Chapter 2

## Introduction to Part A

Part A of this thesis examines the development of pedestrian skill level in respect of three key skills amongst typically developing primary school-aged children across the age range of 5 – 12 years. It also examines developmental trends in respect of four neuropsychological functions in the same children and concludes with an examination of the relationships between these factors.

### 2.1 Study 1.1

The first study reported in Chapter 4 examines the development of the ability of children to select safe crossing routes. This is a skill that has been long since shown to develop significantly between the ages of 5 and 11 (Ampofo-Boateng & Thomson, 1991; Thomson et al., 1992; Ampofo-Boateng et al., 1993). Studies investigating the development of this skill have previously stressed the importance of considering children's conceptual as well as behavioural response to this task (Ampofo-Boateng & Thomson, 1991; Thomson et al., 1992; Tolmie et al., 2002). Tolmie et al. (2006) also studied the perceived difficulty of this task amongst adolescents, though no previous studies have considered this amongst younger children. Thus children's behavioural responses, conceptual understanding and their perceived difficulty of this skill will be duly investigated.

### 2.2 Study 1.2

The second study reported in chapter 5 investigates the development of children's ability to select gaps between cars in a flow of traffic which as sufficiently large enough to cross through safely. This is another key skill which becomes particularly important once children begin to cross busy streets where the common advice to “wait until the road is clear before crossing” becomes impractical because of high traffic levels. Like safe place finding, past research has shown this skill to develop gradually across middle childhood, approaching adult levels of competence around 11-12 year of age (Lee et al., 1984; Young & Lee, 1987; Tolmie et al., 2002; Thomson et al., 2005). In the present study, this development will be explored by means of a range of relevant behavioural variables to which will be added children’s perception of task difficulty, which has never previously been assessed in relation to visual timing skills.

## 2.3 Study 1.3

The third study in Part A of this thesis (reported in chapter 6) investigates the development of children’s ability to correctly predict the future actions of other road users and the ability to identify cues in the environment required to do so. Past research has shown clear developmental differences in the performance of this task amongst typically developing children and adolescents (Tolmie et al., 2002, Foot et al., 2006). Tolmie and colleagues (2002) also studied the perceived difficulty of this skill amongst adolescents. No past research however has considered the perceived difficulty of this task amongst younger, more vulnerable children. Therefore developmental differences in both behavioural performance as well as perceived difficulty of this task will be considered in chapter 5.

**2.4 Study 1.4**

The final study in part A of this thesis, reported in chapter 7, builds on recent findings which have linked children's cognitive development with the development of pedestrian skill level. These studies, reviewed in the general introduction, suggest aspects of cognition (particularly EF) appear to underpin children's readiness to interact safely with traffic (e.g. Barton & Morrongiello, 2011, Stavrinos et al., 2011, Tabibi & Pfeffer, 2003).

These studies however have neither examined the development of EF itself or its relation to child pedestrian skill development comprehensively. They have utilised global measures of cognitive function (which make it difficult to determine which aspects of cognition are important) and have not examined child pedestrian skill level beyond a small number of measures of visual gap timing ability, which is just one of many skills central to safe road use. In addition, these studies have focused on a relatively narrow age range.

Study 1.4 investigates the development of cognitive functions via four tasks assessing inhibitory control, working memory, delayed short term visual memory and abstract risk taking. The developmental profiles of these functions are first investigated before their relationship to each of the above three pedestrian skills is also examined.

### 2.5 Research Questions for Part A

Based upon the literature reviewed in chapter 1, the following specific research questions have been formulated for part A of this thesis:

1. What is the developmental trend for children's ability to navigate safe crossing routes?

2. What is the developmental trajectory for children's ability to identify gaps between cars which are safe to cross through and what factors impact upon the development of this ability?

3. How does children's ability to predict the future actions of road users develop through early to mid-childhood?

4. How does the perceived difficulty of these tasks vary as a function of age?

5. What are the developmental trajectories of inhibitory control, working memory, short term visual memory and risk taking?

6. What is the relationship between performance on tasks assessing cognitive function and performance on the above tasks assessing child pedestrian skill level in respect of the three key pedestrian skills described above?

# Chapter 3

## Part A General Method

### 3.1 Introduction

This chapter will provide a detailed account of the methods and experimental procedures common to each of the studies reported in part A of this thesis. It will provide information about recruitment and a description of the characteristics of the sample of participants who took part.

### 3.2 Design

Data were collected from each participant in a single testing session lasting around 2 hours. All participants completed the same tasks and were allocated to one of four age groups: 5-6 year olds, 7-8 year olds, 9-10 year olds and 11-12 year olds. Gender also served as a between groups factor. Participants completed three computer tasks from the Crossroads pedestrian assessment software battery, assessing the three skills outlined in the introduction, and four subtests of the Cambridge Neuropsychological Testing Automated Battery (CANTAB) to assess aspects of neuropsychological functioning, three of which were tasks assessing aspects of EF and one of which was a task assessing short term visual memory, without a prominent executive component. Herein the term neuropsychological function will be used to refer to both.

### 3.3 Participants

A total of 117 participants took part in the studies reported in part A of this thesis. 57 children were male and 60 were female. Children were assigned to one of four age groups according to their chronological age. 30 children were in the 5-6 year old age group, 30 were in the 7-8 year old group, 30 in the 9-10 year old group and 27 in the 11-12 year old group. Full information about the age and gender makeup of the sample is provided in Table 3.1 below.

Table 3.1: Characteristics of Participant Age Groups for Part A

| Age Groups | Total N | N Male | N Female | Mean age in Months (& *SD*) |
|---|---|---|---|---|
| 5-6 year olds | 30 | 14 | 16 | 71.10 (5.98) |
| 7-8 year olds | 30 | 19 | 11 | 93.53 (6.20) |
| 9-10 year olds | 30 | 14 | 16 | 117.70 (7.54) |
| 11-12 year olds | 27 | 10 | 17 | 136.30 (9.66) |
| Overall | 117 | 57 | 60 | 103.84 (6.49) |

Participants were recruited from four schools with different characteristics so as to encapsulate a reasonably wide range of socioeconomic backgrounds and a balanced urban/rural spread. Within each Local Education Authority (LEA), one school was located in an area associated with social deprivation while another was located in an area with a more balance socio-economic profile. The proportion of provision of free school meals (FSM) for each school was used as an initial proxy measure of socioeconomic status (SES) of school catchment areas, which informed the initial selection of schools from which participants would be recruited. Though some have suggested FSM is a limited and inaccurate proxy when used as a measure of SES (Hobbss & Vignoles, 2007; Northern Ireland Assembly, 2010), FSM was used only to determine which schools would be approached for the purposes of recruitment and in this regard, FSM has been described as a reasonable control measure for the SES in respect to an area overall (Halse & Ledger, 2007). SES of the individual participants was determined separately via a process which will be shortly discussed. The data relating to FSM provision was obtained from LEAs in the month prior to the beginning of testing. The urban-rural location of schools was defined using Scottish Index of Multiple Deprivations (SIMD; Scottish Government, 2012) urban-rural ranking using school post codes. Rankings range from the most urban rank (1: Large Urban Area) to the most rural rank (6: Remote Rural Area). Demographic information about the participating schools in terms of FSM provision and urban – rural locale is reported in Table 3.2 below.

Table 3.2: Urban/Rural Rating of School Location and Percentage of pupils receiving Free School Meals*

| | School 1 | School 2 | School 3 | School 4 |
|---|---|---|---|---|
| LEA 1 (Large Rural Area) | 5 (39.2%) | 5 (20.1%) | - | - |
| LEA 2 (City Suburb) | - | - | 1 (7.8%) | 1 (66.8%) |

* The national average percentage of FSM at time of testing was 22.1% (Scottish Government, 2012).

To establish the SES of individual children, the Scottish Index of Multiple

Deprivations or SMID (Scottish Government, 2012) was used. The SIMD provides a measure of deprivation by ranking postcode areas in Scotland from 1 (most deprived) to 6 (least deprived) on the basis of 31 indicators falling into 6 domains (mean current income, employment, housing, health, education/skills and training, and geographic service and telecommunications access). This measure has been widely used in research directly investigating deprivation (Stamatakis, Hillsdon, Mishra, Hamer & Marmot, 2009) as well as for participant matching and control purposes (McMillan, Teasdale, Weir & Steward, 2011). SIMD postcode quintile rankings revealed that the mean household SES for the sample of children was 2.75 in terms of quintile rankings. The proportion of participants falling into each of the quintiles is summarized in Table 3.3.

Table 3.3: Deprivation Quintile rankings of Participant Home Postcode using SIMD

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| N of Participants | 28 | 29 | 5 | 54 | 1 |

Scores of urban/rural residence rating ranged from 1 (large urban area) to 6 (remote rural area). The mean urban/rural score of the participant home address was 2.74. The distribution of participants across urban-rural ranks of the SIMD is summarized in Table 3.4.

Table 3.4: Urban/Rural Ranking of Participant Home Postcode using SIMD

| | Rank 1 | Rank 2 | Rank 3 | Rank 4 | Rank 5 | Rank 6 |
|---|---|---|---|---|---|---|
| N of Participants | 62 | 5 | 1 | 0 | 48 | 1 |

## 3.4 Materials

### 3.4.1 Screening Measures

The Strengths and Difficulties Questionnaire (SDQ; Goodman, 2001) and the British Picture Vocabulary Scale (BPVS; Dunn, Dunn & Styles, 2009) were used as screening measures in the current study.

The SDQ is a short behavioural screening tool for a range of difficulties that may be experienced by children aged between 4 and 16 years old (Goodman, 2001). The SDQ examines 25 attributes, some positive and some negative. Items are divided between 5 behaviour domains: emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems and prosocial behaviour (each domain is represented by 5 items). Scores from the first four of these scales are added together to generate a total difficulties score (based on 20 items). The SDQ has been widely used for a range of research purposes and has demonstrated good reliability and validity (Goodman, 2001). Normative data are available from several countries. The teacher version of the SDQ was used as a screening measure in the current study to ensure typicality of the sample in terms of behaviour. Teachers completed the SDQ after parent/guardian consent had been obtained and before testing was undertaken. All children for whom consent had been obtained scored within the typical range on this measure and so no participants were excluded on this basis.

The BPVS (3rd edition) developed by Dunn et al., (1997) was used as a screening measure of intellectual abilities of participants. The BPVS has been widely used as a measure of verbal intelligence and is a quick but reliable measure designed for use with children aged 3 – 15 years (Dunn et al., 1997). It measures receptive vocabulary which has long been described as being highly predictive of educational success (Dale & Reichart, 1957) and is also a significant predictor of performance on full scale tests of intelligence (Elliott, Murray & Pearson, 1990). The BPVS was chosen over measures of full scale intelligence because it confounds less with EF than measures of full scale intelligence and is commonly used by studies matching specialist groups to controls for this reason (Hughes & Ensor, 2011; Rhodes et al., 2010; Robinson, Goddard, Dritschel, Winsley & Howlin, 2009).

The BPVS contains 4 training plates which allow children to become familiar with the task's procedure which precede 14 sets of 12 plates. Sets increase in difficulty. Each plate contains 4 colour pictures. Children are asked to select which of the 4 pictures contained on a plate best represents the meaning of a word read aloud by the test administrator. The starting plate is determined by the child's chronological age. The test is terminated when participants make 8 or more errors in the same set. The final plate from which children correctly identify an item is converted into a standardised score. Standardised scores correspond to an age-equivalent age range produced from normative data.

All children who completed the BPVS scored within the typical age equivalent range. Three participants failed to complete the BPVS: two refused and one appeared not to understand the instructions in spite of several explanations. Though offered the opportunity to try the experimental tasks, these three children chose not to complete the remaining parts of the experiment. No experimental data was recorded for these participants and their incomplete BPVS data was destroyed and has not been included in this thesis.

Screening using the BPVS and SDQ was important to ensure the sample comprised typically developing children. It was considered important to ensure the sample was not contaminated with data from children with atypical behaviour or ability as study of the responding of typically developing children was what was of interest in part A of this thesis. Examination of differences between typically and atypically developing children is an aim of the later chapters of this thesis in part B.

### 3.4.2 Crossroads Pedestrian Software

The Crossroads pedestrian training software developed by Tolmie et al., (2002) is a virtual reality computerised pedestrian training resource which assesses a range of pedestrian skills and was designed for use with children across the primary school age range. Following its development, the package was adopted by the UK Department for Transport as a government training resource, copies of which were sent to local education authorities across the UK. This training software was later adapted by the research team to construct an assessment tool for research purposes. The assessment programme provides measures of performance across five key pedestrian skills: safe place finding and safe route selection; attention and visual search; visual timing and gap acceptance; the perception of other road user's intentions; and the ability to use designated crossings. Each skill is assessed by means of separate modules which provide data on a number of variables relevant to the skill in question.

The Crossroads software was used to measure children’s pedestrian skill level in preference to roadside testing in the current study for a number of reasons. Firstly, it allows for the study of skills under controlled experimental conditions, so that the problems presented to participants are identical in all respects. This is very difficult or impossible to accomplish at the roadside, where traffic conditions change. Secondly, many of the scenarios presented by the software would, in practice, be very difficult to create in a naturalistic roadside setting. Thirdly, the use of the assessment software eliminates risk associated with roadside testing. The objectives of the present thesis include assessing very young children, aged 5 and also in part B, the assessment of children with ADHD. The ethical implications of testing these groups by the roadside are significant and the associated risks are eliminated by the use of virtual reality as an alternative method.

Performance using this assessment tool has been validated against roadside performance in several studies with positive results (Chinn et al., 2004; Foot et al., 2006; Thomson et al., 2005; Tolmie et al., 2005). Chinn et al. (2004) tested children on roadside versions of the safe places and visual timing tasks and found highly significant correlations between all key measures on the roadside and computer versions. Thomson et al. (2005) also compared performance on the two versions of the visual timing task, while Tolmie et al. (2005) and Foot et al. (2006) made similar comparisons in respect of the visual attention and predicting drivers’ intentions tasks respectively. All found strong correlations between performance on the virtual reality software and children’s roadside behaviour. In addition, virtual reality training studies by the same authors have shown that improvements in performance following Crossroads training transfer to judgements made at the roadside, further suggesting that the virtual reality and roadside versions of the tasks are good proxies for each other (Thomson et al., 2005; Tolmie et. al., 2002; Foot et al., 2006). These findings are consistent with a wide range of recent studies demonstrating good correspondence between virtual reality and behavioural measures across a wide range of contexts, including traffic behaviours (Barton & Schwebel, 2006; McComas, MacKay & Pivik, 2002; Schwebel, Gaines, Severson, 2008). As a result, virtual reality simulation has become a popular approach in studying pedestrian skills in both children and adults (Clancy et al., 2006; Dommes et al., 2012; Holland & Hill, 2010; Oxley, Ihsen, Fildes, Charlton & Dey, 2005; Stavrinos et al., 2011; Simpson, Johnston & Richardson, 2003).

Three tasks contained within the Crossroads pedestrian assessment battery were selected for use in the studies reported in this thesis. These tasks were selected because of the well established importance of the skills they measure in respect of the safety of children's pedestrian behaviour (Thomson et al., 1996). The tasks assess three distinct skills as follows:

- *Safe place finding* which has been described as the ability to identify dangers posed by features of the traffic environment such as road layout and the presence of obstructions blocking the view of the road and the ability to adjust crossing locations and routes accordingly.

- *Visual timing and gap acceptance*, which is the ability to coordinate road crossing with vehicle movements and to identify gaps in a flow of traffic that are safe or not safe to cross through.

- *Predicting the intentions of other road users* which refers to the ability to identify cues indicating the upcoming actions of other road users and make accurate predictions about what others are about to do based on these cues.

These tasks and their outcome measures will be described in more detail in the forthcoming chapters.

### 3.4.3 Cambridge Neuropsychological Automated Testing Battery

The Cambridge Neuropsychological Automated Testing Battery (CANTAB: Morris et al., 1987) is a testing battery comprising a broad range of tasks assessing discreet neuropsychological functions delivered via a touch screen tablet computer. Studies report strong neural correlates with task performance (e.g. Alichniewicz, Brunner, Klunemann & Greenlee, 2012) and automated delivery allows for strict control between testing sessions (Green, Mihic, Nikkel, Stade, Rasmussen, Munoz & Reynolds, 2009). This battery was selected for use in the current thesis as it allows for the study of neuropsychological functions via tasks which produce distinct measures of performance in respect of separable cognitive functions. This is important, because disentangling the contributions of specific executive and other cognitive functions to children's pedestrian behaviour was a direct aim of the present research. There is also a large literature providing normative data and developmental trends in respect of the various subtests against which the findings of the current thesis can be compared (e.g. De Luca, Wood, Anderson, Buchannan, Proffitt, Mahony & Pantelis, 2003, Luciana & Nelson, 2002,). A large part of the present thesis (presented in part B) also focuses on children with ADHD. A number of studies have used the CANTAB battery to study the cognitive profile of this group (Gau & Shang, 2010; Rhodes et al., 2004, 2005, 2006) providing additional normative data in respect of the ADHD population, which makes the CANTAB a particularly appropriate tool for use in the present thesis.

Four subtests from the *CANTAB* battery were selected for use in the studies contained within this thesis. The use of the CANTAB tasks allows for these functions to be assessed independently and their specific contribution to pedestrian skill level to be examined directly, which is a direct objective of this thesis. Recent studies examining the relationship between EF and children's pedestrian behaviour have used alternative measures of these functions to generate composite measures of EF which they have in turn linked with pedestrian skill level (Barton & Morrongiello, 2011; Barton & Schwebel, 2007; Kovesdi & Barton, 2013; Tabibi & Pfeffer, 2003; Vinje, 1981). As already highlighted however, this is a crucial limitation of these previous studies. The use of tasks which tap into multiple aspects of EF means the contribution of individual functions is unknown. In addition, a number of previous studies have demonstrated that these tasks discriminate neuropsychological profiles of children with developmental disorders including

ADHD which will be a focus of the second half of this thesis. Three of the tasks used to assess neuropsychological function were tests of aspects of executive functioning and one assessed short term visual memory, without a prominent executive component.

The *Stop Signal Task* (SST), which was used to assess inhibitory control; the ability to inhibit a proponent response. Participants respond using a button box, making or inhibiting motor movements (button presses) according to the presentation of visual stimuli, meaning the CANTAB SST measures motor inhibition. This makes the SST a particularly appropriate measure of inhibitory control for the current study given the importance of inhibiting automatic motor responses by the roadside (such as darting out into the road). The outcome measure is stop signal reaction time; the mean time in milliseconds between presentation of the go stimulus and appearance of the stop signal at which participants successfully inhibited their response. Lower reaction times indicate greater inhibitory control. A number of studies have also used this task previously to examine inhibitory control in specialist clinical populations, reporting findings which demonstrate the SST is sufficiently sensitive to detect differences in inhibitory control between children with and without ADHD (Soreni, Crosbie, Ickowicz & Schachar, 2009; Tillman, Thorell, Brocki & Bohlin, 2007), which will be a focus of part B of this thesis. In addition, recent studies have reported a relationship between performance on tasks considered to include an inhibitory component (amongst other aspects of EF) and children's pedestrian skill level (Barton & Morrongiello, 2011; Barton & Schwebel, 2007) but have not measured this directly.

The *Spatial Working Memory Task* (SWM) was used to measure working memory. This is a search task assessing working memory for spatial stimuli and requires participants to use mnemonic information to work towards an end goal. The task requires participants to maintain and manipulate information in mind whilst the search for hidden tokens, remembering where they have already searched. Returning to search in a box under which a token has already been located or previously shown to be empty constitutes an error. This is an appropriate measure of working memory for the purposes of this thesis, given the importance of maintaining and manipulating spatial information specifically by the roadside (such as the speed and distance of approaching vehicles from multiple directions). The outcome measure is the number of between search errors; the number of times a participant returned to check a box where a token had already been found. Past research has also shown that the task is sensitive to detecting differences between control children and clinical population such as those with ADHD (Kempton et al., 1999, Rhodes et al. 2004, 2005). Additionally, measures of EF derived from other tasks which include working memory components, such as the Stroop task (Engle, 2002), have also recently been linked with children's pedestrian skill level (Barton & Morrongiello, 2011) but once again studies have used composite measures which include a working memory component but do not measure this directly.

The *Cambridge Gambling Task* (CGT) was used to assess risk taking and decision making in an abstract context. This is a gambling task which assesses children's propensity to take risks and the quality of decision making by presenting children with scenarios in which they need to choose a quantity of points to wager based on their confidence in correctly locating a hidden token. Children select to gamble on either blue or red based on 10 blue and red boxes which vary in terms of the number of each colour between trials. The token can be hidden under a blue or a red box. Once children have chosen a colour, they must choose how many points to wager based on their belief about the likelihood of success. There are three outcome measures; risk taking (the mean proportion of points that the participant chose to gamble on trials for which they chose the more likely outcome), overall proportion bet (the mean proportion of points that the participant chose to gamble on each trial regardless of whether betting on the more or less likely outcome) and the quality of decision making (the mean proportion of trials on which the participant chose to gamble on the more likely outcome). The CGT has been used previously to examine developmental differences in the propensity to take risks amongst typically developing children (Leijenhorst, Westenberg & Crone, 2008) and also amongst children with ADHD (Coghill, Seth & Matthews, 2013; Groen, Gaastra, Lewis-Evans & Tuach, 2013). Since a number of studies have recently proposed a strong relationship between propensity for risk taking and traffic injuries in children (Granié, 2009; Hoffrage et al., 2003), and differences in risk taking have been reported between children with and without ADHD (Drechslet, Rizzo & Steinhausen, 2008; Garon, Moore & Waschbusch, 2006) it was considered appropriate to include a measure of risk taking in the present study.

The *Simultaneous and Delayed Match to Sample Task* (DMtS) was used to measure non-executive delayed short term visual memory. This task assesses the ability to remember the components of complex abstract visual stimuli (abstract colour and shape patterns) over varying delays, before selecting one match from four similar patterns. The visual nature of this task makes it appropriate for use here given the requirement for pedestrians to maintain visual information in short term memory (such as the views to left, right or behind the participant when making crossing judgements [Vinje, 1981]). The outcome measure is the percentage of correct responses. The DMtS task has also been shown to be highly sensitive in detecting differences in short term visual memory between children with and without ADHD (Kempton et al., 1999; Rhodes et al., 2004), again making this an appropriate measure for the studies reported in this thesis.

### 3.5 Procedure

The first stage of recruitment involved a formal approach to two LEAs in Scotland which were contacted in writing to request permission to undertake research in schools. It was considered important to invite LEAs from both urban and rural areas to reflect the rather different traffic experience children from these background would encounter, which might in turn be expected to impact on their pedestrian skill development. One LEA covered a large rural area while the geographic area of the other covered a densely populated urban city suburb. After permission had been granted by both of these LEAs, permission was sought and granted via letter to 4 Head Teachers: 2 from each LEA. Written consent was sought from parents/guardians of participants (see appendices 2 and 3 for a copy of the study information sheet and consent form). Child assent was sought verbally on the day of testing.

Following ethical and LEA approval and the granting of Head Teacher and parent/guardian permission, the researcher obtained a list of the pupils whose parents/guardians had consented to their child's participation from each of the 4 schools. Children were tested individually in a quiet room within their school. This allowed children to provide informed assent and complete the tasks under controlled experimental conditions.

The permission of parents/guardians was requested and obtained in writing via information sheets and consent forms distributed and collated by schools. Children who assented to take part on the day of testing then completed all tasks during a single school day at their state primary school. Inclusion criteria were being of primary school age (between the ages of 5 and 12 years) and having no history of developmental disorder. All participants were fluent English speakers. The teachers of participating children completed a SDQ (Goodman, 1997) to ensure the typicality of the sample. All children for whom consent was returned scored within the typical range on this measure.

The researcher first introduced himself to the participants, explained the purpose of the study and what the tasks would involve. Children were told that their Head Teacher and parent/guardian had consented to their participation but it was stressed it was their decision whether or not they wanted to take part. It was felt this was important given the length of the testing session. After this had been explained children were asked for their assent to take part. If this was granted the researcher explained each of the tasks participants would go on to complete, namely the BPVS, safe place finding table-top model, the Crossroads battery (including the safe place finding, visual (gap) timing and driver intentions tasks (as well as tasks from the CANTAB battery (including the Stop Signal, Spatial Working Memory, Simultaneous/Delayed Matching to Sample and Cambridge Gambling Tasks).

The BPVS was completed by all participants first. It was thought the short and simply nature of this task would allow participants to adjust to the testing environment and to get to know the researcher. Although each experimental task measured very different skills (and so learning effects were not expected) the length of the testing session required the study to control for participant fatigue. The order of task presentation was therefore controlled through counterbalancing and randomisation which has been described as an appropriate countermeasure to control for fatigue effects (Bradley & Daily, 1994). Participants were also invited to take short breaks between tasks as necessary. Half of the participants completed the pedestrian tasks first while the other half completed the CANTAB tasks first. The sequence of presentation for both the pedestrian battery and the CANTAB battery of tasks was pseudo-randomised. The sequence of tasks was presented in one of 4 sequences. The four sequences for Crossroads task presentation are presented in Table 3.5 below.

Table 3.5: Sequence of Presentation for Pedestrian Behaviour Battery

| Place of subtest in Sequence | Sequence 1 | Sequence 2 | Sequence 3 | Sequence 4 |
|---|---|---|---|---|
| 1st | SP Model | Ints | VT | SP |
| 2nd | SP | SP Model | Ints | VT |
| 3rd | VT | SP | SP Model | Ints |
| 4th | Ints | VT | SP | SP Model |

SP=Safe Place Finding Task; VT=Visual (gap) Timing Task; Ints=Predicting Intentions Task

The 4 sequences for CANTAB task presentation order are presented in Table 3.6 below.

Table 3.6: Sequence of Presentation for CANTAB Battery

| Place of subtest in Sequence | Sequence 1 | Sequence 2 | Sequence 3 | Sequence 4 |
|---|---|---|---|---|
| 1st | SST | CGT | DMtS | SWM |
| 2nd | SWM | SST | CGT | DMtS |
| 3rd | DMtS | SWM | SST | CGT |
| 4th | CGT | DMtS | SWM | SST |

SST=Stop Signal Task; SWM=Spatial working memory; DMtS= Delayed matching to sample task; CGT=Cambridge gambling task

Each task was explained to participants in terms of its aim and operation before participants began trials. Instruction about the operation of each task was provided verbally at the beginning of each task respectively. These instructions were standardised and taken from the instruction manual which accompanies the CANTAB software produced by Cambridge Cognition® who licence and own rights to the software and in the case of the Crossroads software as detailed by Tolmie et al. (2002). Both the Crossroads and CANTAB subtests included practice trials which allowed participants to establish how tasks worked before data collection began.

Participants were made aware of the nature and purpose of practice trails. Following practice trials participants were able to ask any questions they wished to before formally beginning each task.

Following completion of the final task, participants were thanked for their participation by the researcher and given the opportunity to ask any additional questions they had about the study and its aims. Often children asked for feedback on their performance. In these instances, the researcher explained that there were no right or wrong answers and that the aim of the study was to establish what children of different ages thought was the best way to respond as a whole, rather than individual performance.

# Chapter 4

## Study 1.1: The Development of Safe Place Finding Ability

### 4.1 Introduction

Safe pedestrian-traffic interaction relies on a range of skills and abilities. The ability to distinguish safe from dangerous routes across a busy road and navigate crossing routes accordingly is one such skill which pedestrians must master in order to navigate the traffic environment safely. This skill requires the accurate perception of hazards in the traffic environment and the ability to adjust crossing routes to account for these (Ampofo-Boateng & Thomson, 1991; Tolmie, Thomson, Foot, Whelan, Sarvary and Morrison, 2002). Some argue this is one of the most crucial pedestrian skills of all, vital for safe pedestrian – traffic interaction (Tabibi & Pfeffer, 2007).

At first glance, planning a safe route across a road might seem relatively straightforward. In reality however, this skill is perceptually and cognitively demanding. Determining the safest location to initiate a road crossing in a street populated with hazards requires pedestrians to identify potential crossing locations, assess dangers posed by environmental hazards such as blind corners, turns in the road and parked vehicles, and then reach a decision about which is the safest place from which to attempt to cross. This task is complicated further still by the fact that vehicles can be travelling at different speeds and can enter the view of pedestrians from a number of directions. The processing of this information necessitates the use of a number of underlying cognitive functions whose importance will be examined in depth in Chapter 6 (Study 1.4).

A number of authors have shown that selecting safe crossing routes is very difficult for young children who appear particularly poor at distinguishing safe from dangerous locations at which to initiate a crossing (Ampofo-Boateng & Thomson, 1991; Thomson et al, 1992; Ampofo-Boateng et al., 1993; Demetre & Gaffin, 1994; Thomson & Whelan, 1997; Tolmie et al., 2002; Tabibi & Pfeffer, 2007; Whelan et al, 2008). Children tend to opt for the quickest, most direct route when asked to select the safest way to cross, even if this places them at considerable danger (Ampofo-Boateng & Thomson, 1991). They assume this to be the safest approach because it allows for the completion of the task quickly and allows them to spend the least amount of time on the road. This means children often cross streets diagonally which results in them spending more time in the path of oncoming vehicles than necessary.

Moreover, children are poorly attuned to the hazard posed by roadside locations that limit their view of approaching traffic such as near a corner, below the brow of a hill or close to obscuring objects such as hedges, road works or parked vehicles. This also makes it more difficult for drivers to see the pedestrian and adjust their behaviour (such as speed) accordingly, increasing risk further still. Children's awareness of the dangers posed by crossing at parked vehicles for example appears particularly poor (Demetre & Gaffin, 1994; Thomson & Whelan, 1997). Younger children (below the age of 9 years) appear not to attend to these at all. As children reach 10 years of age, they begin to recognise such hazards and start to move away both from parked cars and other hazards impeding their view of the road, to locations from where they have a clear view of the road and its features.

Ampofo-Boateng and Thomson (1991) were among the first to study developmental age trends in children's safe place finding ability. Thomson and colleagues recruited 5, 7, 9 and 11 year olds and showed children aged 5 and 7 years were very poor at discriminating between safe and dangerous crossing locations and appeared to focus exclusively on the visible presence (or absence) of approaching cars in making decisions. Only from age 9 did children begin to demonstrate some improvement in their ability to select safer places and by 11 years old children appeared significantly more capable of crossing at safe places.

Whitebread and Neilson (2000) also considered the development of safe place finding and the contribution of visual search strategy to this skill in 5-11 year olds. Using photographs of real road scenes, the authors tasked participants with selecting whether or not each photograph depicted a safe place from which to attempt to make a crossing. In line with similar work by Tolmie et al. (1998, 2002, 2006) which also investigated children's conceptual understanding by asking them to provide justifications for their selections, the findings demonstrated linear developmental improvements both in the identification of safe places but also in terms of children's conceptual understanding of why a location was safe or dangerous: that is, they demonstrated a concordance between the development of children's behavioural responses and their underlying conceptual understanding of the task.

This distinction between children's behavioural responses and their underlying conceptual understanding appears to be critical in determining whether or not children are capable of making skilled judgements at the roadside.  Indeed, the importance of conceptual understanding and metacognitive awareness has long been argued as important in the child pedestrian literature (Whitebread & Neilson, 1998; Thomson et al., 1996; Tolmie et al., 2005; Thomson et al., 2005).  Indeed these authors argue that children's vulnerability to pedestrian accidents may reflect not simply a lack of ability in terms of specific perceptual, cognitive and motor competencies but rather a lack of ability in terms of knowing how and when to deploy these competencies, as well as an underlying lack of awareness of why some courses of action might be safer than others.  A number of more recent studies have since suggested that children's conceptual understanding is a key determinant of their behavioural decision-making and is what drives the age-related improvements in children's pedestrian behaviour (Thomson et al., 2005).  The importance of considering conceptual understanding of the task as well as the qualities of the crossing decisions made by children of different ages would therefore appear vital in assessing the development of pedestrian competence and will be an important focus of the current study.

Tolmie, Thomson, O'Connor, Foot, Karagiannidou, Banks, O'Donnell and Sarvary (2006) studied how difficult children consider the safe route task to be.  Tolmie and colleagues asked a sample of children aged 11-15 years to make difficulty ratings about how easy or hard they considered the task to be, both before and after choosing crossing routes.  Children tended to judge the task as being easier after they had completed it, compared with how difficult they thought it would be before attempting it. Yet this reduction in perceived difficulty following completion of the task was not justified relative to children's performance. Tolmie and colleagues report this trend amongst all age groups, but note this tendency appears more prominent in adolescents than children in their final year of primary school. Tolmie and colleagues suggest the tendency of children to rate the task as being easy, in spite of their relatively poor performance, may be a result of a failure to attend to performance feedback, a finding also reported amongst novice drivers (Guppy, 1993, Matthews & Moran, 1986). Yet no past research has investigated children's perceived difficulty of this task amongst children in early to mid-childhood. It might reasonably be expected that young children will not perceive the task as being very difficult at all, given their seeming lack of understanding about the purpose of the task and ability to complete it safely (Ampofo-Boateng & Thomson, 1991, Whitebread & Neilson, 2000). Thus the perceived difficulty of the task of selecting a safe crossing route would certainly appear worthy of investigation amongst young children and will be duly considered in the current study.

In summary, safe place finding is a cognitively and perceptually demanding task. Correspondingly, studies have shown that selecting a safe place to cross a road is not something young pedestrians perform safely, reliably or consistently, but is something which improves with age. The ability to identify hazardous locations and construct routes that avoid them develops over a protracted period across childhood and doesn't begin to approach adult levels of competence until around 12 year of age. Since various studies have shown that children's conceptual understanding of such hazards is particularly weak (Whitebread & Neilson, 1998; Thomson et al., 1996; Tolmie et al., 2005; Thomson et al., 2005), it seems likely that children's ability to solve such problems may depend quite heavily on the development of underlying cognitive functions. Hence this skill has been included in the portfolio of skills to be investigated amongst children with ADHD in the current thesis.

The current study aimed to determine developmental differences in children's place finding ability, its relationship to their conceptual understanding as demonstrated by the explanations they give for their decisions, as well as their perception of the difficulty of the task both before making crossing decisions and again afterwards in the light of the experience of doing so. Later in the thesis, children's behavioural decision making and conceptual understanding in relation to the development of more generalised cognitive and executive functions will be explored, as discussed in the introduction to the thesis.

In light of the reviewed literature, the following hypotheses were formulated:

1. There will be clear age trends in children's ability to select safe locations and routes across the road.
2. There will be corresponding age trends in children's conceptual understanding of the task reflected in the quality of their justifications for the crossing decisions they make. Older children will have higher conceptual understanding compared with younger children.

3. There will be age trends in children's perception of the difficulty of the task, with older children perceiving the task as more difficult compared with younger children.
4. Following the experience of making crossing decisions, older children will be more likely to revise their initial assessment of task difficulty and rate the task as more difficult than they had initially rated it.

## 4.2 Method

### 4.2.1 Participants

A total of 117 children took part in the study of which 57 were male and 60 were female. A total of 30 children were aged 5-6years, 30 were aged 7-8, 30 were 9-10 and 27 were aged 11-12 years. Further details about the sample and recruitment are provided in the general method section in Chapter 2.

### 4.2.2. Design

This was an independent groups study: the 4 age groups and gender served as the between groups factors. All participants completed the same tasks.

### 4.2.3. Materials and Procedure

Children were tested in a quiet, empty room in their school. Two versions of the safe place finding task were administered: one using a table top model and another delivered via a standard laptop computer.

The table top version of the safe place finding task was created for use in the current study. The model comprised a purpose-built traffic mat which depicted a standard road layout, pavements, buildings, areas of grass as well as a number of hazards including corners, junctions, parked cars and trees/hedges which could obscure views of the road. Toy cars and a model pedestrian were used to depict crossing situations about which children were asked to make decisions. This methodological approach has been used previously to study safe route selection and has been described as an excellent approach to engaging children and in maintaining interest (Ampofo-Boateng & Thomson, 1991; Ampofo-Boateng et al., 1993; Thomson et al., 1992). Performance on this task has also been previously shown to correspond to performance by the roadside (Ampofo-Boateng & Thomson, 1991, Thomson et al., 1992).

As a second measure, the safe place finding computer task from the Crossroads pedestrian training software developed by Tolmie et al. (2002) was selected. Performance on this task has been shown to correlate closely with performance by the roadside, as reviewed in Chapter 2. The task was presented to participants on a standard laptop computer. Participants completed a practice trial which allowed them to familiarise themselves with the software's operation from which no data was recorded. Participants were then presented with 8 experimental trials comprising a variety of roads, hazards and start/end points. Participants were instructed to negotiate an avatar child from a predetermined starting point through the traffic environment safely to a fixed target destination. Participants used a standard computer mouse to move the avatar through 8 experimental trials. Routes were coded using the same coding protocol as used in previous studies (Ampofo-Boateng & Thomson, 1991, Thomson et al., 1992; Thomson & Whelan, 1997). These trials produced behavioural scores ranging from A (very unsafe) to D (very safe). Behavioural scores for both the table top and computer versions of the task were produced using the coding parameters summarised in Table 4.1 below. An assessment of the reliability of coding was conducted by an independent researcher for data from 17 participants which represented 10% of the sample for all table top and computer trials. Inter-rater reliabilities of routes coded as safe were highly correlated (r=. 84).

Table 4.1: Coding Key for Behavioural Scores on the Safe Place Finding Task

| Code | Description |
|---|---|
| A | Routes leading directly to the target destination typically involving a diagonal crossing, often does not move from starting location before walking out into road and takes no account of hazards. May spend more time on the road than necessary. |
| B | A straight route across the road, often moves away from the start location towards the target location before crossing, but does not take account of hazards. Spends less time on the road than an A response. |
| C | Takes account of some hazards and spends minimum time possible on the road but inadvertently moves closer to another hazard. Often involves making a detour away from dangerous locations. |
| D | Takes full account of hazards by negotiating a route which avoids all possible hazards. |

Responses were then categorised into two broad response groups (safe and unsafe) in line with the procedure previously adopted in studying this skill (Ampofo Boateng &

Thomson, 1991, Tolmie et al., 2002, 2006). Responses which were coded as A and B were combined into a single unsafe group (the proportion of responses which were unsafe) and those coded as C or D were then combined into a safe group (the proportion of responses which were safe). Because the proportion of unsafe routes (those coded as A or B) was the inverse proportion of those coded as safe (C or D), safe and unsafe scores were perfect negative correlates. All analyses are based upon safe scores alone.

In line with previous studies investigating safe place finding ability (Thomson et al., 2005, Whitbread & Neilson 2000), participants were also asked to verbally justify the route they selected by the experimenter in order to generate a measure of their conceptual understanding of the task. Children were asked "*why did you choose that way?*" and their verbal responses were recorded for subsequent analysis. No feedback was provided on performance on any trials. The verbal responses offered by children were then categorised using a scale defined by Tolmie et al. (2002) which has previously been found to encapsulate the nature of children's justifications in response to the above question relating to conceptual understanding. The scale is ordinal in that each category implies a higher degree of conceptual understanding than those previous. Thus, where a child said nothing, that they didn't know or were not sure why they chose a particular route, this attracted the lowest score of zero. A score of one was awarded when children offered a response which demonstrated greater engagement in the task but was of no relevance to safety or the objective of the task. This slightly higher score reflects their engagement in the task at hand. Responses which were related to road safety but not directly relevant to the task or trial at hand were awarded a slightly higher score of two to reflect the awareness of the aim of the task. When children successfully identified a relevant hazard which required evasive action in their response, a score of three was awarded. The highest score of four was awarded when children both identified a hazard which they needed to avoid and explained why their chosen alternative route was an appropriate and safer alternative. All responses fitted into this structure and inter-rater reliabilities conducted by an independent person for 10% of the sample on coding were highly correlated (r=.97). A summary of the coding system for conceptual responses is presented in Table 4.2 below.

Table 4.2: Coding Key for Conceptual Scores on the Safe Place Finding Task

| Code | Description |
|---|---|
| 0 | Don't know/not sure. |
| 1 | Something irrelevant and/or unrelated to road safety. For example, "*Because he might want to look at that shop window*". |
| 2 | Something related to road safety but not relevant. For example "*To stay safe*". |
| 3 | Correctly identifies a relevant hazard but cannot explain why selected route is safer. "*To move away from that parked car*". |
| 4 | Identifies hazards correctly & explains why alternative is safer. For example "*To move away from that parked car which could be blocking his view, to make sure he can see both ways*". |

Participants were also asked about how difficult they thought trials *would be* as each road scene was presented. They were then asked how difficult they thought it *had been* at the end of each trial, before moving on to the next. Difficulty estimations were made using a sliding bar (included in the software). No scale was visible, children were simply asked to move the slider to the point on the bar between very difficult and very easy they felt represented the difficulty of the trial. Difficulty estimations were made only on the computer trials.  Though no numeric scale was presented to participants (given the age of some, this would have been inappropriate), selections made using the slider varied between 0 and 100.

The table top model task was similar in procedure to the computer task but presented through a 3D model comprising roads and pavements, model buildings, trees, pedestrians and toy cars.  The model contained a variety of road layouts and hazards. A small plastic figure was used to indicate the starting location and a movable sticker was used to display target destinations. Children moved the figure by hand to demonstrate chosen crossing routes.  Children completed 12 table top model trials. The presentation order of the model and computer tasks were counterbalanced with half of the children completing the model first and the other half first completing the computer version first.   The same coding strategy used for the table top task as was used for the computer version of the task, as described above.  Figure 4.1 below provides an illustration of the table top model its contents and layout as well as a screenshot from the Crossroads visual gap timing task.

Figure 4.1: Illustrations of Safe Place Finding Tasks

## 4.3 Results

The mean proportion of each of the 4 behavioural response categories (A-D) was calculated for each participant on both the safe place finding crossroads computer task and for the table top model as a function of age. These data are presented in Table 4.3 below.

The mean proportion of safe routes was calculated by combining C and D scores. The mean proportion of unsafe routes was the sum of routes coded as A or B. Although a progression from a response rated, for example as A (very unsafe) to one rated as B (unsafe), represents some improvement, such shifts were not of direct interest because they do not represent significant change in the safety of children's behaviour and children responding with unsafe (B) responses would still have limited insight into the factors which determine whether a crossing location is dangerous or safe. This approach has been adopted by previous studies investigating this skill.

Table 4.3: Mean (&S.D.) Proportion* of Response Category by Age Group and Modality

| Age Group | Computer Version | | | | Table Top Model | | | | Combined | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | A | B | C | D | A | B | C | D |
| 5-6 years | .32 (.25) | .50 (.25) | .17 (.16) | .01 (.05) | .30 (.47) | .56 (.26) | .14 (.16) | .00 (.00) | .31 (.26) | .54 (.22) | .15 (.14) | .01 (.02) |
| 7-8 years | .09 (.14) | .50 (.21) | .35 (.17) | .06 (.11) | .18 (.16) | .45 (.18) | .31 (.20) | .06 (.09) | .14 (.12) | .48 (.16) | .32 (.16) | .06 (.08) |
| 9-10 years | .03 (.10) | .39 (.22) | .46 (.24) | .13 (.14) | .04 (.08) | .43 (.19) | .45 (.20) | .08 (.17) | .04 (.07) | .41 (.18) | .45 (.18) | .10 (.13) |
| 11-12 years | .01 (.03) | .25 (.24) | .38 (.21) | .36 (.29) | .01 (.04) | .32 (.23) | .43 (.22) | .23 (.27) | .01 (.03) | .29 (.21) | .41 (.18) | .28 (.26) |

*Disparities in the proportion of safe and unsafe proportions are a function of rounding.
NB:A= very unsafe, B=unsafe, C=more safe, D=very safe

Table 4.4 displays the mean proportion of safe and Standard Deviation (SD) of unsafe routes as a function of age group.

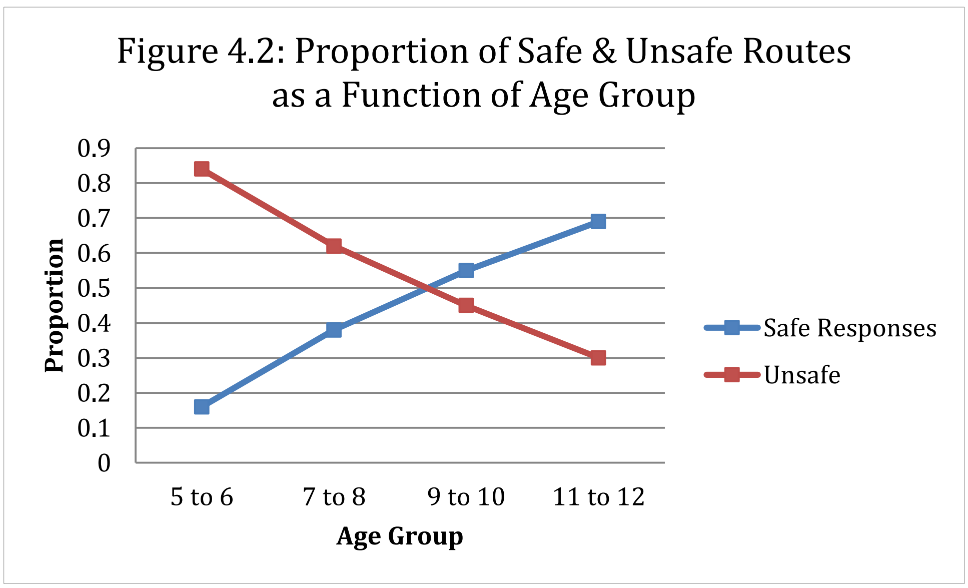
Table 4.4: Mean (& S.D.) Proportion* of Safe and Unsafe Responses by Age Group

| Age Group | Computer Version | | Table Top Model | | Combined | |
|---|---|---|---|---|---|---|
| | Unsafe | Safe | Unsafe | Safe | Unsafe | Safe |
| 5-6 years | .83<br>(.17) | .18<br>(.16) | .85<br>(.16) | .15<br>(.16) | .84<br>(.15) | .16<br>(.15) |
| 7-8 years | .59<br>(.23) | .41<br>(.23) | .63<br>(.20) | .37<br>(.20) | .62<br>(.19) | .38<br>(.19) |
| 9-10 years | .42<br>(.26) | .59<br>(.26) | .46<br>(.21) | .54<br>(.20) | .45<br>(.21) | .55<br>(.21) |
| 11-12 years | .25<br>(.24) | .75<br>(.24) | .33<br>(.24) | .66<br>(24) | .30<br>(.22) | .69<br>(.27) |

*Disparities in the proportion of safe and unsafe proportions are a function of rounding.

As already outlined, the mean proportion of safe routes therefore reflects the number of routes not coded as unsafe, meaning the measures are negative correlates of each other. Results will therefore address only the percentage of safe routes henceforth. A one-way Analysis of Variance (ANOVA) with task modality (computer vs. model) was used to test if there were differences in responding as a function of task modality. The proportion of safe routes was not significantly different between table top model trials and computer trials ($F[1,108]=0.00$, $p=.972$), therefore these data have been combined into an overall proportion of safe responses comprising table top and computer trials which will be reported hereafter.

A two way ANOVA with age and gender as the independent factors and the overall proportion of safe routes (including both computer & table top model trials) as the dependent variable also revealed a significant main effect of age ($F[3,105]=38.17$, $p<.001$, $\eta^2=.508$). Figure 4.2 demonstrates that this is because the ability to select safe crossing routes improves with age. There was no main effect of gender ($F[1,105]=0.05$, $p=.828$, $\eta^2=.000$) and no interaction between gender and age ($F[3,105]=0.23$, $p=.878$, $\eta^2=.006$).




The mean proportion of verbal justifications falling into the 5 categories of conceptual understanding were next calculated for each participant, again for both the table top and computer versions of the task as reported in Table 4.5 below.

Table 4.5: Mean (& S.D.) Proportion* of Conceptual Understanding Level as a Function of Age Group and Modality

| Age | Computer Version | | | | | Table Top Model | | | | | Combined | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | 0s | 1s | 2s | 3s | 4s | 0s | 1s | 2s | 3s | 4s | 0s | 1s | 2s | 3s | 4s |
| 5-6 years | .15 (.03) | .31 (.03) | .31 (.29) | .23 (.25) | .00 (.02) | .18 (.19) | .27 (.28) | .40 (.28) | .15 (.20) | .00 (.00) | .17 (.17) | .29 (.26) | .35 (.24) | .19 (.18) | .00 (.01) |
| 7-8 years | .07 (.03) | .13 (.15) | .30 (.19) | .41 (.24) | .09 (.17) | .13 (.14) | .20 (.22) | .35 (.20) | .29 (.22) | .03 (.09) | .10 (.14) | .16 (.15) | .32 (.15) | .35 (.18) | .06 (.11) |
| 9-10 years | .07 (.03) | .08 (.12) | .23 (.21) | .47 (.21) | .15 (.19) | .07 (.12) | .09 (.12) | .31 (.21) | .45 (.29) | .09 (.13) | .07 (.12) | .08 (.11) | .27 (.15) | .46 (.19) | .11 (.11) |
| 11-12 years | .10 (.03) | .01 (.03) | .05 (.07) | .39 (.25) | .44 (.30) | .05 (.10) | .04 (07) | .09 (.10) | .58 (.29) | .23 (.28) | .07 (.11) | .03 (.05) | .07 (.07) | .49 (.24) | .33 (.27) |

*Disparities in the proportion of safe and unsafe proportions are a function of rounding.

These responses were then further categorised as follows. Scores of zero represent no conceptual understanding. Responses which were 1s and 2s were combined into a single low conceptual understanding category. Scores which were 3s or 4s were combined to produce a single high conceptual understanding category. Data were combined in this way because it was considered important firstly to separate responses scored as zero from all others as these represent no understanding or engagement in the task at all. Justifications coded as 1 and 2, though representing distinct response types, share the common feature of irrelevance, either to the task (in the case of scores of 1) or the trial (scores of 2). Responses scored as 3 or 4 on the other hand, share the common feature of correctly identifying a hazard (for those coded as 3) and reasonably outlining a relevant justification for the route chosen to avoid this (for those coded as 4). Thus responses coded as 1 or 2 mean the child has little understanding of the reasons for their decision and are unable to justify the reasons for their chosen response. Whereas those coded as 3 or 4 represent higher understanding whereby children responding in this way can provide a reason for their decision. Data are presented in this format in Table 4.6.

Table 4.6: Mean (& S.D.) Proportion* of Conceptual Understanding Level as a function of Age Group

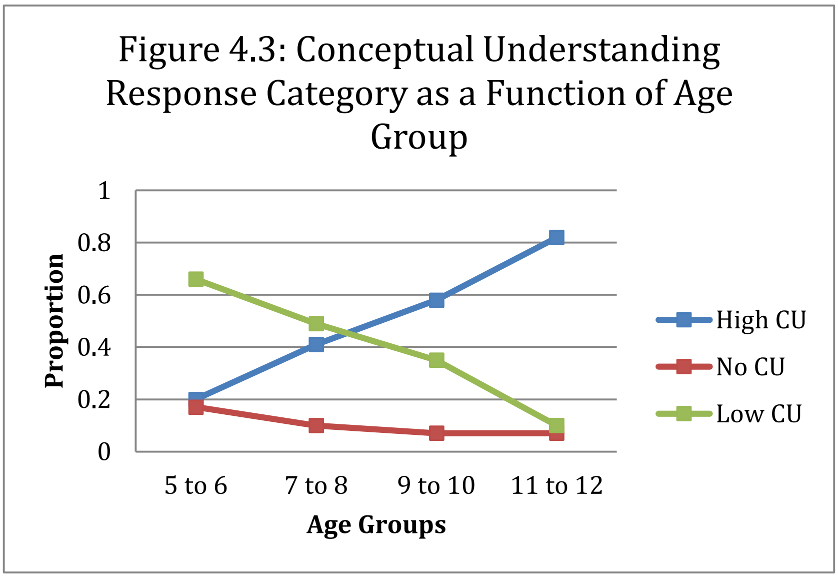
| | Computer Version | | | Table Top Model | | | Combined | | |
|---|---|---|---|---|---|---|---|---|---|
| Age Group | No CU | Low CU | High CU | No CU | Low CU | High CU | No CU | Low CU | High CU |
| 5-6 years | .15 (.22) | .62 (.29) | .25 (.25) | .18 (.19) | .67 (.27) | .15 (.20) | .17 (.17) | .66 (.22) | .20 (.19) |
| 7-8 years | .07 (.16) | .43 (.22) | .50 (.26) | .13 (.15) | .55 (.25) | .32 (.23) | .10 (.14) | .49 (.18) | .41 (.21) |
| 9-10 years | .07 (.14) | .31 (.23) | .62 (.24) | .07 (.12) | .40 (.26) | .54 (.31) | .07 (.12) | .35 (.18) | .58 (.22) |
| 11-12 years | .10 (.17) | .06 (.29) | .83 (.19) | .05 (.10) | .14 (.14) | .81 (.34) | .07 (.11) | .10 (.09) | .82 (.16) |

*Disparities in proportions are a function of rounding.

As with the behavioural scores, conceptual scores are proportions meaning they represent the inverse of each other.  Our results will focus on the proportion of high conceptual understanding as this represents the (optimal) level of understanding children should aim for and is the inverse proportion of the sum of the other two response types.

As can be seen above, scores of conceptual understanding on both the table top model and computer versions of the task were also similar.  To test if there were differences in conceptual scores as a function of task (computer versus table top model), task once more was included as a factor in the ANOVA which revealed no significant differences ($F[1,41]=0.44$, $p=.512$).  These data were therefore also collapsed into a combined conceptual score comprising the proportion of responses reflecting high levels of conceptual understanding on the model and on the computer task.

ANOVA also revealed a significant effect of age ($F[3,105]=47.26$, $p<.001$, $\eta^2=.575$), but once more that there was neither a main effect or gender ($F[3,105]=0.72$, $p=.399$, $\eta^2=.007$) nor an interaction with age ($F[3,105]=0.79$, $p=.504$, $\eta^2=.002$).  Age trends are illustrated in Figure 4.3 below.




Mean perceived difficulty estimations for pre-trial and post-trial estimations were calculated for each age group and are presented in Table 4.7 below.

Table 4.7: Mean (& S.D.) Pre & Post-Trial Difficulty ratings* as a function of age group.

| Age Group | Mean Pre-trial Estimation | Mean Post-trial Estimation |
|---|---|---|
| 5-6 years | 38 (23.15) | 22 (17.59) |
| 7-8 years | 31 (19.14) | 23 (17.90) |
| 9-10 years | 35 (17.05) | 32 (22.67) |
| 11-12 years | 40 (19.60) | 40 (22.23) |

* Maximum score = 100.

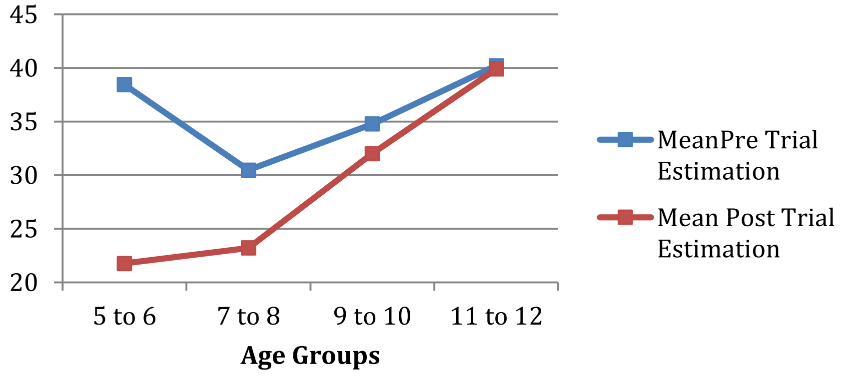
First, a two way ANOVA with age and gender as factors and pre-trial estimations as the dependent variable revealed no main effect of age ($F[3,108]=1.55$, $p=.206$, $\eta^2=.041$) or gender ($F[1,108]=1.36$, $p=.529$, $\eta^2=.004$) and there was no interaction

($F[3,108]=1.34$, $p=.266$, $\eta^2=.036$). Thus, before attempting the task, children of all ages and both genders thought it was going to be equally difficult.

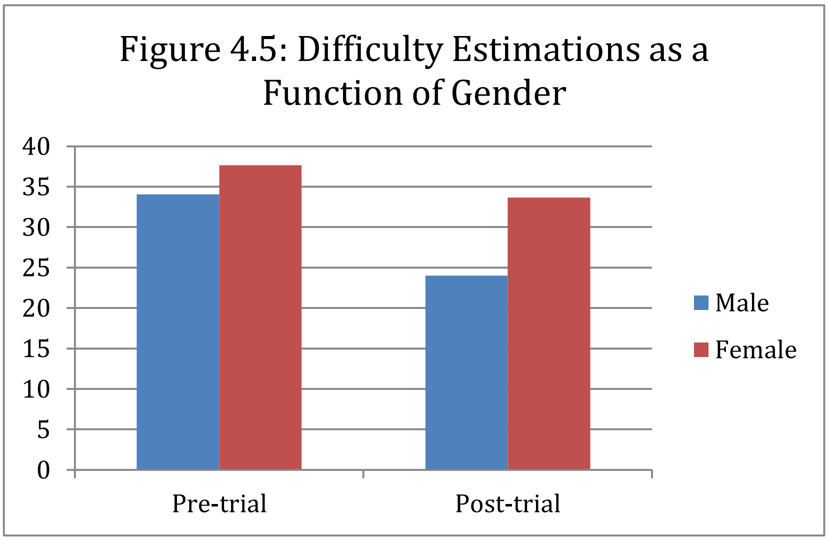
This analysis was repeated for post-trial difficulty estimations which revealed a main effect of age ($F[3,108]=4.27$, $p=.007$, $\eta^2=.106$) and a main effect of gender ($F[1,108]=4.63$, $p=.034$, $\eta^2=.041$) but there was no interaction ($F[3,108]=1.00$, $p=.396$, $\eta^2=.027$).

The two youngest age groups judged the task to be much easier after completing it than the older children. This was in spite of the fact that the judgements of the younger children were much poorer than those of the older children. The effect of attempting the problem and performing poorly has led them to think it was even easier than they initially thought. Thus they did not benefit from the experience of trying to solve the problems, unlike the older children who modified their ratings to indicate that they considered the task was harder than they had at first thought. This trend is shown in Figure 4.4 below.

Figure 4.4: Difficulty Estimations as a Function of Age Group



In addition, although girls rated difficulty higher than boys on both estimations, this difference was only significant for post-trial ratings. Boys tend to rate the task as being significantly less difficult on reflection compared with girls. The effects of gender on difficulty estimations are presented in Figure 4.5 below.




**4.4 Discussion**

The results relating to behavioural measures support the first hypothesis and confirm those reported previously (Ampofo-Boateng & Thomson 1991; Thomson et al.,1992; Whitebread & Neilson, 2000; Barton, Ulrich & Lyday, 2010). They demonstrate that the ability to select safe crossing routes improves as children develop. The findings show five and six year old children select very few safe routes indeed: less than one fifth of selections are safe. Eleven and twelve year olds on the other hand select safe routes with relative success (almost three quarters of selections were safe). This development between the ages of five and twelve represents a period of considerable change in both children's behavioural performance and conceptual understanding of the task and its purpose. These findings of course carry important implications for road safety education and underlie the government's adoption of the Kerbcraft programme as a national training resource (Whelan et al., 2008).

Younger children appear not to take account of hazards when choosing a crossing location and make direct (i.e. diagonal) crossings with little awareness of the risks posed by these decisions. Younger children also show an unwillingness to move from their starting location at all before initiating a crossing. One explanation that has been offered for this, in addition to their lack of insight as to why the initial crossing location was unsafe, is that children may aim to complete the task and exit the traffic environment as quickly as possible (Tolmie et al., 2002). Children might be forgiven for adopting such an approach given they are told repeatedly that the roadside is a dangerous environment. Older children on the other hand not only recognise potential hazards and select safer crossing locations accordingly but also appear willing to spend a greater deal of time getting from A to B in order to cross in a safer way. This change likely represents a more evolved understanding of the difficulty of the task at hand; something reflected in their conceptual scores and perceived difficulty ratings as discussed below.

These findings are corroborated by the verbal justifications representing conceptual understanding which children offered for routes, where the least elaborated response categories in terms of conceptual understanding predominated in the two younger age groups. This category is defined by answers including reference to routes being the quickest and indeed many young participants in this study justified unsafe selections as such. Future research should address this issue in more detail. The desire of young children to complete crossings in as brief a time period as possible may result in shorter consideration of the task before making and implementing a decision and could be a possible focus for future intervention.

By the age of 9/10 and especially 11/12 years, the majority of routes children selected were safe, with far fewer unsafe routes chosen by these age groups. Importantly though, even 12 year olds still crossed in unsafe ways around 25% of the time. Thus we must not confuse the considerable improvement in skill level with absolute competence among children approaching the end of their primary school years. Indeed, Tolmie et al (2005) found that young people aged 12-15 years had not reached a ceiling in relation to adults on the safe place finding task. Educators and public health practitioners should be mindful of the need to strive to improve competence in children of all ages, including older groups who cross in a safe way *most* of the time. The nature of pedestrian injury is such that a single unsafe crossing can result in death or serious injury regardless of overall competence and the improvement of skill level amongst older children should remain a goal of road safety education. Future research should aim to target older children and young teenagers and identify means to improve the safety of their behaviour further still;

from mostly safe to completely safe.

The lack of gender differences on most of the measures is consistent with the overwhelming majority of previous studies of children's pedestrian skill development in spite of the well known and substantive differences in injury rates between boys and girls. The factors that give rise to this difference in injury rates has puzzled researchers for many years and has stubbornly resisted compelling interpretation (see Foot, 1985) but most researchers are satisfied that differences in skill levels between the genders is not a key factor (see Thomson, 1991 for a review). The present findings are consistent with this view.

However, a gender difference was found in the revised difficulty ratings made after undertaking the crossing task, with girls rating the task as more difficult than the boys. The reasons for this are not entirely clear but do demonstrate a clear difference between genders. One possibility might be that girls are more sensitive to feedback and information about their relative performance than are boys (Niederle & Vesterlund, 2010). It appears there are also gender differences in the accuracy of the self-evaluation of one's performance (Beyer, 1990). Girls both have lower expectations for their performance than boys (possibly due to an underestimation of their own ability; Carr, Thomas & Mednick, 1985) and also appear to externally attribute success more often than males (Sohn, 1982). This possibility merits future research in the child pedestrian context.

The findings relating to perceived difficulty support the hypothesis that older children would perceive the task as more difficult than younger children. However, contrary to our initial hypothesis, this only applies to the ratings made *after* undertaking the task. What is striking about this effect is that it is the older children who performed far more competently who adjusted their ratings in this way. It may be that, for younger children who do not clearly see the hazards that need to be overcome, there is no obvious reason why they should see the task as retrospectively more difficult. For them there was no hazard to overcome in the first place. Older children, by contrast, in trying to find a means of avoiding hazards which they perceive to exist, seem to have become increasingly aware of how difficult it can be to find a safer alternative. As a result, they upgrade their difficulty rating of the task. It seems likely that, as competence and conceptual understanding develop, there emerges the basis for autonomous learning through experience in the manner seen here. But such autonomous learning cannot emerge before children are able to see the need for it.

In summary, this study aimed to establish developmental trends in children's ability to find safe road crossing routes in terms of their behavioural decisions and conceptual understanding. It also aimed to establish trends in the perceived difficulty of the task of crossing roads. The findings show that both behavioural responses and conceptual understanding of the task improve significantly with age. The findings correspond closely to previous studies investigating the development of this skill across childhood. These findings provide a strong basis upon which the relationship between pedestrian skill development and neuropsychological function can be examined. This will be addressed later in the thesis.

The current study has also extended previous research by demonstrating behavioural and conceptual development develop concordantly and appear closely related to children's ability to perceive the difficulties posed by the crossing task, which can be expected to strongly influence how children approach the task. This relationship between conceptual understanding and behavioural decision-making further emphasises the need to explore the relationship between children's cognitive development and the development of pedestrian skill level, which is the key overall aim of the thesis and will be addressed in chapter 6.

# Chapter 5

## Study 1.2: The Development of Visual Gap Timing Ability

### 5.1 Introduction

The previous chapter addressed the skill of safe route selection, which is one of a number of skills previously shown important for safe pedestrian behaviour. Another skill vital for safe pedestrian behaviour is that of visual timing which has been described as the ability to coordinate road crossing with vehicle movements (Lee et al., 1984; Tolmie, Thomson, Foot, Whelan, Sarvary & Morrison, 2002). This ability is essential in allowing pedestrians to identify gaps between moving vehicles in a flow of traffic that are sufficiently large to allow for a safe crossing through them to be made. Early work described this skill as the ability to ensure traffic is far enough away in order to cross safely (Chapman, Wade & Foot, 1982) while others have argued this skill is characterised by the ability to discriminate safe from unsafe gaps between approaching vehicles (McKelvey, 1984). This skill is crucial when pedestrians must cross busy streets where it is not possible to follow the traditional strategy of waiting for traffic to dissipate before attempting to cross and when making crossings in streets without designated crossings (Thomson et al., 2005).

This is no easy task even for adults, which is evidenced anecdotally by the frequency of which even adult pedestrians move out into the street and then have to either run or walk faster, change their crossing route or turn back quickly in order to avoid an oncoming vehicle. Research has also shown empirically that the performance of adult pedestrians on gap timing tasks is far from perfect (Oxley et al., 2005), though it seems older adults (Holland & Hill, 2007; Lobjois & Cavallo, 2007) and children (te Velde et al., 2005) perform this task more poorly still.

Liu and Tung (2013) argue the time needed to make a road crossing should incorporate the time available due to the gap, the distance between an approaching vehicle and the pedestrian, the vehicle's speed as well as the walking speed and mobility capabilities of the pedestrian. Tolmie et al. (2002) argue the width of the road must also be taken into account while others have identified environmental and pedestrian factors such as weather and road surface conditions as well as tiredness and the carrying of objects which might slow walking pace as being additional important factors (Simpson, Johnston & Richardson, 2003). There are thus a large number of variables which pedestrians must take into account when performing this skill which makes it one of the most cognitively demanding.

The ability to accurately judge whether enough time is available to cross a road safely can be said to require pedestrians to make time-to-contact (TTC) or time-to-arrival judgements (Simpson et al., 2003). TTC has been defined as the ability to accurately estimate the time remaining before an approaching object reaches a person's location (Tresillian, 1995). Lee and Young (1985) describe the level of precision at which humans can time movements and actions as one of the most remarkable aspects of human motor skill.

Research has shown adults are less accurate in making TTC judgements when judging larger versus smaller TTC values (Schiff & Detwiler, 1979), a trend which has also been demonstrated in relation to judgements about approaching vehicles (Sweard, Ashmead & Bodenheimer, 2007). Adults however tend to be cautious and underestimate time to contact for approaching objects: that is, they estimate an object will arrive sooner than it does in reality (Gray & Reagan, 1999). Research investigating the development of this skill amongst children however, has shown they appear much less able (and are less consistent) than are adults, missing many safe opportunities to cross when it is safe to do so and also making many tight fits (Lee et al., 1984; Young and Lee, 1987; Demetre et al., 1992).

More recent research which has made use of virtual reality has confirmed that young children around age 5 appear to miss a significantly greater number of opportunities to cross between cars when it is safe to do so compared with older children and adults. They also squander time before initiating a crossing when it is safe to do so and make more tight fits as a result (Barton & Schwebel, 2007). By age 7 years, children continue to struggle to make safe decisions and still appear to be at significant risk of being struck by a vehicle while attempting to cross between cars in a flow of traffic (Schwebel, et al., 2008). Even by age 9, Schwebel and colleagues report children continue to squander significantly more time before initiating a crossing compared with adults which in turn leaves them less time in which to complete the crossing once it has been initiated.

As children begin to approach adolescence around the age 11-12 years, however, they become more capable of making safe gap timing judgements, albeit continuing to perform significantly less well than adults (Connelly, Conaglen, Parsonson &

Isler, 1998). Conaglen and colleagues also observed significant differences in the strategies children use to make gap timing judgements whereby two thirds of children use distance alone to inform their decisions. By adulthood however, pedestrians perfect these skills to a level whereby they miss very few safe opportunities to cross and make few tight fits by consistently rejecting gaps that are too small (Lee et al., 1984). Similar developmental trends have been found in research addressing gap timing abilities of children as cyclists whereby young cyclists also have higher starting delays and leave much less time to spare compared with adults (Plumert, et al., 2004).

Adolescents have previously been shown to perceive gap timing tasks as relatively difficult compared to the other pedestrian skills investigated in the current thesis (see Tolmie et al., 2006). Tolmie et al. also report little variation in difficulty ratings between children in their final year of primary school and those in their 3rd year of secondary school. However, these findings relate to early adolescence (age 11-15 years) rather than the younger age range which is the focus of the present thesis. No previous studies have investigated how difficult primary school children consider the gap timing task to be and so trends relating to perceived difficulty of the visual timing task among younger pedestrians are currently unknown and will once again be a focus of the current study.

In light of the reviewed literature relating to pedestrian gap timing ability it is hypothesised that:

1. There will be age trends in children's performance on the gap timing task, with performance improving with age whereby;
    i. The size of gaps children are willing to attempt to cross through will increase;
    ii. their starting delays will decrease;
    iii. the number of missed opportunities will also decrease;
    iv. and the number of tight fits will decrease

2. There will be age trends in children's perception of the difficulty of the task, with older children perceiving the task as being significantly more difficult compared to younger children.

3. Following the experience of making crossing decisions, older children will be more likely to revise their initial assessment of task difficulty and rate the task as more difficult than they had initially rated it.

## 5.2 Method

### 5.2.1 Participants

The same 117 children who took part in the study reported in the previous chapter took part in the study being reported here. 57 children were male and 60 were female. 30 children were aged 5/6years, 30 were aged 7/8, 30 were 9/10 and 27 were aged 11/12 years. Further details about participants and their recruitment are reported in the general method section (chapter 2).

### 5.2.2 Design

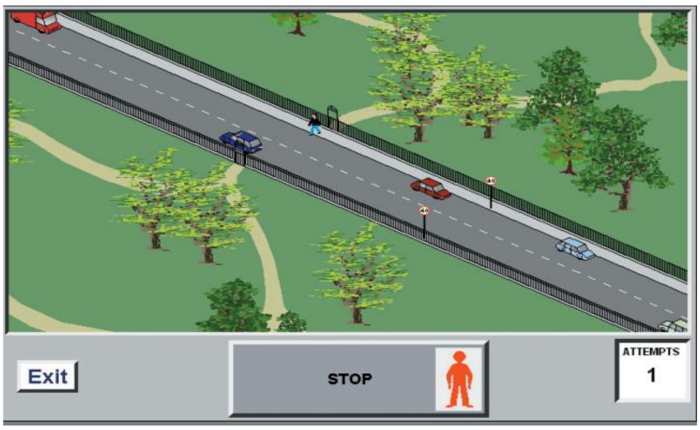
This study was of a between subjects design. Age group and gender served as the between subjects factors. All participants completed the same task.

### 5.2.3 Materials and Procedure

The gap timing task was delivered via a standard laptop computer operating the Crossroads pedestrian training and assessment software (Thomson et al, 2005) as described in Chapter 2. The gap timing task required participants to guide an avatar character across 5 road scenes. Each road scene varied in terms of its layout, urban/rural locale and in terms of the volume and speed of traffic flows. This ensured variation in the size of available traffic gaps, and variations in road width created variations in the time required to cross on different trials. In addition, some trails featured traffic on only the near or far-side lanes, whereas other featured traffic moving in both directions. This resulted in some gaps being near-near, some far-far, some near-far, and some far-near. Participants viewed the road layouts from the same perspective as the depicted pedestrian (i.e. from behind the pedestrian, so that their right-left orientation was the same) but from a slightly elevated 'birds-eye' perspective, rather than the street level perspective of the pedestrian, as shown in Figure 5.1. This ensured that the participant had a clear view of the action in both directions from a single viewpoint, without having to make head movements.

Participants viewed the traffic flow for 10 seconds before being asked to start making crossing decisions partly so that they could see how easy or difficult it would be to find a safe gap (thus allowing them to make pre-trial difficulty estimations, and also so that they could see the pedestrian who walked along the pavement towards the starting point during this time. This allowed participants to observe the pedestrian's walking speed which was necessary in order to estimate the time required to cross relative to the time available for crossing based on the gaps between cars. Participants were first invited to complete a series of 3 practice trials. This allowed participants to familiarise themselves with the operation of the software and workings of the task. No data were collected from the practice trials. Participants then completed a series of 6 crossings on 4 different road scenes. This provided a total of 24 experimental trials from which 6 measures of performance were derived. These variables and details of their scales of measurement are presented in Table 5.1. A screenshot from the visual gap timing task is provided in Figure 5.1 below.

Figure 5.1: Screenshot from the visual gap timing task.



| Outcome Variable | Unit of Measurement | Description |
|---|---|---|
| Accepted Gap | Seconds | The mean gap size participants were willing to attempt to cross through. |
| Start Delay | Seconds | The mean length of time from the point at which the lead car in a traffic flow passes the crossing location, until the point at which the participant initiates a crossing. |
| Effective Gap | Seconds | Since pedestrians usually delay stepping into a gap, there is typically a mismatch between the true size of the gap and the size of the gap remaining when taking account of this delay. The latter is defined as the effective gap. |
| Estimated Crossing Time | Seconds | The mean length of time participants estimated it would take to reach the opposite side of the road. |
| Missed Opportunities | Total Number | The number of times a participant chose not to cross when there was sufficient time to do so safely. This was defined as one and a half times the total time needed to cross. |
| Tight Fits | Total Number | The number of crossings when an approaching car's time to contact with the pedestrian's crossing line is less than the time required for the pedestrian to reach the far kerb. |

Table 5.1: Visual Gap Timing Task Outcome Variable Descriptions

Perceived difficulty was measured through the software using a sliding bar which participants were instructed to move on a scale ranging from very easy to very difficult. Scores selected using the sliding bar ranged from 0 to 100. After observing the flow of traffic and the avatar's walking speed for 10 seconds, participants were asked to rate how difficult they thought trials *would be* before attempting to cross each of the 4 road scenes and were also asked to reflect on how difficult they thought trials *had been* immediately following completion (before moving on to the next road scene). Further details about the procedure and Crossroads software can be found in chapter 2.

## 5.3 Results

### 5.3.1 Behavioural Measures

The mean score for each outcome variable of the visual timing task was calculated as a function of age group and gender. These data are presented in Table 5.2 and show broad age related improvement in performance with age, with the mean accepted gap size, mean effective gap size, and estimated crossing times increasing with age. Correspondingly, starting delays and number of missed opportunities reduce with age.

Data were analysed by means of a Multivariate Analysis of Variance (MANOVA) with age and gender as the independent variables and the 6 performance measures as dependent variables. MANOVA revealed a significant main effect of age across all variables, therefore the six performance measures were individually examined in turn to establish which individual variables vary with the age of participants.

Individual ANOVAS on the mean accepted gap variable revealed that mean accepted gap size varied significantly between age groups ($F[3,109]=10.51$, $p<.001$, $\eta^2=.224$), with the duration of gaps increasing with age as illustrated in Figure 5.2. There was no main effect of gender (F[1,109]=2.76, *p*=.100, $\eta^2$=.025) and no interaction between gender and age (F[3,109]=0.90, *p*=.445, $\eta^2$=.024).

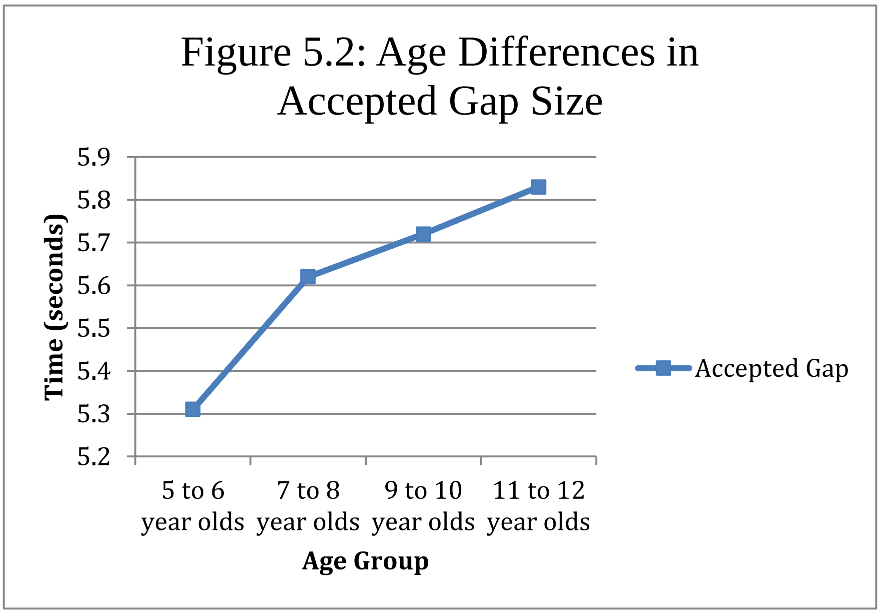
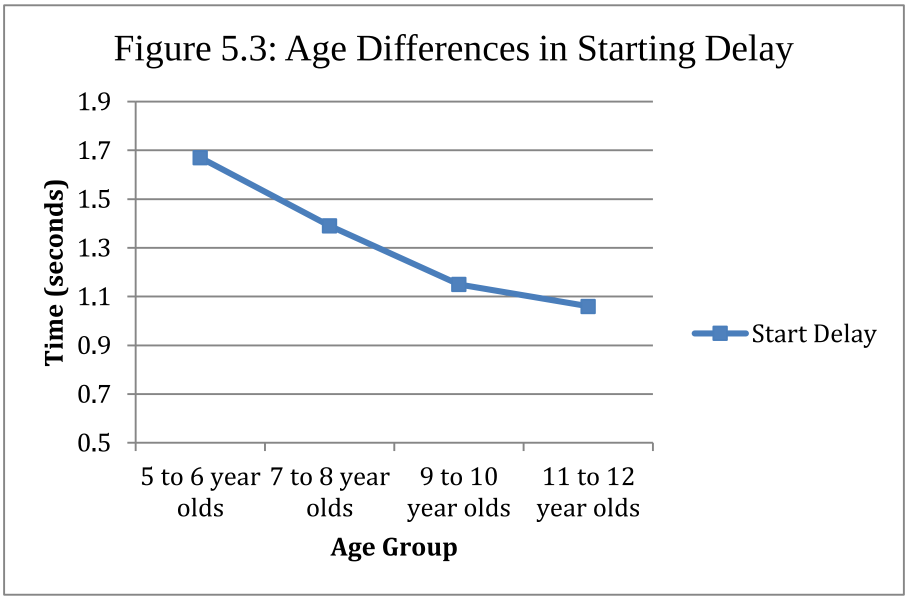


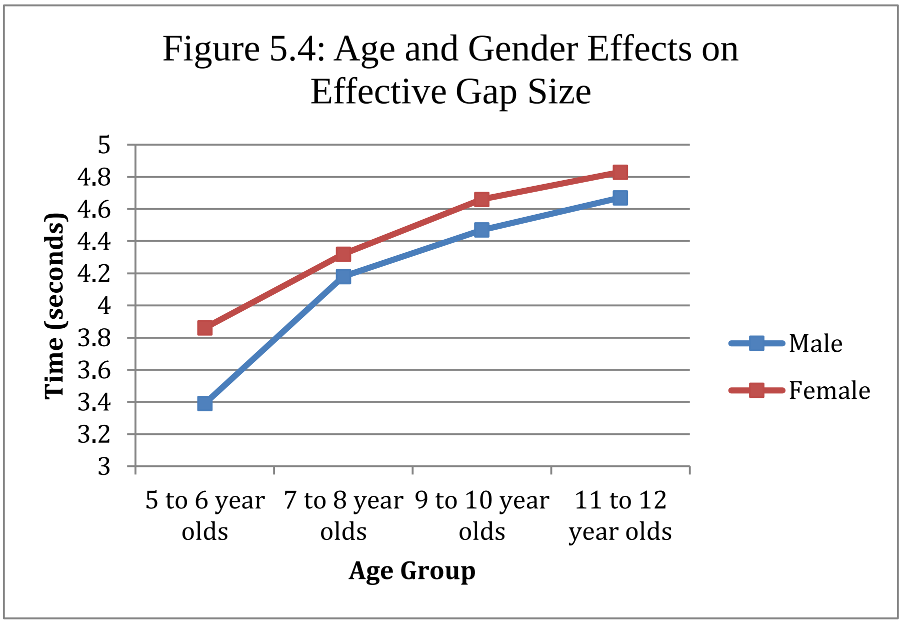
Table 5.2: Mean (& S.D.) for performance measures on the Visual Gap Timing Task as a function of Age Group and Gender

| Age Group | Accepted Gap (seconds) | | | Effective Gap (seconds) | | | Start Delay (seconds) | | | Estimated Crossing Time (seconds) | | | Number of Missed Opportunities | | | Number of Tight Fits | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined |
| 5-6 years old | 5.14 (0.41) | 5.45 (0.44) | 5.31 (.44) | 3.39 (0.49) | 3.86 (0.71) | 3.64 (.65) | 1.76 (0.39) | 1.60 (0.53) | 1.67 (.47) | 3.52 (0.61) | 3.07 (0.58) | 3.28 (.63) | 1.11 (0.42) | 1.53 (0.80) | 1.33 (.67) | 3.27 (0.81) | 2.33 (1.10) | 2.77 (1.07) |
| 7-8 years old | 5.61 (0.35) | 5.64 (0.30) | 5.62 (.33) | 4.18 (0.64) | 4.32 (0.40) | 4.23 (.56) | 1.43 (0.48) | 1.33 (0.39) | 1.39 (.45) | 3.46 (0.42) | 2.87 (0.57) | 3.24 (.55) | 1.45 (0.78) | 1.09 (0.77) | 1.32 (.78) | 2.12 (1.07) | 2.14 (0.94) | 2.13 (1.01) |
| 9-10 years old | 5.66 (0.45) | 5.76 (0.29) | 5.72 (.37) | 4.47 (0.69) | 4.66 (0.46) | 4.58 (.58) | 1.20 (0.38) | 1.10 (0.24) | 1.15 (.31) | 3.73 (0.95) | 3.38 (0.77) | 3.54 (.86) | 1.82 (1.36) | 1.47 (0.89) | 1.63 (1.13) | 1.84 (0.95) | 1.45 (0.90) | 1.63 (.93) |
| 11-12 years old | 5.81 (0.32) | 5.84 (0.39) | 5.83 (.36) | 4.67 (0.75) | 4.83 (0.48) | 4.77 (.58) | 1.14 (0.63) | 1.02 (0.43) | 1.06 (.50) | 3.69 (0.56) | 3.90 (0.89) | 3.82 (.78) | 1.08 (0.87) | 1.84 (1.45) | 1.56 (1.30) | 1.53 (1.11) | 1.15 (1.05) | 1.29 (1.06) |
| Overall | 5.54 (0.45) | 5.68 (0.39) | 5.61 (0.42) | 4.14 (0.78) | 4.43 (0.65) | 4.29 (0.73) | 1.40 (0.51) | 1.25 (0.47) | 1.33 (0.49) | 3.58 (0.65) | 3.35 (0.81) | 3.46 (0.74) | 1.39 (0.94) | 1.52 (1.05) | 1.46 (0.99) | 2.23 (1.15) | 1.73 (1.10) | 1.97 (1.15) |

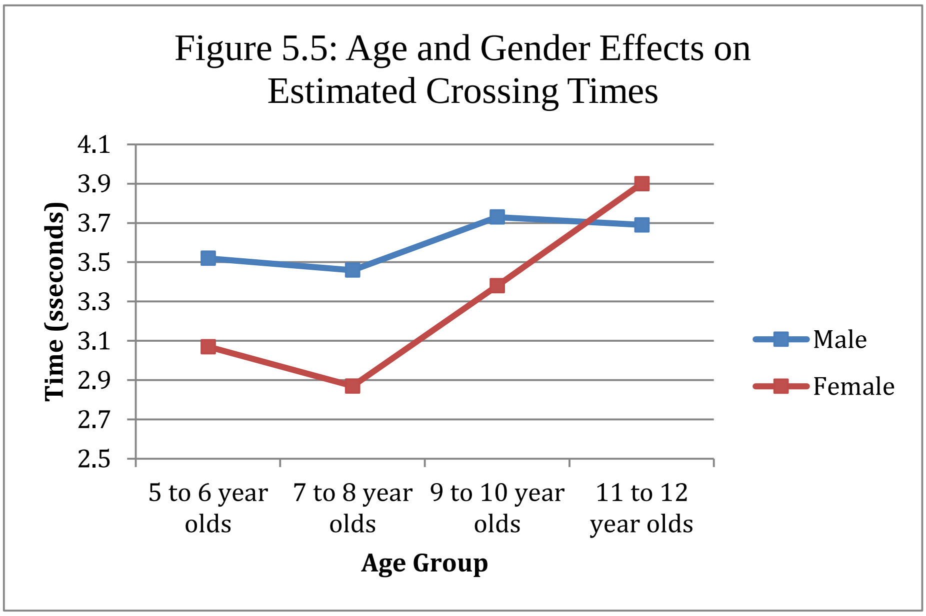
ANOVA also revealed a main effect of age group for starting delay (F[3,109]=10.63, $p$<.001, $\eta^2$=.226) but not gender (F[3,109]=2.12, $p$=.148, $\eta^2$=.019). Figure 5.3 illustrates that this is because starting delays reduced consistently with age, with older participants having smaller delays before stepping into an accepted gap compared with younger participants. There was no age by gender interaction (F[3,109]=0.03, $p$=.992, $\eta^2$=.001).



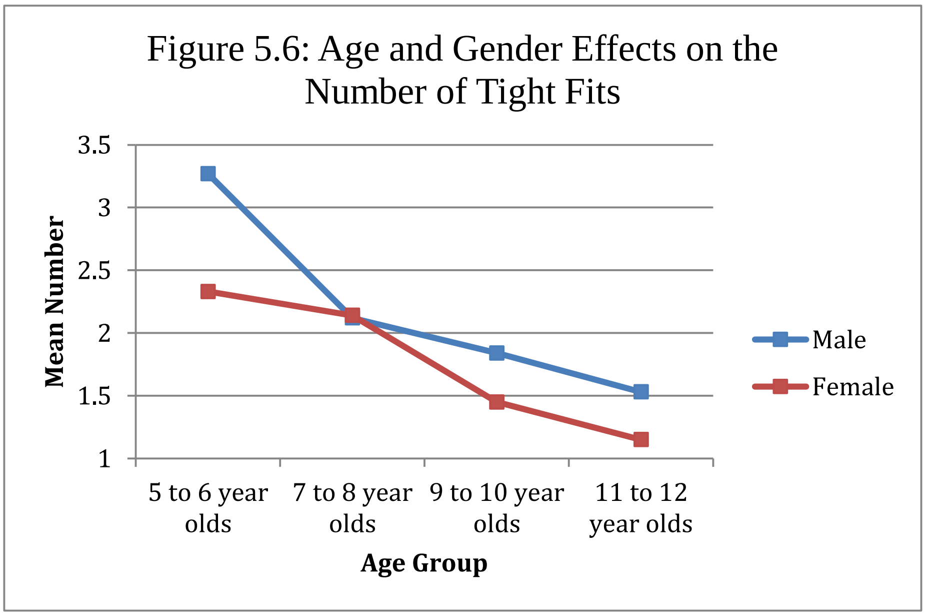

Correspondingly, there was also a main effect of age on effective gap size, which also varied significantly as a function of age (F[3,109]=20.29, $p$<.001, $\eta^2$=.358). Figure 5.3 shows this is because older children squandered much less of the gap as a result of long starting delays, meaning that they retained more time to make the crossing than younger children. A main effect of gender was also found for mean effective gap (F[1, 109]=4.66, $p$=.033, $\eta^2$=.041), with girls retaining larger effective gaps than did boys overall, also illustrated in Figure 5.4. There was no age by gender interaction (F[3,109]=0.52, *p*=.671, $\eta^2$=.014).




There were also main effects of both age (F[3,109]=4.37, *p*=.006, $\eta^2$=.107) and gender (F[3,109]=4.99, *p*=.027, $\eta^2$=.044) on the estimated time participants thought the pedestrian would need to cross the road. Figure 5.5 shows that older children thought the pedestrian would need more time to cross than younger children, and girls judged that more time would be needed to cross than boys overall. There was no interaction between age group and gender (F[3,109]=1.70, *p*=.171, $\eta^2$=.045).




There were also significant main effects of age (F[3,109]=11.46, p<.001, $\eta^2$=.240) and gender (F[3,109]=4.99, *p*=.027, $\eta^2$=.044) on the number of tight fits, with the number lower in girls relative to boys and decreasing consistently across the age range as illustrated in Figure 5.6. There were no significant interaction between age and gender (F[3,109]=1.13, *p*=.342, $\eta^2$=.030).



Finally, ANOVA revealed that the number of missed opportunities did not vary as a function of either age ($F[3,109]=0.86$, $p=.466$, $\eta^2=.023$) or gender ($F[1,109]=.415$, $p=.521$, $\eta^2=.004$). There was no interaction between age and gender ($F[3,109]=2.26$, $p=.086$, $\eta^2=.058$).

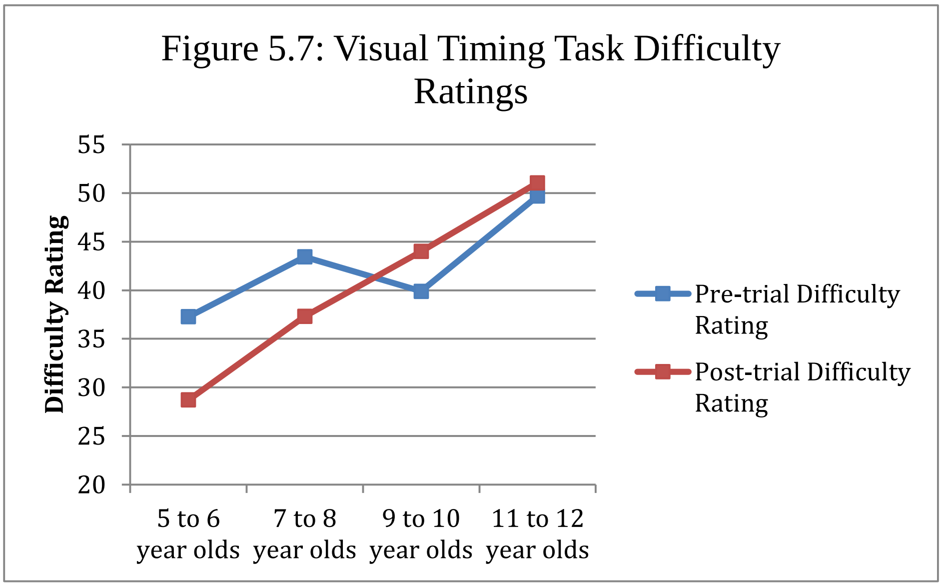
### 5.3.2 Perceived Difficulty

Mean perceived difficulty estimations made immediately before trials (pre-trial), immediately after trials (post-trial) and overall difficulty estimation of the task as a whole (made on completion of the task) were calculated for each age group and as a function of gender. These data are presented in Table 5.3 below.

Table 5.3: Mean (& S.D.) Pre & Post-Trial Difficulty for the Visual Timing Task as a function of Age Group and Gender

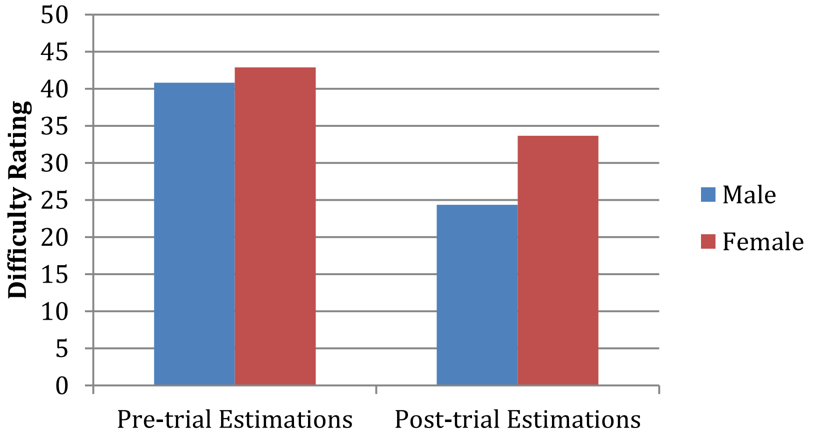
| Age Group | Mean Pre-trial Estimation | | | Mean Post-trial Estimation | | |
|---|---|---|---|---|---|---|
| | Male | Female | Combined | Male | Female | Combined |
| 5-6 years | 43.35 (25.80) | 39.55 (15.50) | 41.26 (20.44) | 16.57 (17.33) | 27.05 (16.87) | 22.35 (17.59) |
| 7-8 years | 37.76 (24.65) | 35.41 (21.47) | 36.90 (23.18) | 24.29 (15.57) | 21.35 (22.06) | 23.21 (17.90) |
| 9-10 years | 42.68 (13.62) | 42.95 (20.43) | 42.82 (17.17) | 26.96 (18.63) | 36.75 (25.62) | 32.02 (22.67) |
| 11-12 years | 40.82 (31.65) | 50.81 (16.95) | 47.11 (23.40) | 30.99 (22.19) | 45.16 (21.15) | 39.91 (22.23) |
| Overall | 40.83 (23.61) | 42.89 (18.81) | 41.89 (21.21) | 24.36 (18.20) | 33.67 (22.83) | 29.14 (21.14) |

Pre-trial difficulty estimations were examined by means of a two way ANOVA with age and gender as factors and revealed there was no main effect of either age ($F[3,109]=0.91$, $p=.438$) or gender ($F[1,109]=0.11$, $p=.740$). When the same analysis was conducted for post-trial estimations however, both an effect of age (F[3,109]=4.27, *p*=.007) and gender (F[1,109]=4.63, *p*=.034) were revealed. By contrast to pre-trial estimations of difficulty, Figure 5.7 shows that post-trial estimations increased significantly with age. Thus, older children were more likely to revise their difficulty estimates in an upwards direction in light of the experience of trying to find safe gaps for the depicted pedestrian to cross through, whereas such revised judgements reflecting greater perceived difficulty at post-test were absent in younger children.




In addition, although there were no gender differences in respect of pre-trial estimations, females rated the task as being significantly more difficult than males at post-trial estimation as shown in Figure 5.8 below.

Figure 5.8: Gender Differences in Difficulty Estimations




**5.4 Discussion**

The results of the current study support the first hypothesis that pedestrian gap timing ability improves with age amongst children aged 5-12 years old. Findings also add to the literature which has suggested there may be some gender differences in respect of this skill. In support of the second and third hypotheses, the current study has also demonstrated clear developmental differences in the perceived difficulty of the visual gap timing task amongst children for the first time.

**5.4.1 Developmental Differences in Visual Gap Timing**

The findings relating to performance measures provide support for previous studies investigating the development of gap timing ability amongst young pedestrians which have reported similar age trends to those revealed through the current study.

The mean size of gaps which children were willing to accept increased with age; older children squandered less time once a decision to cross had been made; and therefore the effective size of the gap remained safer for older than for younger children which presumably accounts for the fact that older children made fewer tight fits. In general, older children's performance resulted in safer performance, broadly mirroring the findings relating to safe place finding ability already reported in this thesis.

The significantly longer starting delays observed in younger children is consistent with claims that young children fail to look ahead or anticipate prospective crossing opportunities, in a way that older children do with relative success (Thomson, 1991). The short starting delays of older children, by contrast, suggest that they were anticipating the arrival of approaching safe gaps and so were able to take advantage of them promptly when they arrived. These differences are consistent with claims in the literature that younger children tend to focus on vehicles one by one, thus failing to identify gaps until they arrive and thus losing part of the gap as they try to reach a decision as to whether it permits safe crossing or not.

Some authors have argued that the long starting delays in younger children reflects their need for more time to process the information required to assess whether it is safe to begin crossing compared to older children (Schwebel, Gaines & Severson, 2008). It is likely that older children who have more experience of interacting with traffic would develop the ability to make such judgements over a shorter period of time, likely through practice. This interpretation is supported by the findings of Tolmie et al., (2002) and Thomson et al. (2005), who found that such judgements could be improved in children as young as 5 years as a result of training and the opportunities for practice this affords.

The mean estimated time children thought the pedestrian avatar needed to complete a crossing also increased significantly with age. Younger children appear to underestimate crossing time, which may explain their acceptance of smaller gaps and their tendency to squander a part of that gap through long starting delays. Under the circumstances, it is unsurprising that they make more tight fits compared with older children and, of course, they miss very few opportunities to cross safely.

Taken together, these findings represent a broad range of age related improvements in making decisions about crossing through gaps in traffic flows. The pattern of results in this study are consistent with previous studies which have used a range of methodologies, confirming both the developmental profile of the performance of this skill across early to mid-childhood and the validity of the simulation approach to the study of this skill given results revealed in the present study compare very closely to those reported by previous studies which have adopted a range of methodological approaches and revealed similar trends (Lee et al., 1984, Tolmie et al., 2002, Thomson et al., 2005).

### 5.4.2 Gender Differences in Visual Gap Timing

The current study revealed some gender differences in the performance of the gap timing task which add to an interesting and somewhat mixed literature. On the one hand, past study of gap timing ability has reported, quite consistently, that boys and girls respond similarly on the gap timing task (Barton & Morrengillo, 2011; Thomson et al., 2005, Thomson et al., 1996, Whitebread & Neilson, 2000). Other studies, however, have suggested there may be small gender differences on aspects of the task favouring girls (Barton & Schwebel, 2007, Simpson, Johnston & Richardson, 2003).

Consistent with this, girls in the current study chose larger effective gaps, and made fewer tight fits than boys, which taken together suggest a more cautious approach to decision making than their male counterparts. This finding, of course, aligns with the epidemiological data which has consistently demonstrated for some time, that boys are substantially more susceptible to pedestrian injuries compared with girls (DiMaggio & Durkin, 2002, Pless, Verreault, Arsenault, Frappier & Stulginskas, 1987).

Notably however, girls in the current study estimated that significantly *less* time was needed to cross compared with boys as shown through their significantly shorter estimated crossing times. This contrasts both with the other gender differences revealed in the current study, as well as most gender trends reported previously which generally suggest more cautious decision making in females. Some broad comparisons may, however, be made to the findings of abstract TTC studies which suggest that females may be poorer in making TTC judgements compared with males (McLeod & Ross, 1983). Furthermore, in a study of elderly pedestrians, Holland and Hill (2010) found that elderly females performed more poorly than elderly males in estimating their own walking speed (and left smaller safety margins as a result).

Future research may wish to further examine such gender differences, which tend to lend themselves to a simple interpretation at present.

### 5.4.3 Perceived Difficulty

The findings relating to perceived difficulty are interesting and partially support the second hypothesis; that there would be age trends in children's perception of the difficulty of the task whereby older children would perceive the task as being more difficult than younger children. The findings show whilst there was no effect of age for pre-trial difficulty estimations, ratings made after the task had been completed varied as a function of age whereby older children rated the task as being much more difficult than younger children. Thus the current study has shown that the experience of undertaking the gap timing task fosters an appreciation of its difficulty amongst older, but not younger children. These trends align with those reported in the previous chapter relating to the perceived difficulty of the safe place finding task (Chapter 4). Here too, older participants rated the task as being more difficult compared with younger children at post-trial, which suggests that similar processes are engaged across the two tasks.

It might be expected that younger children, whose behavioural performance is significantly poorer than that of older children, would view the task as being more difficult. The findings of the current study however demonstrate that this is not the case. Younger children view the task as being no more difficult than older children at pre-trial rating. Moreover, after completing the task, younger children rate the task as being even easier than they did at pre-trial. Older children on the other hand rate the task as being more difficult at post-trial. This finding is likely a reflection of the greater metacognitive understanding amongst older children.

Younger children rated the task as being even easier than they originally thought despite both the experience of attempting the task and their relatively poor performance. Younger children therefore seem not only to fail to understand the complexity of the task but are also not well attuned to their own performance. Older children by contrast, rate the task as being more difficult after having attempted it. It would therefore appear that older children come to appreciate its complexity and adjust their difficulty rating accordingly. This pattern of results likely reflects the development of metacognitive understanding which past research has shown follows a similar developmental trajectory (Kreutzer, Leonard & Flavell, 1975 and is important for learning (Wang, Haertel & Walberg, 1990).

Whilst a similar mismatch between perceived difficulty and performance amongst younger children was also found in respect of the safe place finding task reported in chapter 4, very little past research has investigated the perceived difficulty of the visual (gap) timing task. In a study of young people in the age range of 11-15 years, Tolmie et al. (2002) report that the perceived difficulty of the gap timing task when first presented was high and consistent across the age range investigated. The findings of the current study suggest the same cannot be said for younger children where there are clear developmental differences. Whilst difficulty estimations made before completing the task remain static across childhood, older children benefit from the experience of completing the task and revise their difficulty estimations in an upward direction when asked about difficulty at post-trial. The same cannot be said for younger children who perceive the task as being significantly less difficult compared to older children in spite of both the experience of undertaking it and their relatively poorer performance.

The implications of this are significant, especially in light of the correlation between perceived difficulty and performance. High pre-trial ratings were negatively correlated with the number of tight fits, whereby those who rated the task as being more difficult before even trying it made fewer tight fits. This would suggest that an initial appreciation (or expectation) of greater difficulty is associated with safer performance in terms of this performance measure. The findings relating to post-trial estimations further demonstrate a positive link between perceived difficulty and performance. Indeed, post-trial estimations were negatively correlated with starting delay and tight fits. This suggests those who rated the task as being more difficult after having completed it had shorter starting delays and made fewer tight fits. In addition, post-trial difficulty estimations were positively correlated with effective gap size suggesting those with high post-trial estimations had larger effective gaps. This would suggest those who rate the task as being more difficult make safer crossings. Those with higher pre-trial estimations performed more safely, presumably because they had some insight into the complexity of the task and took it seriously from the offset. Those who updated their difficulty ratings after having completed trials also appear to have performed more safely. Future research should seek to explore the impact of applying these findings via intervention, perhaps by incorporating reflection on one's own performance and addressing perceived difficulty explicitly via training. This seems particularly prudent given that metacognitive abilities have been shown to be susceptible to training (Hattie, Biggs, & Purdie, 1996, Dignath, Buettner & Langfeldt, 2008).

### 5.4.4 Summary and Conclusions

The current study has demonstrated age-related developmental improvements in children's skill level in a manner similar to that reported in the preceding chapter relating to the safe place finding task. The ability to cross through gaps in a flow of traffic broadly improves as children grow older. Younger children accept smaller gaps; delay initiating their crossing for longer and thus squander a larger part of the accepted gap; think that less time is needed to cross the road; and so make more tight fits. Performance across these measures improves steadily across the age range. The current study has also found some evidence of subtle gender differences in relation to some aspects of the task which adds to a small but growing evidence base which suggests males and females may respond differently to the gap timing task, though further research directly examining gender differences in the performance of this skill is needed to confirm these differences.

The current study has also provided insights into the perceived difficulty of the gap timing task amongst young pedestrians for the first time. Although there were no age differences in respect of pre-trial difficulty ratings, the findings suggest those children who thought the task would be difficult from the offset took the task more seriously and performed more safely as a result. The experience of completing the task (and doing so more safely than their younger peers), older children update their difficulty estimations at post trial ratings, presumably because their safer completion of the task has fostered an appreciation of its complexity.  Unlike older children, younger children do not revise their estimates in an upwards direction in the light of their experience of trying to make a series of actual crossings. On the contrary, they rated the task as being easier rather than more difficult, in spite of their lower level of performance.  This suggests they fail to perceive the difficulty and complexity of the task and the experience of undertaking the task does not seem to improve the accuracy of these perceptions relative to performance.

# Chapter 6

## Study 1.3: The Development of the ability to Predict Road User Intentions

### 6.1 Introduction

The perception of driver intentions refers to a pedestrian's sensitivity to cues which are indicative of driver's future actions, the ability to correctly anticipate these and to adjust road crossing decisions accordingly (Tolmie, Thomson, Foot, Whelan, Sarvary & Morrison, 2002). This is an important skill required in order to maintain safety given the transactional nature of the traffic environment and one which has been previously shown to be poorly developed in young children relative to older children and adults (Foot et al., 2006; Tolmie et al., 2002; Tolmie et al., 2006).

Tolmie et al., (2002) were among the first to highlight that children must not only develop their own skill level and build an awareness of hazards in the environment, but must also gain an appreciation of the intentions and likely future actions of other road users as well. This reflects the social dynamic of safe interaction with the traffic environment, which is governed by both formal rules of the road and cultural/societal norms, as well as individual differences in the application of these rules to one's own behaviour. In order to accurately make judgements about the likely actions of drivers and other road users, pedestrians must firstly be aware of the possible actions which *could* be chosen and then secondly attend to environmental cues which provide insights into the most likely action which *will* be chosen by other road users. Thus while the task is of a social nature, it also contains perceptuo-cognitive components which made this an appropriate skill to be investigated in the current thesis.

It has been argued for some time that road users must be able to foresee what is likely to happen on the road (Bjorkman, 1963). Making accurate predictions about events in the immediate to near future is essential and can be made by adults based on understanding of causal, social and physical relationships (Bjorkman, 1963).

Foot et al., (2006) argue if pedestrians are to become safe road users, they must recognise that other users are also active agents of the traffic environment and contribute significantly to how events are likely to unfold before them. In other words, children must come to understand that the rules of the road are open to interpretation and at times we may choose to break them or make errors which result in behaviour that may be contrary to expectations and local traffic laws. Children must therefore gain appreciation of the interactive nature of road use and that all road users including pedestrians have a responsibility to maintain safety.

The social dynamics of safe road use has been acknowledged previously in relation to children's perception of responsibility for traffic accidents which appears to develop with age. Thornton, Andree, Rodgers and Pearson (1998) argue children's perception of responsibility evolves from a damage avoidant towards an error avoidant perspective as they grow up whereby young children avoid damaging things while older children avoid making the kinds of mistakes that could lead to damage in the first place. Thornton et al. argue that below the age of 8 years, most children blame the person who causes damage even if this is not their fault. For example a driver who mounts the kerb and knocks over a bin in order to avoid a child on the road will be deemed as responsible for the damage by children under 8. Older children aged 8 and over on the other hand begin more often to blame the person who made the error which brought about the causal chain of events. These findings suggest children's appreciation for the interactive nature of safety on the road develops as they grow up.

Despite this interactive component of safely negotiating the traffic environment, the skill of predicting the prospective actions of other road users has received comparatively little research attention compared with those skills already addressed in this thesis. Only a small number of studies have explored the development of this ability amongst pedestrians empirically. The broader literature relating to the perception of intentionality in a wider range of contexts must therefore be addressed in order to gain insights into the development of this skill across childhood and the factors which likely impact upon its development.

### 6.1.1 Development of the ability to predict intentions and future actions

Human adults are remarkably accurate in their ability to predict the future behaviour and actions of others. Some have argued we are much more able to predict the future biological motion of people compared with objects and that there may be a dedicated neural basis for this (Blakemore & Decety, 2001). Others have argued this dedicated neural system implicated in the prediction of other people's future actions is different to the systems used to predict the likely future actions we will perform ourselves

(Ramnani & Miall, 2004). Frith and Frith (2006) argue this dedicated mechanism has likely evolved as a product of the much less predictable nature of interacting with other humans compared with interaction with inanimate objects in the environment. Others however have argued the neurological basis for this is universal and predicting future actions (in terms of both biological action and the prospective movement of objects) is underpinned by activation of the same brain region; the *posterior superior temporal sulcus* (Schultz, Imamizu, Kawato and Frith, 2004).

Understanding other people's intentions also involves representing the mental states of others and so can be said to involve theory of mind (Baron-Cohen, Leslie & Frith, 1985). Some have argued we are able to predict the future intentions of others by simulating their likely cognitive processes (Curruthers & Smith, 1996) although others have argued we can infer and deduce the mental states of others without such simulation (Davies & Stone, 1995). Although the neurological basis for this ability is contested, typically developing human adults appear remarkably able to predict the intentions and future actions of others.

The accuracy with which humans are able to predict the future actions of others has been linked to our experience of performing that same actions or behaviours ourselves (Romani et al., 2003). Romani and colleagues showed adults video clips depicting human movement during basketball games and found differences between expert and non-expert players, whereby experience of playing basketball resulted in significantly more accurate predictions compared with the non-playing novice group. This suggests children with more experience of the traffic environment will be better able to predict the prospective actions of road users. We may therefore reasonably expect that older children will be significantly better able to predict the future actions of drivers compared with their younger, less experienced peers as a result of their greater exposure to traffic. On the other hand we may also expect that all children will be relatively poor at predicting the intentions of drivers in particular because they quite obviously will have no experience of using the road from that perspective.

Whilst many studies in this field have focused on the ability to predict prospective actions and intentionality in adult populations and amongst specialist groups, such as those with autism, only a small number of studies have investigated this ability amongst typically developing children from which we can draw inferences about the development of this skill as children grow up. That said, when humans do observe the movements of others, we make inferences about the goals of the action and so consider the intentions of the person performing that action (Wolpert et al., 2003). This happens implicitly amongst adults, but children fare less well in this regard (Wolpert et al., 2003).

The human ability to predict the intentions and future actions of others appears to develop dramatically during childhood and a number of studies have examined how this ability changes during infancy. Baldwin and Baird (2001) for example studied the ability of infants (10-11 months old) to analyse and predict prospective physical behaviour of humans in everyday contexts. In this study the infants were shown video clips which were suddenly paused. Pauses were made either while the actor was in the middle of the pursuit of their intended action (half way through the completion of an action) or pauses were made at a point after the actor had completed the action. Findings showed infants display significantly greater interest in videos which were paused before the completion of an action, which the authors argue suggests infants are able to anticipate (and detect disruption in the completion of) intended actions from a very young age. The authors argue the ability to detect disruption in the completion of an action is a precursor to the development of intentional understanding which emerges in early childhood.

Durkin (1995) argues even toddlers are aware of the practical relevance of intentionality in relation to everyday behaviour. Evidence for this is provided by a number of studies which have shown toddlers make reference to their own and other people's intentions in language (Dunn, 1988; Shultz & Wells, 1985). By age 3 to 4 year,s for example, it appears children are able to differentiate between their own deliberate versus accidental utterances (Shultz & Wells, 1985; Schultz, Wells & Sarda, 1980). Some have taken these findings as evidence of intentionality understanding amongst children of this age, but some have questioned this interpretation (Astington, 1991). Indeed, these findings relate to the understanding of one's own intentions rather than the intentions of others. Furthermore use of language is not necessarily indicative of intentionality understanding in more applied (behavioural) contexts (Astington, 1986). The theory of mind literature suggests that some competence in relation to knowing what other people are thinking emerges around this age also (Astington, 1993; Perner, 1991). The majority of research in this field focuses on children between the ages of 3 and 5 when it is said most children begin to pass false belief tasks used to assess Theory of Mind (ToM:

Premack & Woodruff, 1978).

A number of studies have demonstrated predicting intentionality is not something children are able to do intrinsically from birth. Feinfield, Lee, Flavell, Green and Flavell (1999) investigated the understanding of intention in preschool children aged 3 and 4 years and report children from just 3 years old were unable to separate intentions from what they want to happen. By 4 years however it appears this ability is much better developed and children of this age begin to predict the intentions of others more consistently. This suggests by the time children reach 4 years old they will be able to predict the intentions and likely future actions of others with relative accuracy. This seems supported by other findings which have also suggested by age 3 years old children appear able to distinguish between intended actions and actions that were mistakes (Schultz, Wells & Sarda, 1980).

A number of other studies have reported findings which suggest this may be optimistic and it is not until later in childhood that children develop broad competence in relation to this skill. Some for example have argued it is not until children are of primary school age that they begin to understand the intentions of others. Olson and Astington (1986) studied comprehension of the language of intentionality amongst primary school children and report at age 5 years, children have very limited understanding of the meaning of vocabulary which relates to intention (e.g. intend to/plan to), with improvements only being evident as children enter middle childhood around aged 7 and competence only emerging around age 9. Vikan and Santos (1987) build on these findings and suggest children begin to understand positive relationships between intentionality and subsequent actions around 5 but it is not until between ages 7 and 9 that they are able to understand negative relationships (whereby intentionality may not always result in expected or intended behaviour). Thus while younger children aged 5 may demonstrate some understanding about what prospective behaviour *should* be, they will likely have limited understanding of what future actions *could* be. Thus before the 7-9 year age range, it would seem children are less able to anticipate unexpected actions which do not match up to their own expectations.

In the traffic context, this body of research suggests below the age of 7-9 years children will likely expect the actions of drivers to match up with the expected behaviour according to the rules of the road from their limited experience as a pedestrian. Children will likely assume that other road users will think similarly to them. Until around age 6 by when most (but not all) children attain ToM, children may even struggle to understand simply that other road users can have different perspectives, intentions and goals to themselves (Baron-Cohen, 2001).

### 6.1.2 Predicting the intentions of other road users

Despite both developmental differences in the ability to predict intentionality and the future actions of others outlined above and the importance of this skill when applied to the traffic context, very few studies have addressed this skill in relation to child pedestrian safety directly. Past studies which have considered this in a traffic context have largely focused on adult drivers and make reference to this skill as an aspect of hazard perception rather than as a skill in its own right or importantly, in relation to pedestrian behaviour.

Predicting the future actions of other road users forms part of the modern hazard perception component of the British driving test which has been a compulsory step in the process of obtaining a driving licence in the UK since 2002 (Driver & Vehicle Standards Agency, 2015). The test requires participants to identify developing hazards. That is to identify actions of pedestrians, drivers or other road users which are likely to become hazardous in the future. The sooner these developing hazards are spotted, the higher the mark received (UK Driver and Vehicle Standards Agency, 2015 [online]). Thus it can be argued the better able one is to accurately make predictions about the future actions of other road users, the more likely one is to pass the hazard perception part of the driving test. Foot et al. (2006) argue a case for this skill being important for the development of safe pedestrian behaviour too and observe although some studies have considered the ability to 'read the road' amongst drivers (e.g. Mills, Rolls, McDonald & Hall, 1998; Mourant & Rockwell, 1972) there appears to be a significant dearth in the literature with respect to the examination of this ability amongst pedestrians.

Tolmie et al. (2002) studied the ability of 7, 9 and 11 year old children to accurately predict the intentions of drivers using computer simulation in the form of the Crossroads pedestrian training and assessment software battery. Tolmie and colleagues highlight the particular difficulty of testing this pedestrian skill by the roadside given the difficulty of controlling for the occurrence of events which can be predicted and controlling for their outcome and specifically advocate a virtual reality approach to studying this skill. Findings of this study demonstrate that the ability improves as a function of age and that the number of correct predictions improves incrementally between the ages of 7, 9 and 11 years. The authors also report a corresponding increase in the number of environmental cues children attend to in order to arrive at and justify decisions about intentionality. It would appear that developmental trends in relation to the number of correct predictions and number of environmental cues identified are concordant. This study also demonstrated that performance on this task can be accelerated through computer simulated training for children of all ages.

Foot et al. (2006) report similar age differences to those reported by Tolmie and colleagues above in relation to the development of this skill but note it is unclear whether these differences are a reflection of experience or cognitive development (or both). In line with the findings reported by Tolmie et al. (2002), the study by Foot and colleagues also reports a corresponding increase in the number of environmental cues children identified in order to reach decisions.

A more recent study provides insights into the development of this skill in adolescence. Tolmie et al. (2006) investigated the development of the ability to predict the future actions of road users amongst children aged 11 to 15 years old (compared with adults). The findings of this study suggest development of this skill continues into adolescence with significant improvements in performance being apparent between pupils in their first compared with third year of secondary school.

These studies together provide a clear picture of the developmental improvements in relation to child pedestrians' ability to predict the future actions of other road users between the ages of 7 and 11 years old. Competence of children below the age of 7 years of age in relation to this skill however is unknown and will be examined in the current study.

### 6.1.3 Perceived difficulty

Tolmie and colleagues (2006) also considered how difficult participants find the task of predicting the future actions of road users both before and after its completion. Both adolescent and adult participants in the study by Tolmie and colleagues rated the task as being easier than a visual timing task and as being similarly difficult to the safe place finding task. The authors also report little variation in the perceived difficulty of the task in children of different ages (11-15 years). The findings of study 1.1 in this thesis show young children perceive the safe place finding task as being significantly easier than older children despite their relatively poorer performance. This suggests young children do not understand the complexity of maintaining safety on the road whereas older children appear to grasp the many variables which must be attended to and rate task difficulty accordingly. Yet no previous research has considered the perceived difficulty of the predicting intentions task amongst primary school aged children and forms a second explicit aim of the present research.

The current study aimed to provide a comprehensive developmental profile of the ability to accurately predict the intentions and future actions of drivers among young pedestrians aged between 5 and 12 years old. It aims also to examine trends in perceived difficulty of the task amongst primary school aged children for the first time. On reflection of the above literature it is hypothesised that:

1. The ability to accurately predict the intentions and actions of drivers will improve with age.

2. The number of environmental cues identified and used as a justification for predictions will increase with age.

3. Perceived difficulty will increase with age with younger children rating the task as being significantly less difficult than older children.

## 6.2 Method

### 6.2.1 Participants

As before, 117 participants took part in this study. 57 were male and 60 were female. 30 children were aged 5-6 years; 30 were 7-8; 30 were 9-10 and 27 were aged 11-12 years old. Full demographic details about participants and their recruitment are detailed in the general method section (chapter 2).

### 6.2.2 Design

This study was of a between groups design. The 4 age groups and gender served as the between subjects factors.

### 6.2.3 Materials and Procedure

The predicting driver actions task was selected from the *Crossroads* pedestrian training and assessment software described in chapter 2. The software was run on a standard laptop computer. The predicting driver intentions task presented participants with 12 scenarios involving a computer generated avatar interacting with 12 virtual road scenes. Road scenes varied in terms of their layout, urban/rural locale and in terms of the number of hazards and vehicles present. The number of cues indicative of likely prospective actions also varied between trials as did the speed of vehicles.

Each trial presented participants with a short video clip in which a pedestrian avatar is preparing to make a road crossing. Each scenario presented a different sequence of action. Scenarios included actions which are both in keeping with the Highway Code and scenarios in which the driver breaks the rules of the road, but cues indicate this is likely to be the case. When the action then pauses children are asked to make predictions about what they think is most likely to happen next. For example, in one trial, participants observe a man leave a building and get into a car. The participants hear the noise of the engine starting and see the car's reverse lights come on before the action freezes. In this scenario the correct prediction was that the car would reverse out of the driveway. The cues to indicate this were the starting of the engine and the reverse lights. Another scenario depicts a child waiting to cross at a zebra crossing. An approaching car starts to speed up. The clip pauses as the car nears the crossing. Here the correct prediction was that the car would keep going rather than stop. The cues here included the fact the car did not break (and in fact started to speed up) and the absence of brake lights. Participants completed 12 experimental trials (following the 1 practice trail from which no data was collected). A screenshot from one of the trials is presented in Figure 6.1 below.

Figure 6.1: Screenshot from the predicting road user intentions task


When the clips paused children were asked the following questions:

1. *What do you think will happen next?*

2. *How can you tell?*

   (Asked unless participant said "*don't know/not sure*" in response to question 1).

3. *Could anything else happen?*

4. *How can you tell?*

   (Asked if answer other than '*no/don't know'* is provided in response to question 3).

Participants were given the opportunity to elaborate on their initial response via questions 3 and 4). This was considered important in case participants offered a sensible response to question 1 and 2 which wasn't in fact the outcome of the clip. After participants had responded to these questions, the clip resumed and the outcome of the scenario was displayed. Responses to the above four questions produced a total of three main experimental outcome variables for this task which are detailed below.

The number of correct predictions is the total number of correct predictions participants made (out of a maximum of 11). Three of the trials required participants to make 2 predictions. This is the total correct irrespective of attempt or number of cues used to justify predictions (if any). An independent rater coded a 10% sample of responses. Inter rater reliability correlations for the number of correct predictions was very high (r=.95).

The number of correct predictions on participant's first attempt comprises the number of scenarios participants correctly predicted in response to question 1 (above) on their first attempt (questions 1 and 2). The number of correct predictions made on second attempt is the total number of correct predictions participants made on their second attempt (in response to questions 3 and 4 above). That is, the number of outcomes participants predicted through second responses, following an incorrect prediction in response to question 1. Scoring of attempt (first vs. second) was also checked by means of an inter rater reliability for the same 10% of the sample, by the same rater which was also very high (r=.96).

The number of correctly identified cues was calculated as the total number of environmental cues identified by children in their justification for their predictions. That is, the total number of correctly identified cues which were indicative of the likely outcome of each trial. This total comprises cues regardless of whether children were correct in their prediction on the first or second attempt. Only correct (indicative) cues were recorded. The number of correctly identified cues was also rated by an independent rater. Inter rater reliability was highly correlated (r=.90).

As with the other Crossroads tasks, perceived difficulty was once again measured via the software using a sliding bar which participants were instructed to move on a scale ranging from very easy to very difficult. Scores selected using the sliding bar along a non-numeric scale ranging from very easy (far left of screen) to very hard (far right) resulted in a corresponding difficulty score ranging from 0 to a maximum of 100. Participants completed difficulty ratings both before and after trials had been completed. Further details about the procedure and Crossroads software can be found in chapter 2.

## 6.3 Results

### 6.3.1 Behavioural Measures

The mean number (and standard deviation) of correct predictions overall was calculated for each of the age groups. These data are presented in Table 6.1 below.

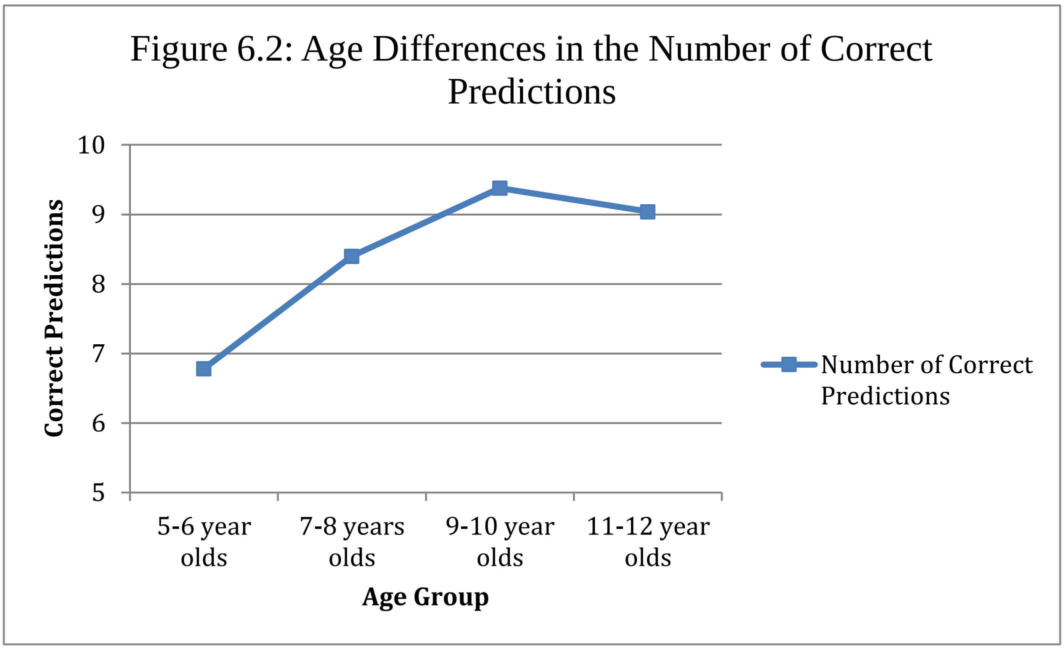
Table 6.1: Mean (and S.D.) Number of Correct Predictions* on the Predicting Road User Intentions Task as a function of Age Group and Gender

| Age Group | Male | Female | Combined |
|---|---|---|---|
| 5-6 years | 6.64 (2.27) | 6.69 (1.96) | 6.67 (2.07) |
| 7-8 years | 8.63 (2.09) | 8.00 (1.73) | 8.40 (1.96) |
| 9-10 years | 8.64 (2.41) | 9.69 (1.01) | 9.20 (1.85) |
| 11-12 years | 9.10 (1.85) | 9.12 (2.47) | 9.11 (2.23) |
| Overall | 8.23 (2.32) | 8.42 (2.20) | 8.33 (2.27) |

*out of a maximum of 11

These data show the overall number of correct predictions generally increases with age, reflecting an age related increase in accuracy of predictions.

A two way ANOVA with age and gender as the independent variables revealed the number of correct predictions of driver actions varied significantly between age groups ($F[3, 109]=9.53$, $p<.001$, $\eta^2=.292$) with the number of correct predictions increasing significantly as children grow older. There was no effect of gender ($F[1, 109]=0.10$, $p=.758$, $\eta^2=.003$) and no interaction ($F[3,109]=1.35$, $p=270$, $\eta^2=.073$). Age trends in relation to the number of correct predictions are presented in Figure 6.2 below.




Next, the number of cues children used to reach decisions was calculated as a function of age group and gender. The Mean number (and SD) of appropriately identified cues was calculated for each age group and are presented in Table 6.2 below.

Table 6.2: Mean (& S.D.) Number of Cues Identified on the Predicting Road User Intentions Task as a function of Age Group and Gender

| | Males | Females | Combined |
|---|---|---|---|
| 5-6 years | 6.29<br>(2.70) | 6.31<br>(3.65) | 6.30<br>(3.19) |
| 7-8 years | 10.74<br>(3.71) | 10.36<br>(4.13) | 10.60<br>(3.80) |
| 9-10 years | 11.50<br>(2.95) | 12.31<br>(1.96) | 11.93<br>(2.46) |
| 11-12 years | 13.20<br>(4.39) | 11.00<br>(3.20) | 11.82<br>(3.76) |
| Overall | 10.26<br>(4.15) | 9.98<br>(3.93) | 10.12<br>(4.02) |

A two way ANOVA with age and gender as independent variables revealed the number of environmental cues correctly identified was significantly different between age groups ($F[3,109]=18.90$, $p<.001$, $\eta^2=.367$). No effect of gender was found ($F[1,109]=0.47$, $p=.494$, $\eta^2=.003$) and there was no interaction ($F[3,109]=0.73$, $p=534$, $\eta^2=.023$). Age trends in the number of cues identified by participants are shown in Figure 6.3 below.

Figure 6.3: Age Differences in the Number of Cues Identified

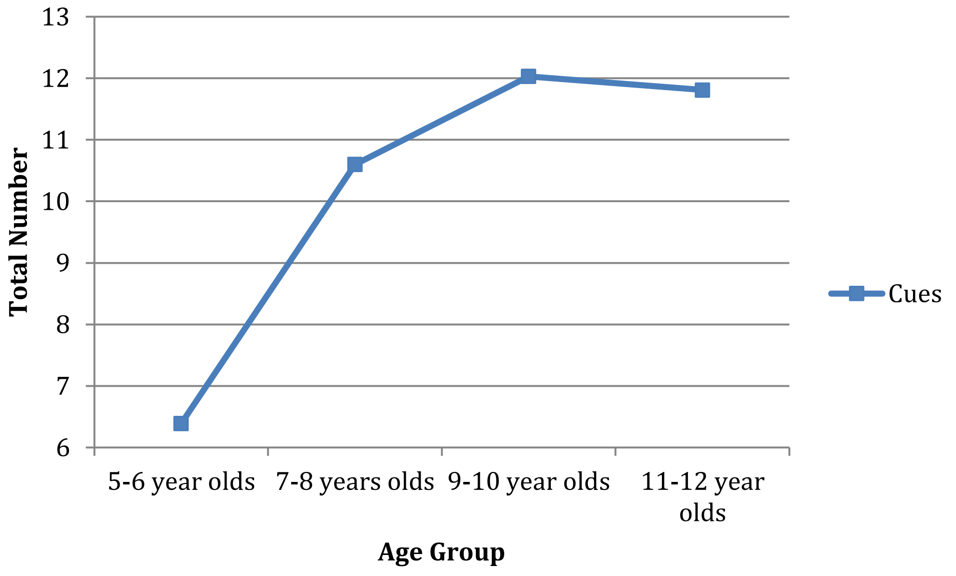


Table 6.3: Mean (& S.D.) Pre & Post-Trial Difficulty ratings* on the Predicting Driver Intentions Task as a function of Age Group and Gender

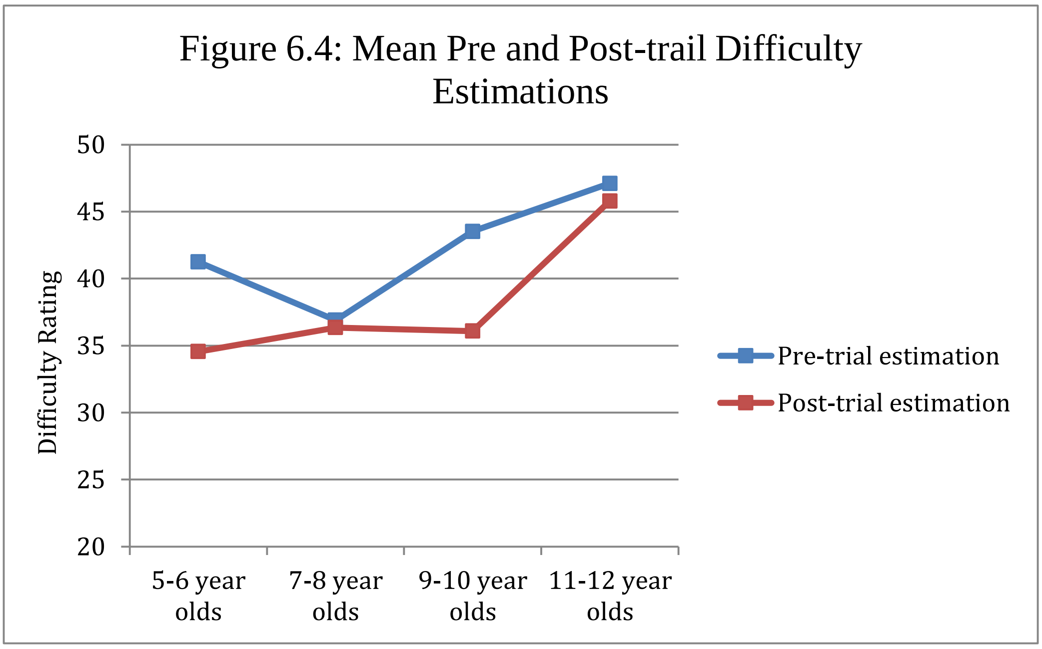
| | Mean Pre-trial Difficulty Estimations | | | Mean Post-trial Difficulty Estimations | | |
|---|---|---|---|---|---|---|
| | Male | Female | Combined | Male | Female | Combined |
| 5-6 years | 43.35 (25.81) | 39.55 (15.50) | 41.25 (20.44) | 35.12 (13.59) | 34.10 (19.98) | 34.56 (17.13) |
| 7-8 years | 37.76 (24.65) | 35.41 (21.47) | 36.90 (23.18) | 38.75 (18.85) | 32.20 (25.72) | 36.35 (21.42) |
| 9-10 years | 42.68 (13.62) | 44.25 (20.41) | 43.52 (17.30) | 39.50 (17.98) | 33.10 (17.93) | 36.09 (17.94) |
| 11-12 years | 40.82 (31.65) | 50.81 (16.95) | 47.11 (23.40) | 38.81 (23.74) | 49.90 (19.15) | 45.79 (21.23) |
| Overall | 40.83 (23.61) | 43.23 (18.84) | 42.08 (21.22) | 38.11 (18.11) | 37.96 (21.27) | 38.03 (19.73) |

*Maximum score = 100

### 6.3.2 Perceived Difficulty

Mean perceived difficulty estimations for pre and post-trial difficulty estimations were calculated for each age group and are presented in Table 6.3 below. There is a general increase in perceived difficulty which appears concurrent with age at both pre-test and post-test.

A 2 way ANOVA with age and gender as between groups factors and pre-trial difficulty ratings as the dependant variable revealed no main effect of age ($F[3,109]=0.91$, $p=.438$, $\eta^2=.025$) or gender ($F[1,109]=0.11$, $p=.740$, $\eta^2=.001$) and no interaction between age and gender ($F[3,109]=0.55$, $p=.649$, $\eta^2=.015$). When the same analysis was conducted for post-trial ratings, once again there was no main effect of age (F[3,109]=1.38, $p$=.252, $\eta^2$=.037) or gender (F[1,109]=0.04, $p$=.846, $\eta^2$=.000) and there was no interaction (F[3,109]=1.18, $p$=.320, $\eta^2$=.032).




## 6.4 Discussion

### 6.4.1 Behavioural Measures

In support of the first hypothesis, findings of the current study demonstrated that the ability to predict prospective actions of other road users improves significantly as a function of age.  Younger children were significantly less able to correctly predict the future actions of drivers compared with older children whereby ability improves overall as children grow up.

These findings align well with past research which has reported similar developmental trends in respect of the development of this skill amongst children aged 7-11 years old (Foot et al., 2006; Tolmie et al., 2002), with similar developmental improvements in performance appearing common to all three. Developmental improvement in the performance of this skill revealed in the present study is thus closely concordant with those previously reported.

In support of the second hypothesis, results of the current study demonstrate the number of environmental cues children attend to in order to make predictions about prospective actions of road users also increases significantly as a function of age. Unsurprisingly, it was children in the youngest age group who identified the fewest cues when justifying their predictions. The identification of cues appears to increase steadily throughout early to mid-childhood, with the mean number of cues slowly beginning to level off around age 9-10.

This increase in sensitivity to relevant and useful information in the traffic environment follows a remarkably similar trajectory to the ability to accurately predict upcoming actions of other road users. This finding also aligns well with past research which has reported very similar developmental trends in this regard (Foot et al., 2006; Tolmie et al., 2002).

Sheehy and Chapman (1985) argue developmental trends in children’s identification of hazards in the traffic environment follows a similar developmental trajectory to the identification of cues indicative of the future actions of others. Sheehy and Chapman argue this can be explained by children’s developing conceptualisation of what hazards actually are. They argue improvement in hazard perception reflects a transition from a focus on structural to functional aspects of hazards. Younger children perceive hazards to be an intrinsic part of an object or situation they perceive whereby some objects or situations (like a moving car) will always be dangerous whilst others (such as a teddy bear) are not. With age however, comes recognition that the risk posed by a potential hazard is contextual, and in the traffic environment; a product of what the child does in relation to a hazard. It is only as children grow up that they realise almost any object can be hazardous or non-hazardous, depending on the situation and their own behavioural response. It is thus only with age that children come to appreciate their attention towards a range of features of the environment can yield useful information about the traffic environment and how events are likely to unfold before them.

### 6.4.2 Perceived Difficulty

In relation to the third hypothesis, the findings of the current study revealed no age differences in relation to how difficult participants perceived the task to be, in spite of such a trend being apparent in the previous two skills. Past research has demonstrated that perceived difficulty ratings of this skill develop at a somewhat stilted rate during adolescence with little variation between children in the early years of secondary education and adults (Tolmie et al., 2006). The findings of the current study suggest little difference in amongst younger children either. Indeed children as young as age 5-6 years rate the task as being similarly difficult to children aged 11-12 years. The reasons for this are unclear but it would appear that children are not well attuned to the complexity of this task or their own performance on it.

Tolmie and colleagues (2006) found that participants (both adolescents and adults) rated the predicting intentions task as easier overall compared with both the safe place finding and visual timing tasks. That is to say, participants judged this task as being less difficult compared with tasks assessing other pedestrian skills. In addition, difficulty ratings of this task do not align well with children's behavioural performance and skill level. Younger children do not view task difficulty any differently than older children. This is in spite of younger children making far fewer correct predictions and being much less able to identify the cues that led them to their judgements. Unlike the older children, younger children have no basis to rate the task as being easy, because for them it was not as evidenced by their significantly poorer performance. Thus younger children are not only less skilled but they also appear to have poorer insight into their skill level and overestimate their performance and skill level relative to older children.

### 6.4.3 Conclusions and future research

The current study demonstrates significant age differences in the ability of children to accurately predict the future actions of other road users. Findings show this ability improves significantly with age between the 5 to 12 year age range. The findings also demonstrate that children are more receptive to environmental cues specifying the likely future actions of others with age. Of interest was the lack of age difference in relation to the perceived difficulty of this task, which is surprising given the age differences revealed in relation to the other skills addressed in part A of this thesis in this regard. This may well be a reflection of the different way in which humans process and make predictions about the future actions of others (Frith & Frith, 2006, Schultz, Imamizu, Kawato & Frith, 2004) or may be a reflection of the differing ways we view making errors in this regard compared with error making in other contexts (Frith & Frith, 2006).

Given the obvious link with ToM, future research should investigate the contribution of this ability to the performance of this task. Indeed, some groups may be particularly poor at this task given the requirement to make predictions about the intentions and mental states of others, such as those with Autism Spectrum Disorder (Baron-Cohen, 1997) who appear to struggle with behaving safely by the roadside (Josman, Ben-Chaim, Friedrich & Weiss, 2008).

Tolmie et al. (2002) also highlight the ambiguity of road signals as being a potentially important factor which no previous research investigating the development of the ability to predict the intentions of road users has considered. Indeed, for some, a perfectly clear and correct signal on the road may not necessarily be clear to other road users. On the other hand, a driver may make what would appear a very clear signal and then subsequently complete an action or manoeuvre which is at odds with the expected based up on the signal. Adults though, even as experienced road users, do still make errors in this regard. Children however who are much less experienced will likely find this more difficult still. Yet as Tolmie and colleagues (2006) highlight, no previous research has addressed the readiness or ability of children to read signals accurately. Ten years on, this lack of research remains. Indeed, the current study does not provide insights in this regard either. Future research may therefore wish to address this issue and examine the ability of children to interpret road signals as pedestrians and determine what impact, if any, this has on their accuracy of making predictions about the future actions of other road users.

In summary, the current study investigated the development of the ability to accurately predict the intentions of other road users amongst children aged 5 to 12 years. Younger children appear significantly less able to perform this skill than do older children as evidenced by both the number of correct predictions and in relation to the number of environmental cues identified in order to justify decisions. Performance in respect of both of these variables improves significantly with age. Crucially, younger children perceive the task as being as easy as their better performing older peers. This is in spite of their significantly poorer performance. Young children are thus not only less able to predict the intentions of other road users compared with older children, but also significantly over estimate their own skill level.

# Chapter 7

## Study 1.4: Neuropsychological Functioning and Child Pedestrian Skill Level

### 7.1 Introduction

The findings of the studies reported in this thesis so far highlight clear developmental improvement in pedestrian skill level as children grow older across each of the three pedestrian skills under examination; i) the ability to plan safe crossing routes, ii) the ability to identify gaps between cars in a flow of traffic which are safe to cross through and iii) the ability to predict the intentions of other road users. These findings mirror and extend those of previous studies which have also examined their development across childhood and have described similar age trends to those reported in the preceding chapters. Research has recently begun to examine factors which may underpin these trends and in particular, has set out to identify the cognitive underpinnings of safe pedestrian behaviour. A number of studies have set out to examine the cognitive abilities which influence the safety of children's use of the road (Barton, 2006, Barton & Morrongiello, 2011, Clancy et al., 2006, Schwebel, 2004, Stavrinos et al., 2011) and aspects of neuropsychological function have been identified as being particularly important (Barton & Morrongiello, 2011; Barton and Schwebel 2007, Stavrinos et al., 2011).

#### 7.1.1 Development of Cognitive Function

Research addressing the development of EF in childhood suggests components of EF have different developmental trajectories (Anderson, 2002). Attention set shifting (the ability to switch responding according to rule change) for example seems to begin to develop at aged 3-4 years (Espy, 1997). Inhibitory control (the ability to inhibit an automatic and naturalistic stimulus response) on the other hand appears to develop later in childhood. Whilst 3-year-olds have the capacity to learn the rules required for inhibitory control, preschoolers (at age 3) struggle to withhold correct response regardless (Bell & Livesey, 1985; Livesey & Morgan, 1991). Levy (1980) reported similar trends with significant differences on a stop signal task (SST) when comparing 3 and 7 year-olds in respect of both reaction time and errors. Williams et al. (1999) also report significant differences in inhibitory control as assessed by a SST between children aged 6-8 and 9-12 years whereby reaction times between of older children were approximately 50ms faster than those of younger children, suggesting inhibitory control begins to develop early in childhood but later than attention switching as described above.

Working memory appears to develop at a more protracted rate. Although some studies suggest working memory develops most significantly between the ages of 4 and 7 years (Luciana and Nelson, 1998), others suggest this aspect of neuropsychological function continues to develop until around age 12 (Luciana & Nelson, 2002). More recent research has also suggested the development of working memory continues into adolescence with some studies reporting significant differences on working memory task performance between 11-14 years (De Luca, Wood, Anderson, Buchannan, Proffitt, Mahony & Pantelis, 2003) with others reporting development continues later sill, into adolescence, up to 18 years of age (Klingberg, Fprssberg & Wssterberg, 2002). Although working memory and short term memory capacity have been strongly correlated (Kyllonen & Christal, 1990), Baddeley and Hitch (1974) argued working memory and short term memory are distinct constructs, a view that has been generally accepted for some time (Atkinson & Shiffrin, 1968, Miller, Galanter, & Pribram, 1960).

In contrast to the development of working memory, delayed short term visual memory appears to develop more quickly and this development appears to correspond to the physical maturation of neurocorrelates, particularly the hippocampus (Bachevailer & Mishkin, 1984). Indeed, STM is evident in infants before 5 years of age whereby even at pre-school age, children can complete delayed non-match to sample tasks with relative success (Diamond, 1990). Development in STM task performance in terms of difficulty develops as one may expect, with younger children better able to cope with short delays than longer delays but improvement in STM performance even for longer delays is still evident by mid-childhood (Diamond, 1990; Overman, 1990). Paule, Bushnell, Maurissen, Wenger, Buccafusco, Chelonis and Elliott (1998) demonstrate such developmental improvement in a study which compared performance of children aged 4 to 12 on a delayed match to sample task which assesses the ability to hold an item in memory over time (up to 12 seconds). The findings reveal accuracy broadly increases between these ages. For 4-year-old children a 20% reduction in performance was observed between the shortest and longest delay but for 11 year olds, this reduction was just 3% suggesting STM is well developed by this age.

In contrast to the clear developmental profiles of a number of other aspects of neuropsychological function, studies investigating age differences in children's propensity to take risks (also considered an aspect of EF), are more varied in their findings.

The human propensity to take risks in relation to a range of health threatening behaviours (including risky road behaviour) is well documented and suggests this aspect of neuropsychological function is worthy of consideration in studies investigating the neurocognitive predictors of pedestrian behaviour. Many laboratory tasks have been designed to assess risk taking and decision making in chidhood (e.g. Bechara, Damasio, Damasio, & Anderson, 1994, Rogers et al., 1999, Van Leijenhorst et al., 2008). Yet performance on tasks such as the Cake Gambling task (based on the Cambridge Gambling Task) has been shown to not differ significantly between children age 8 and adults (Van Leijenhorst et al., 2008). Similarly, Ernst, Grant, London, Contoreggi, Kimes and Spurgeon (2003) examined developmental differences in risk taking using the Iowa Gambling Task (Bechara, Damasio, Damasio & Andreson, 1994) and also report no differences in the performances of adolescents aged 12 to 14 when compared with adults. Van Leijenhorst et al (2008) report that males were more likely to take risks compared with females, with a number of other studies also reporting similar findings (Bolla, Eldreth, Matochik & Cadet, 2004, van den Bos, den Heijer, Vlaar & Houx, 2007, van den Bos, Homberg & Visser, 2013). Thus it would appear gender is more strongly associated with risk taking than is age (even when comparing performances of children to that of adults).

It would appear that a number of components of EF and related neuropsychological functions such as aspects of short term memory (Miyake et al., 2000), appear to develop at similar but distinctive rates. The recent studies which have explored the cognitive factors which underpin children's developing pedestrian competence have not accounted for this because they have relied upon composite measures of cognitive function which do not discriminate between different aspects of cognition. These studies and the implications of their reliance on composite measures of neuropsychological function will now be discussed.

### 7.1.2 Cognitive Function and Child pedestrian Behaviour

Some of the earliest work to examine psychological factors which may predispose some pedestrians to injury more than others was reported by Pless, Taylor, and Arsenault (1995) who investigated whether poor attentional control on the Connors Continuous Performance Test (CPT; Rosvold, Mirsky, Sarason, Bronsome & Beck, 1956) was associated with pedestrian injury. Among children and adolescents (aged 5-15) who presented at an accident and emergency department, those who attended as a result of a pedestrian or cycling injury were found to be significantly more impulsive than children in the control group who were injured in other ways.

Tabibi and Pfeffer (2003) compared the performance of 6, 8 and 10 year old children to that of adults on a computer task in which participants had to distinguish safe from dangerous places to make road crossings, similar to those used in previous research in this field (e.g. Ampofo-Boateng and Thomson, 1991; Thomson et al., 1992). Participants also completed a Stroop task assessing attention switching (Stroop, 1935). The findings showed linear improvements on both the safe place finding and Stroop tasks with age. Performance on the Stroop task also correlated significantly with ability to correctly identify safe crossing locations. The authors conclude attention switching is an essential skill required for children to safely identify appropriate crossing sties.

Barton et al. (2010) build on these findings by exploring the contribution of working memory, selective attention and visual search to children's ability to select a safe crossing route. Using a table top model to measure safe route selection and a total efficiency score on the Contingency Naming Test (CNT, Anderson, Anderson, Northam & Taylor, 2000), as a composite measure of inhibition, attention switching and working memory, Barton and colleagues showed that younger children were poor at selecting safe routes and that performance on the CNT was predictive of children's ability to identify safe crossing routes. These findings lend support to those of Tabibi and Pfeffer (2003) but suggest the cognitive underpinnings of safe pedestrian behaviour are broader than had been previously reported. Nevertheless, the full cognitive profile required for completion of this task is still contentious and has informed the design of the present research.

A review paper by Barton (2006) suggests that, while selective attention has most frequently been studied in relation to child pedestrian behaviour, there are other cognitive abilities that may also be driving developmental change in pedestrian competence. In particular Barton argues that aspects of higher order cognition, including working memory and other aspects of EF, will likely be important.

In a more recent paper, Barton and Morrongiello (2011) examined the impact by means of three measures of EF on children's performance on a pedestrian visual timing task using a pretend road paradigm. In this study, children aged 6-9 years completed an animal Stroop task (Wright, Waterman, Prescott & Murdoch-Eaton, 2003) which taps selective attention, working memory, inhibition and monitoring (Barton & Morrongiello, 2011), as well as the efficiency scores on the CNT (Anderson et al., 2000) as a composite measure of filtering and working memory. Parents also completed the Behaviour Rating Inventory of Executive Function, which is designed to assess using EF in everyday contexts (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000) from which the inhibitory control and monitoring (metacognitive) subscales were used. The findings demonstrated that all of these measures predicted the safety of children's behaviour on the visual timing task but that efficiency score on the CNT was the strongest predictor.

In a further study, Barton and Schwebel (2007) investigated the contribution of inhibitory control to children's visual gap timing ability and compared this to their scores on the inhibitory control subscale of the parent-completed Child Behaviour Questionnaire (CBQ; Rothbart, Ahadi, Hershey & Fisher, 2001). The CBQ is a measure of temperament in terms of 15 characteristics including impulsivity, attention focusing and inhibitory control (Rothbart et al., 2001). Barton and Schwebel report that children who had poor inhibitory control as measured by the CBQ took significantly more risks on the crossing task.

This developing area of research indicates there are significant relationships between aspects of neuropsychological function and pedestrian behaviour. In particular, aspects of EF appear important factors which at least partly underpin the readiness of children to behave safely by the roadside. What is not clear from the existing literature, is which aspects of EF are most important. For example both the studies by Tabibi and Pfeffer (2003) and Barton and Morrongiello (2011) used the Stroop task which has been said to assess selective attention, working memory, inhibition and monitoring (Barton & Morrongiello, 2011). Barton and Morrongiello also used the CNT as a composite of filtering and working memory whilst Barton et al. (2010) used this measure to produce a composite of inhibition, attention switching and working memory.

Previous studies have therefore been unable to report on the specific contribution of different aspects of cognitive function and have instead linked broad, composite measures of EF with single pedestrian skills. Indeed, every previous study to the writer's knowledge has investigated a single pedestrian skill rather than the broader range of skills addressed in this thesis, which have been previously shown important for the safe navigation of the traffic environment. A more complete profile of the cognitive underpinnings of these skills is therefore required. This forms one of the aims of the present research.

This study aims to systematically investigate the relationship between four components of neuropsychological functioning (inhibitory control, working memory, short term visual memory and risk taking) in relation to the three pedestrian skills identified in this thesis. Age differences in neuropsychological functioning will firstly be examined to establish the typical trajectory of development for these cognitive skills across childhood. Next, the relationship between neuropsychological functioning and child pedestrian skill level will be explored for each of the three skills addressed in the preceding chapters (safe place finding, visual timing and the ability to predict the intentions of other road users).

On reflection of the reviewed literature, it is hypothesised that:

1. Performance on the inhibition, spatial working memory and delayed short term visual memory tasks will improve with age, with gains in inhibitory control being apparent at an earlier age compared with short term visual memory and spatial working memory.

2. Neuropsychological functioning will predict pedestrian skill level, with higher scores on measures of neuropsychological functioning being associated with better pedestrian decision making on the tasks assessing pedestrian skill level whereby:
   i) Short term visual memory is expected to predict safe place finding ability because short term memory is needed to remember multiple hazards and features of the environment which inform decisions about safe crossing locations (Vinje, 1981).
   ii) Working memory is expected to be predictive of performance on the visual timing task because of the requirement to remember and integrate multiple variables (such as speed and distance) to determine

whether enough time is available to complete a crossing before the arrival of a vehicle.

iii) Short term visual memory is expected to relate to the intentions task because predictions about future events are based on events that have already unfolded that must be remembered until the end of the sequence. Delayed short term visual memory is also likely important for the intentions task to allow children to manipulate information being held in STM in order to make a correct prediction. For example if a car has already signalled that it is going to turn into a junction but then speeds up as it approaches it, children must remember the presence of the signal and the car's speed whilst also estimating its distance from the junction in order to determine whether the driver intends to turn or rather has indicated too early, or by accident.

iv) Previous research reported by Hoffrage et al., (2003) reported children who took more risks on an abstract game also took more risks when crossing between cars in a flow of traffic reflected in starting delays. Risk taking may therefore be expected to relate to performance on the visual gap timing task.

## 7.2 Method

### 7.2.1 Participants

The same 117 children took part in the current study (57 were male and 60 were female). 30 children were aged 5/6years, 30 were aged 7/8, 30 were 9/10 and 27 were aged 11/12 years. A full description of the sample is provided in the general method section (chapter 3).

### 7.2.2 Design

The design was a between-groups design, in which age group and gender were the between-group factors.

### 7.2.3 Materials and Procedure

Participants completed four subtests from the CANTAB battery (Frey et al., 1996) to assess neuropsychological functioning (inhibitory control, working memory, risk taking and short term visual memory) using a touch-screen tablet device. Three pedestrian skill tasks, selected from the *Crossroads* training and assessment software (Tolmie et al., 2002), were administered using a standard laptop computer. Developmental trends in the performance of these tasks have already been reported in chapters 3, 4 and 5 of this thesis.

The SST (assessing inhibition), SWM (assessing spatial working memory), DMtS (assessing delayed short term memory) and CGT (assessing risk taking) tasks were selected from the CANTAB task battery. The safe place finding, visual timing and predicting intentions tasks were selected from the Crossroads software. CANTAB tasks were delivered via a touch screen computer interface and the Crossroads tasks using a standard laptop computer. Full verbal instructions on the operation of each task were provided by the researcher before participants began each task and all tasks included practice trails not included in the data analysis to allow participants to familiarise themselves with the operation of each before testing began. Further details about the tasks and their administration are detailed in the general methods section (chapter 2).

Full descriptions of the CANTAB and pedestrian tasks have been outlined previously in chapter 3. Descriptions of the outcome measures of each of the pedestrian and neuropsychological tasks are presented in Tables 7.1 and 7.2 below.

Table 7.1: Summary of Crossroads Task Outcome Measures

| Tasks and Outcome Measures | Description |
|---|---|
| **Safe Place finding Task** | |
| Proportion of Safe Routes | The proportion of safe crossing routes children selected on the safe place finding task. |
| Proportion of High Conceptual Responses | The proportion of justifications for crossing routes selected on the safe place finding task that reflected high conceptual understanding. |
| **Visual Timing Task** | |
| Accepted Gap | The mean gap size participants were willing to attempt to cross through. |
| Start Delay | The mean duration from the point at which the lead car in a traffic flow passes the crossing location, until the point at which the participant initiates a crossing. |
| Effective Gap | Since pedestrians usually delay stetting into a gap, there is typically a mismatch between the true size of the gap and the size of the gap remaining when taking account of this delay. The latter is defined as effective gap. |
| Estimated Crossing Time | The mean length of time participants estimated it would take to reach the opposite side of the road. |
| Missed Opportunities | The number of times a participant chose not to cross when there was sufficient time to do so safely. This was defined as one and a half times of the total time needed to cross. |
| Tight Fits | The number of crossings when an approaching car's time to contact with the pedestrian's crossing line is less than the time required for the pedestrian to reach the far kerb. |
| **Road User Intentions Task** | |
| Proportion of Correct Predictions | The proportion of correct predictions children made on the predicting road user intentions task. |
| Number of Cues Identified | The number of environmental cues children successfully identified and used to justify their predictions. |

Table 7.2: Summary of CANTAB Task Outcome Measures

| Tasks and Outcome Measures | Description |
|---|---|
| **Stop Signal Task** | |
| Stop Signal Reaction Time (SSRT) | The mean time in seconds between presentation of the go stimulus and appearance of the stop signal at which participants successfully inhibited their response during the last 50% of trials (i.e. the processing time required to inhibit a pre-potent response). Lower reaction times indicate greater inhibitory control. |
| **Spatial Working Memory Task** | |
| Between Search Errors (BSE) | The number of errors made between searches (the number of times a participant returned to check a box where a token had already been found in a previous search). Greater BSE reflects poorer spatial working memory. |
| **Simultaneous and Delayed Match to Sample Task** | |
| Percentage of correct responses (% correct) | The percentage of trials on which participants chose the correct stimulus. Data can be examined across all trials with a delay condition as well as for each delay condition separately (0ms, 4000ms and 12000ms). Higher percentages reflect superior performance. |
| **Cambridge Gambling Task** | |
| Risk Taking | Mean proportion of points that the participant chose to gamble on trials for which they chose the more likely outcome. Lower scores reflect greater self-control. |
| Overall Proportion Bet | Mean proportion of points that the participant chose to gamble on each trial regardless of whether betting on the more or less likely outcome. Lower scores reflect greater self-control. |
| Quality of Decision Making | Mean proportion of trials on which the participant chose to gamble on the more likely outcome. Higher scores reflect higher quality of decision making. |

## 7.3 Results

### 7.3.1 Spatial Working Memory

First, the mean number of between search errors (BSE) was calculated as a function of age group and gender. This measure provides insight into errors made between searches (the number of times a participant returned to check a box where a token had already been found in a previous search). The task also had three difficulty levels, determined by the number of boxes required to be searched which varied between trials (4, 6 or 8 boxes). Difficulty increases with a greater number of boxes because participants need to remember a greater number of past checking locations. Errors were also calculated for each difficulty level separately, once more as a function of age group and gender. The data pertaining to BSE are presented in Table 7.3.

It can be seen that the data demonstrate a reduction in overall BSE as age increases and thus an improvement in working memory task performance is seen as children grow older. A two-way ANOVA was performed on overall BSE with age group and gender as between group factors revealed a main effect of age ($F[3,109]=11.42$, $p<.001$, $\eta^2=.239$) but no main effect of gender ($F[1,109]=0.74$, $p=.729$, $\eta^2=.001$). These was no interaction between age and gender ($F[3,109]=0.74$, $p=.533$, $\eta^2=.020$). Age trends in respect of BSE are shown in Figure 7.1 below.

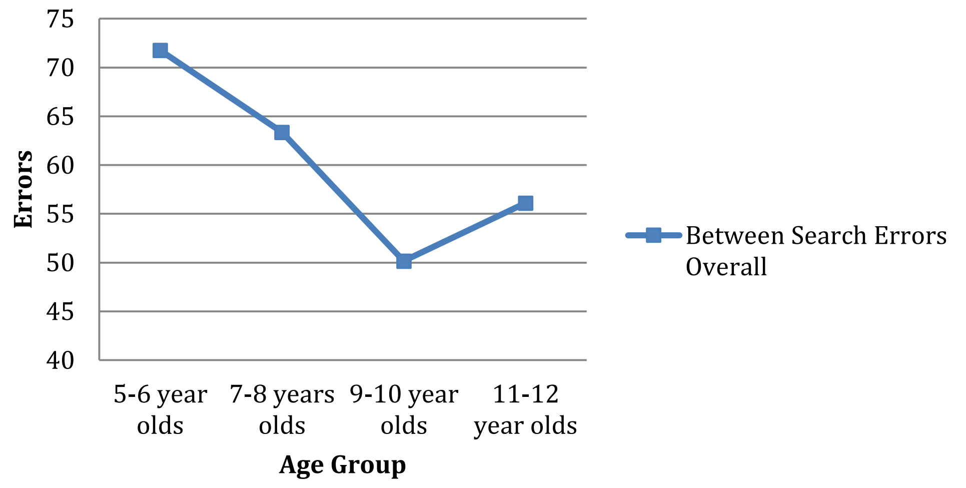


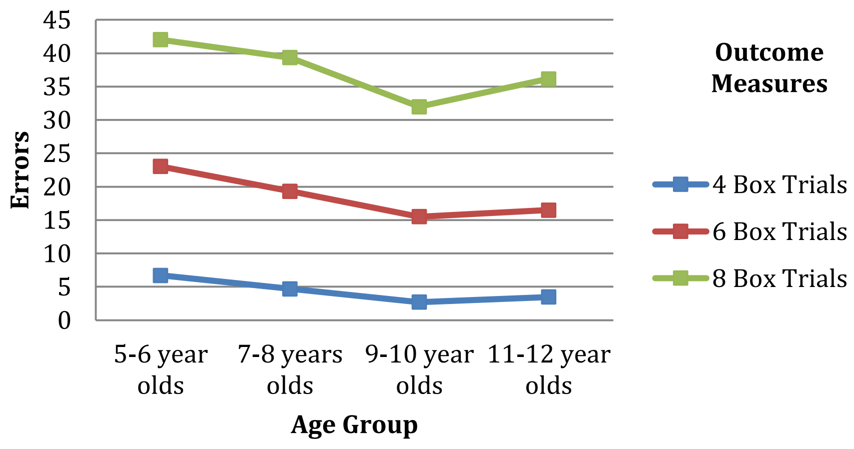

Figure 7.1: Age Differences in the Number of Overall Between Search Errors

Table 7.3: Mean (& S.D.) Number of Between Search Errors as a function of Age Group and Gender

| Age Group | BSE Overall | | | BSE 4 Box Trials | | | BSE 6 Box Trials | | | BSE 8 Box Trials | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined |
| 5-6 years | 68.93 (15.93) | 74.25 (11.77) | 71.77 (13.88) | 6.21 (3.96) | 7.13 (3.76) | 6.70 (3.82) | 21.57 (6.48) | 24.31 (8.60) | 23.03 (7.68) | 41.14 (12.18) | 42.81 (5.92) | 42.03 (9.24) |
| 7-8 years | 65.32 (11.80) | 60.00 (18.79) | 63.37 (14.57) | 4.68 (3.27) | 4.73 (3.69) | 4.70 (3.36) | 19.74 (5.89) | 18.64 (8.45) | 19.33 (6.81) | 40.89 (6.90) | 36.63 (9.14) | 39.33 (7.92) |
| 9-10 years | 50.29 (16.42) | 50.06 (16.55) | 50.17 (16.20) | 2.21 (1.93) | 3.13 (3.05) | 2.70 (2.60) | 14.57 (8.19) | 16.32 (6.53) | 15.50 (7.27) | 33.50 (8.85) | 30.63 (8.45) | 31.97 (8.61) |
| 11-12 years | 58.40 (12.72) | 54.77 (13.63) | 56.11 (13.18) | 4.40 (3.57) | 2.94 (3.01) | 3.48 (3.24) | 18.30 (6.15) | 15.41 (7.06) | 16.48 (6.77) | 35.70 (5.46) | 36.41 (7.80) | 36.15 (6.91) |
| Overall | 61.30 (15.62) | 59.67 (17.58) | 60.46 (16.54) | 4.40 (3.47) | 4.43 (3.72) | 4.42 (3.58) | 18.67 (7.02) | 18.62 (8.28) | 18.64 (7.66) | 38.23 (9.16) | 36.62 (8.82) | 37.40 (8.99) |

Similar differences were also observed when the number of BSE were examined according to trial difficulty level (4 vs. 6 vs. 8 box trials). Responding according to trial difficulty was examined by means of a three way mixed ANOVA with age and gender as between groups factors and trial difficulty level as a repeated measure. A main effect of difficulty was found with errors clearly increasing in line with difficulty ($F[2, 218]=1019$, $p>.001$, $\eta^2=.903$). A main effect of age was also observed ($F[3,109]=11.42$, $p<.001$, $\eta^2=.239$) whereby younger children show somewhat more difficulty than older children, but again there was no main effect of gender ($F[1,109]=0.12$, $p=.729$, $\eta^2=.001$). There was no interaction between age group and difficulty ($F[6,218]=1.79$, $p=.102$, $\eta^2=.047$). Age trends as a function of difficulty level are shown in Figure 7.2 below.

Figure 7.2: Age Differences in the Number of Between Search Errors by Difficulty Level



### 7.3.2 Inhibitory Control

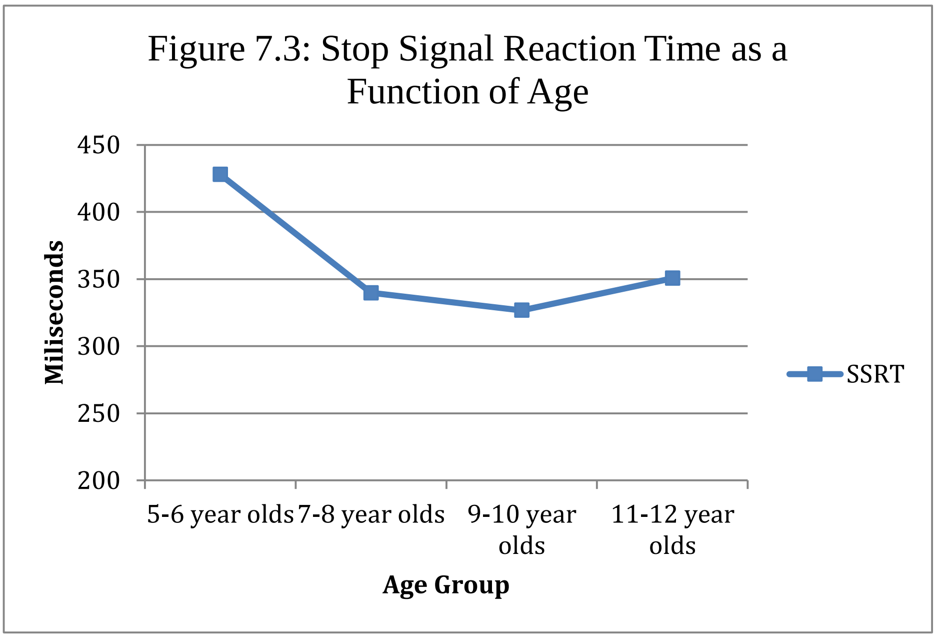
The mean stop signal reaction time (SSRT) on the stop signal task were calculated for each of the 4 age groups and as a function of gender. Means (and SDs) of each outcome measure are presented in Table 7.4 below.

Table 7.4: Stop Signal Reaction Time* on the Stop Signal Task as a function of Age Group and Gender

| Age Group | Stop Signal Reaction Time (milliseconds) | | |
|---|---|---|---|
| | Male | Female | Combined |
| 5-6 years | 426.21<br>(78.50) | 429.37<br>(109.20) | 427.90<br>(94.51) |
| 7-8 years | 345.76<br>(127.11) | 329.29<br>(93.83) | 339.72<br>(114.58) |
| 9-10 years | 377.70<br>(147.72) | 282.09<br>(105.04) | 326.71<br>(113.58) |
| 11-12 years | 270.09<br>(73.90) | 397.90<br>(153.45) | 350.56<br>(142.91) |
| Overall | 360.09<br>(123.51) | 362.83<br>(131.33) | 361.49<br>127.04) |

* in milliseconds.

First, a two way ANOVA with age and gender as factors revealed that SSRT (the primary outcome measure of the Stop Signal Task) varied significantly as a function of age ($F[3, 109]=4.69$, $p=.004$, $\eta^2=.114$) but not gender ($F[1,109]=0.05$, $p=.832$, $\eta^2=.000$). No interaction between age and gender was found ($F[3,109]=4.15$, $p=.008$, $\eta^2=.103$). The developmental trend in respect of SSRT is shown in Figure 7.3 below.

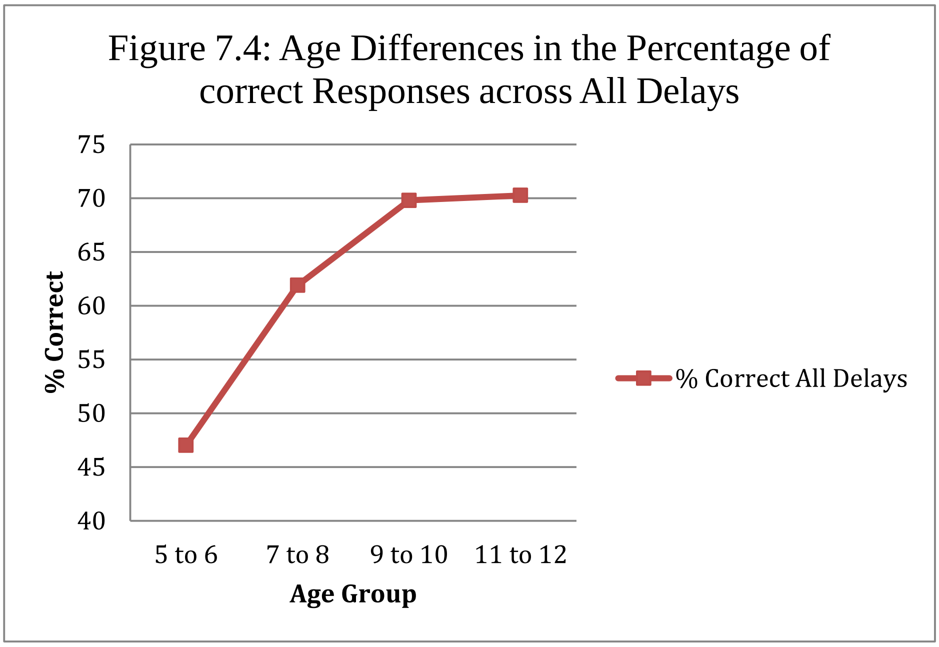



### 7.3.3 Delayed Short Term Visual Memory

The percentage of correct responses across all three delay conditions (0, 4 & 12 seconds) on the simultaneous and delayed match to sample task (percent correct all delays; an overall measure of performance across all delay trials) was calculated as a function of age and gender. These data are presented in Table 7.5.

For the overall percentage of correct responses (all delays), a two way ANOVA with age and gender as between group factors showed a main effect of age ($F[3,109]=16.26$, $p<.001$, $\eta^2=.309$) with older children attaining a higher percentage of correct responses across all delay conditions compared with younger children. There was no main effect of gender ($F[1,109]=0.91$, $p=.342$, $\eta^2=.008$) and no interaction between age and gender ($F[3,109]=1.00$, $p=.394$, $\eta^2=.027$). The effect of age on the percentage of correct responses across all delay conditions is illustrated in Figure 7.4 below.

A further two way ANOVA with age and gender as factors revealed differences in responding between age groups for simultaneous trials with no delay were also significantly different between age groups (F [3,109]=6.71, *p*<.001) but not genders (F[1,109]=0.19, *p*=.660). There was no age by gender interaction (F[3,109]=0.50, *p*=.681).



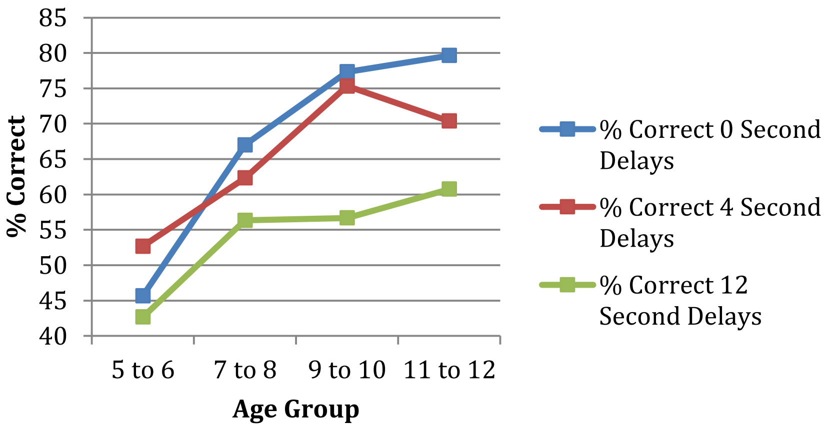

This shows an increase in the accuracy of responding on the DMtS task as evidenced by age related gains even for simultaneous trials that contained no STM component (where participants were simply required match a response to a target stimulus when both were visible) whilst the increase in the percentage of correct responses across all delay conditions represents a growth in STM capacity with age.

Table 7.5: Percentage of Correct Responses on the Delayed Match to Sample Task as a function of Age Group and Gender

| Age Group | % Correct 0 second delay | | | % Correct 4 second delay | | | % Correct 12 second delay | | | % Correct All Delays | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined |
| 5-6 years | 46.43 (19.46) | 45.00 (19.32) | 45.67 (19.06) | 54.29 (27.38) | 51.25 (15.44) | 52.67 (21.49) | 40.00 (14.67) | 45.00 (29.89) | 42.67 (23.78) | 46.90 (16.61) | 47.08 (19.36) | 47.00 (17.82) |
| 7-8 years | 63.68 (18.62) | 72.73 (21.49) | 67.00 (19.85) | 62.11 (20.43) | 62.73 (21.95) | 62.33 (20.63) | 56.32 (21.91) | 56.36 (17.48) | 56.33 (20.08) | 60.70 (14.73) | 63.94 (14.74) | 61.89 (14.56) |
| 9-10 years | 78.57 (10.27) | 76.25 (15.44) | 77.33 (13.11) | 76.43 (22.05) | 74.38 (20.65) | 75.33 (20.97) | 60.71 (21.29) | 53.13 (19.57) | 56.67 (20.40) | 71.90 (10.44) | 67.91 (13.16) | 69.78 (11.94) |
| 11-12 years | 87.00 (22.14) | 75.29 (20.65) | 79.63 (21.57) | 75.00 (20.14) | 67.65 (20.78) | 70.37 (20.48) | 68.00 (18.74) | 56.47 (22.34) | 60.74 (21.47) | 76.67 (13.05) | 66.47 (14.79) | 70.25 (14.79) |
| Overall | 67.19 (22.74) | 67.00 (23.02) | 67.09 (22.78) | 56.97 (23.82) | 64.17 (21.10) | 65.04 (22.38) | 55.44 (21.47) | 52.50 (23.16) | 53.93 (22.28) | 62.87 (17.50) | 61.22 (17.64) | 62.02 (17.51) |

Next, the effect of difficulty in terms of the length of delay was considered by examining performance on 0, 4 and 12 second delay trials separately by means of a three way mixed ANOVA with age and gender as between group factors and delay condition as a repeated measure. This revealed main effects of delay ($F[2,218]=25.09$, $p<.001$, $\eta^2=.154$) and age ($F[3,109]=16.26$, $p<.001$, $\eta^2=.309$) as well as an interaction between age and delay ($F[6,218]=2.31$, $p=.035$, $\eta^2=.060$). There was no main effect of gender ($F[1,109]=0.91$, $p=.342$, $\eta^2=.008$) and no gender by delay interaction ($F[2,218]=0.09$, $p=.912$, $\eta^2=.001$). The effects of age and delay are illustrated in Figure 7.5 below.

Figure 7.5: Age Differences in the Percentage of Correct Responses as a Function of Delay




These findings demonstrate clearly that delayed short term visual memory improves significantly with age. The percentage of correct responses across all three difficulty levels generally increases as children grow older. Whilst the percentage of correct responses for 0 and 4 second delay trials increases dramatically with age, gains with age for the most difficult 12 second delay trials were much less marked, as evidenced by the significant age by difficulty interaction.

### 7.3.4 Risk Taking

The means (and standard deviations) for the outcome measures of the CGT (risk taking, overall proportion bet and the quality of decision making) were calculated as a function of age and gender. These data are presented in Table 7.6 below.

Table 7.6: Responding on Cambridge Gambling Task as a Function of Age Group and Gender

| Age Group | Risk Taking | | | Overall Proportion Bet | | | Quality of Decision Making | | |
|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined |
| 5-6 years | 0.44 (0.08) | 0.47 (0.17) | 0.45 (0.13) | 0.43 (0.05) | 0.47 (0.14) | 0.45 (0.11) | 0.63 (0.17) | 0.73 (0.23) | 0.68 (0.21) |
| 7-8 years | 0.46 (0.14) | 0.46 (0.15) | 0.46 (0.14) | 0.47 (0.13) | 0.44 (0.13) | 0.46 (0.13) | 0.71 (0.18) | 0.86 (0.15) | 0.77 (0.18) |
| 9-10 years | 0.55 (0.17) | 0.50 (0.17) | 0.53 (0.17) | 0.52 (0.15) | 0.48 (0.13) | 0.50 (0.14) | 0.82 (0.19) | 0.79 (0.18) | 0.80 (0.18) |
| 11-12 years | 0.53 (0.18) | 0.49 (0.14) | 0.51 (0.15) | 0.52 (0.13) | 0.46 (0.10) | 0.48 (0.11) | 0.79 (0.19) | 0.75 (0.17) | 0.77 (0.18) |
| Overall | 0.49 (0.15) | 0.48 (0.15) | 0.49 (0.15) | 0.48 (0.12) | 0.47 (0.13) | 0.47 (0.12) | 0.73 (0.19) | 0.78 (0.19) | 0.76 (0.19) |

Two-way ANOVAs with age and gender as factors performed for each of the above outcome measures of the CGT revealed no outcome measures from the Cambridge Gambling Task varied as a function of age. Indeed no age ($F[3,109]=1.76$, $p=.159$, $\eta^2=.047$) or gender ($F[1,109]=0.21$, $p=.652$, $\eta^2=.002$) differences were revealed in relation to risk taking and there was no interaction ($F[3,109]=0.43$, $p=.734$, $\eta^2=.012$).

Similarly, overall proportion bet did not vary between age groups (F[3,109]=1.34, $p$=.267, $\eta^2$=.036) or genders (F[1,109]=0.70, $p$=.406, $\eta^2$=.006), nor was there an interaction between age and gender (F[3,109]=0.83, $p$=.481, $\eta^2$=.022). The quality of decision making was also not significantly different between age groups (F[3,109]=2.55, $p$=.059, $\eta^2$=.066) or genders (F [1,109]=1.70, $p$=.195, $\eta^2$=.015) and once again, there was no interaction (F[3,109]=1.76, $p$=.160, $\eta^2$=.046). Thus there appears to be no difference in responding on the CGT between children of different ages or genders.

### 7.3.5 Summary of Child Pedestrian Task Performance

Clear developmental improvement for the outcome measures for each of the three tasks assessing pedestrian skill level included in this study have already been reported in Chapters 4, 5 and 6 of this thesis. Performance on the safe place finding, visual (gap) timing and predicting intentions tasks varied significantly as a function of age, with performance on all three tasks generally increasing as children grow older. Means and standard deviations for the outcome measures for each of these tasks are summarised in Table 7.7.

| Table 7.7: Summary of Mean (& S.D.) scores on tasks assessing Pedestrian Skill Level | | | | |
|---|---|---|---|---|
| | 5-6 year olds | 7-8 year olds | 9-10 year olds | 11-12 year olds |
| **Safe Place Finding Task** | | | | |
| Proportion of Safe Routes | .16 (.15) | .38 (.19) | .55 (.21) | .69 (.27) |
| Proportion of High Conceptual Responses | .20 (.19) | .41 (.21) | .58 (.22) | .82 (.16) |
| **Visual Timing Task** | | | | |
| Mean Accepted Gap (secs) | 5.31 (.44) | 5.62 (.33) | 5.72 (.37) | 5.83 (.36) |
| Effective Gap (secs) | 3.64 (.65) | 4.23 (.56) | 4.58 (.58) | 4.77 (.58) |
| Start Delay (secs) | 1.67 (.47) | 1.39 (.45) | 1.15 (.31) | 1.06 (.50) |
| Estimated Crossing Time (secs) | 3.28 (.63) | 3.24 (.55) | 3.54 (.86) | 3.82 (.78) |
| Number of Missed Opportunities | 1.33 (.67) | 1.32 (.78) | 1.63 (1.13) | 1.56 (1.30) |
| Number of Tight Fits | 2.77 (1.07) | 2.13 (1.01) | 1.63 (.93) | 1.29 (1.06) |
| **Predicting Intentions Task** | | | | |
| Number of Correct Predictions | 6.78 (2.01) | 8.4 (1.96) | 9.38 (1.59) | 9.04 (2.24) |
| Number of Cues Identified | 6.39 (3.24) | 10.60 (3.80) | 12.03 (2.44) | 11.81 (3.76) |

Next, the extent to which each of the CANTAB measures are predictors of pedestrian skill level will be examined. Multiple regression analyses were conducted to determine the relationship between neuropsychological function and child pedestrian skill level on each of the 3 tasks assessing discreet pedestrian skills, with scores from the primary outcome measures from each of the CANTAB tasks as predictors along with age and gender.

### 7.3.6 Safe Place Finding and Cognitive Functioning

To address the first pedestrian skill, that of children's ability to find a safe crossing location and navigate a safe route across the road, multiple regression analyses were conducted to determine the predictors of the proportion of safe crossing routes (see Table 7.8 below). The key predictors of the proportion of safe routes children offered were identified by regressing the CANTAB task primary outcome measures on the proportion of safe routes. The results showed the CANTAB outcome variables accounted for a statistically significant proportion of the variance ($R^2$ =.53, $p$<.001). The standardised regression coefficients (in Table 7.8) demonstrate DMtS task performance (measuring short term visual memory) to be a statistically significant predictor of the proportion of safe routes on the safe place finding task.

Table 7.8: Predicting the Proportion of Safe Routes on the Safe Place Finding Task from Age, Gender and CANTAB Outcome Measures

| Predictor Variables | $R^2$ | F | $\beta$ |
|---|---|---|---|
| | .533 | 10.71*** | |
| SSRT (Stop Signal Task) | | | -.07 |
| BSE (Spatial Working Memory Task) | | | -.16 |
| % correct all delays (Simultaneous & Delayed Match to Sample Task) | | | .41*** |
| Risk Taking (Cambridge Gambling Task) | | | .08 |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

### 7.3.7 Visual Timing and Cognitive Functioning

Next, further regression analyses were conducted to determine the predictors of children's visual gap timing ability. Separate multiple regression analyses were conducted for each of the 6 outcome measures for the visual gap timing task (see Table 7.9) by regressing the primary outcome measures of the CANTAB tasks against each outcome measure of the gap timing task in the first steps and then by adding age and gender in the second. The results of each of these analyses will now be reported in turn.

First, the key predictors of the size of gaps children were willing to cross through were identified by regressing the primary outcome measures of the CANTAB tasks on the accepted gap size. The results show the CANTAB outcome variables accounted for a statistically significant proportion of the variance in step 1 ($R^2$ =.09, $p$<.001). Standardised coefficients show spatial working memory task performance (BSE) negatively predicts the size of accepted gaps whereby those with more working memory errors accepted smaller gaps.

When the same analysis was conducted for effective gap size, CANTAB task performance again accounted for a significant proportion of the variance ($R^2$ =.19, $p$<.001) with working memory and short term visual memory task performance as independent predictors.

In respect of starting delay, CANTAB task performance accounted for 17% of the variance in the first step ($R^2$ =.17, $p$<.001). Beta weights demonstrate short term visual memory as being negatively predictive of starting delay as might be expected, whereby those with a higher percentage of correct responses on the DMtS had shorter starting delays.

When the same analysis was repeated for estimated crossing time, the results showed none of the CANTAB outcome measures were predictive of estimated crossing time.

The penultimate regression model for the visual gap timing task revealed only SSRT of the CANTAB tasks (assessing inhibitory control) predicted positively the number of missed opportunities in the first step of the model ($R^2$ =.10, $p$<.001) whereby higher SSRTs (and poorer inhibitory control) predicted a higher number of missed opportunities.

The final regression analysis for the visual gap timing task set out to examine predictors of the number of tight fits by once more regressing the primary outcome measures of the CANTAB on the number of tight fits on the visual gap timing task. The results show the CANTAB outcome variables accounted for a significant proportion of the variance ($R^2$ =.11, $p$<.001), with beta weights demonstrating delayed short term memory task performance negatively predicting the number of tight fits. Those with a higher percentage of correct responses on the DMtS made fewer tight fits.

In summary inhibition, working memory and short term visual memory task performance significantly predicted aspects of the visual gap timing task. The measures of neuropsychological function account for between 9 and 19% of the variance depending on the behavioural measure.

Performance on the inhibition task (SSRT) predicted the number of missed opportunities on the visual gap timing task.  In addition, performance on the working memory task predicted accepted gap size and effective gap size on this task also. Short term visual memory was predictive of mean effective gap size, starting delay and the number of tight fits.

Table 7.9: Predicting the Performance on the Visual Gap Timing Task from Age, Gender and CANTAB Outcome Measures

| | Accepted Gap | | | Effective Gap | | | Start Delay | | | Estimated Crossing Time | | | Missed Opportunities | | | Tight Fits | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Predictor Variables | $R^2$ | F | *β* | $R^2$ | F | *β* | $R^2$ | F | *β* | $R^2$ | F | *β* | $R^2$ | F | *β* | $R^2$ | F | *β* |
| | .09 | 2.62 | | .19 | 6.57 | | .17 | 5.49 | | .04 | 1.39 | | .10 | 2.99 | | .11 | 3.48 | |
| SSRT (Stop Signal Task) | | | .08 | | | .02 | | | .03 | | | .13 | | | .28** | | | -.03 |
| BSE (Spatial Working Memory Task) | | | -.20* | | | -.21* | | | .14 | | | -.03 | | | -.02 | | | .14 |
| % correct all delays (Delayed Match to Sample Task) | | | .17 | | | .32** | | | -.32** | | | .19 | | | .16 | | | -.26* |
| Risk Taking (Cambridge Gambling Task) | | | -.01 | | | -.04 | | | .05 | | | .10 | | | -.14 | | | -.01 |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

### 7.3.8 Predicting Road User Intentions and Cognitive Functioning

Further regression analyses were conducted to determine the key predictors of the proportion of correct judgements on the predicting intentions task. As before, the CANTAB task primary outcome measures were regressed on the proportion of correct predictions on the prediction road user intentions task.

The results demonstrate that the CANTAB primary outcome variables account for a statistically significant proportion of the variance ($R^2$ =.65, *p*<.001). The standardised regression coefficients (see beta weights in Table 7.10) indicate spatial working memory and delayed short term visual memory assessed using the DMtS task to be statistically significant independent predictors of the proportion of correct predictions on the predicting road user intentions task. Errors on the working memory task negatively predicted the number of correct predictions. The percentage of correct responses on the short term visual memory task positively predicted the number of correct predictions.

Table 7.10: Predicting the Number of Correct Predictions on the Predicting Road user Intentions Task from Age, Gender and CANTAB Outcome Measures

| Predictor Variables | $R^2$ | F | $\beta$ |
|---|---|---|---|
| | .65 | 9.94 | |
| SSRT (Stop Signal Task) | | | -.08 |
| BSE (Spatial Working Memory Task) | | | -.21* |
| % correct all delays (Delayed Match to Sample Task) | | | .44*** |
| Risk Taking (Cambridge Gambling Task) | | | .21 |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

In summary, the regression model accounted for 65% of the variance showing neuropsychological function significantly predicted the ability of children to predict the intentions of other road users. Inhibitory control and short term visual memory appear to be independent predictors of this skill.

## 7.4 Discussion

### 7.4.1 The development of Neuropsychological Function

The findings of the current study broadly support the first hypothesis that CANTAB task performance would increase with age. The primary outcome measures for 3 of the 4 CANTAB tasks varied significantly as a function of age, representing a broad improvement in neuropsychological function as children grow older. Performance on tasks assessing spatial working memory, inhibitory control and short term visual memory all improved with age.

The findings are well aligned with past research which has also shown EF broadly improves with age and that some aspects of EF develop at different rates to others. Control processes for example appear to emerge relatively early in childhood (typically in infancy) and then continue to develop rapidly in early childhood. In contrast the setting of goals, information processing and cognitive flexibility undergo a critical period of development between the ages of 7 and 9 years and appear to be relatively well developed by age 12 (Anderson, 2002). Research addressing the development of EF therefore suggests EF develops significantly across childhood but components of EF have different developmental trajectories (Anderson, 2002). The findings of the current study would certainly seem to support this notion.

Indeed, clear age related improvements in performance on the stop signal task, spatial working memory task and short term visual memory task were observed, yet when the developmental profiles of these tasks are compared, the developmental aspects of neuropsychological function are not identical.

The findings relating to age differences in responding on the stop signal task assessing inhibitory control for example demonstrates children's performance improved most significantly between ages 5-6 and 7-8 years. This finding is well aligned with the findings of past research which has also argued this aspect of neuropsychological function improves rapidly in early childhood (Diamond &Taylor, 1996) and appears well developed by age 9 (Anderson, Anderson & Lajoie, 1996). In contrast, the findings relating to both spatial and short term visual memory suggest these aspects of neuropsychological function develop slightly later in childhood.

Indeed, the current study showed the most notable development on the spatial working memory task took place between the ages of 7- 10 years. Then, beyond the age of 10, development appeared to level out. A number of previous studies have also reported the development of working memory to follow a similar trajectory (Luciana & Nelson, 1998, Pickering, 2001).

The findings relating to short term visual memory reveal similar trends. Indeed, performance on the delayed short term memory task revealed significant improvement in performance with age, with notable improvement up to the age of 10 and development levelling out thereafter. This finding confirms the developmental trajectory reported by a range of studies of short-term memory which also demonstrate a rapid improvement in performance across early to mid-childhood, with a more gradual improvement thereafter until around 11 years when performance appears to level off (Gathercole, 1999; Gathercole, Pickering, Ambridge & Wearing, 2004; Rhodes et al., 2012).

In addition, Wilson, Scott and Power (1987) report similar developmental differences between children aged 5 to 11 years using a visual pattern span task similar to that used in the current study. Further, this study, like the present research, included three difficulty levels. Trials in the study by Wilson and colleagues included either a 2 or 10 second delay or a 10 second delay with interference. The short term visual memory task in the current study also had 3 difficulty levels. The results of Wilson et al., like those of the current study relating to difficulty, showed similar developmental improvement in performance for all delay conditions with age but also show an effect of difficulty, similar to that reported here. Paule et al. (1998) also report a decline in STM accuracy according to the length of delay but also note an interaction between age and difficulty whereby decline in performance according to the length of delay appears ameliorated by age whereby delay-related decline in performance is less pronounced for older children. Although there was no significant interaction between age and delay in respect of short term visual memory in the current study, results relating to difficulty do appear to reflect a similar trend.

In contrast, findings relating to risk taking task on the Cambridge Gambling task revealed no age or gender differences in responding. The literature on risk taking is rather mixed. On the one hand, some argue a case of clear developmental differences in risk taking amongst children whilst others report none. Indeed, even from the early days of research in this field, researchers seem to have disagreed in this regard. Kerr and Zelazo (2004) for example report significant developmental differences are observable in very early childhood, whereas Kass (1964), reports no age differences on a risk taking task between 6, 8 and 10 year olds.

A possible explanation of this apparent conflict is that age related differences in risk taking might be observed very early in childhood (representing early development of this aspect of decision making) but even by early to mid-childhood detectable age differences on tasks such as that used in the current study appear to dissipate. This account has been offered previously by Kerr and Zelazo (2004) who report the effectiveness of risk taking and decision making appears to develop most rapidly during the preschool years and argue this reflects the development and growth of the orbitofrontal cortex (Zelazo & Muller, 2002). This account seems well supported through a closer inspection of past research (Kass, 1964; Arenson, 1978; Hongwanishkul, Happaney, Lee & Zelazo, 2005). Taken together, along with the findings of the current study, it would appear that there are either no age differences in risk taking on tasks such as that used in the current study during childhood or that developmental improvement takes place before the age of 5 years. It has been argued a range of experiential (Franken & Muris, 2005) and personality (Zuckerman & Kuhlman, 2000) factors as well as social influences (Gardner & Steinberg, 2005) underpin and better explain variation in children's propensity to take risks than do age and gender. Future research may wish to examine the impact of these factors on children's risk taking on the Cambridge Gambling Task specifically.

In summary the findings relating to the development of EF demonstrate middle childhood is an important period for the development of a range of aspects of cognition. Significant differences between age groups were revealed for inhibition, spatial working memory and short term visual memory task performance but not for risk taking on the gambling task. The development trajectories of these functions exemplify that whilst these functions do develop at similar rates, they do not develop entirely in unison. They also confirm the neuro-typicality of the sample given their close resemblance to normative profiles of development reported previously. The developmental trajectories of performance on these tasks also appear similar to the developmental profiles of pedestrian skill development reported in studies 1.1 to 1.3. Indeed some previous studies have argued the development of cognition and children's pedestrian skill level may not only be concurrent but may also be interrelated whereby the development of EF may drive improvement in and predict pedestrian skill level. The contribution of performance on each of the CANTAB (tasks that were explored in the second stage of analysis in this study) appear to support this notion, the findings of which will now be discussed.

### 7.4.2 The relationship between Cognitive Functioning and Pedestrian Behaviour

The findings also broadly support the second hypothesis that EF task performance would predict performance on tasks assessing child pedestrian skill level. Examination of the relationships between CANTAB task performance and performance on the Crossroads tasks assessing pedestrian skill level reveal clear relations between distinct cognitive abilities and each of the pedestrian skills. These findings support and considerably extend past research in this area. Most notably, these findings are well aligned with those reported by past studies in this field (Barton & Morrongiello, 2011, Barton & Schwebel, 2007) but also extend these previous findings in two key ways. Firstly, the findings discussed herein explore the contribution of a more detailed profile of cognitive functions which are related to child pedestrian skill level. They also extend the literature by exploring the contribution of these functions to a more broad range of pedestrian skills than have been previously considered by research in this area.

Performance on the safe route planning task in terms of the number of safe routes children selected was predicted significantly by short term visual memory as assessed using the simultaneous and delayed matching to sample task. These data are the first which show a relationship between delayed short term memory and the ability to plan safe crossing routes empirically. Indeed no previous studies have examined the relationship between cognitive function and safe place finding ability. That said, it has been long since argued short term memory is likely very important in the pedestrian context (Vinje, 1981). The findings of the current study appear to support this notion. It is likely that short term memory is essential in allowing pedestrians to maintain information about traffic conditions in one direction while exploring traffic conditions in another as required during the safe place finding task given the complexity of the scenarios presented to participants.

It has been argued for some time that young children (before at least 6 years of age) are likely to have particular difficulty with remembering the position and orientation of objects in 3D space, especially when there are few characteristics in the environment upon which coding can be based or the environment and its features are unfamiliar (Acredolo, Pick & Olson, 1975, Piaget & Inhelder, 1973, Vinje, 1981). This particular difficulty may go some way to explaining the poor performance of children in the youngest age groups on the safe route planning task revealed here. Indeed in order to identify safe routes on this task, children were required not only to remember the position and orientation of a range of hazards such as parked vehicles and features of the road but they were also unfamiliar with the road layout and features contained within trials.

Aspects of visual (gap) timing task performance were also predicted by neuropsychological function, specifically inhibitory control, spatial working memory and short term visual memory. Performance on the task assessing inhibitory control predicted the number of missed opportunities even when controlling for age. It would appear that children with greater inhibitory control (shorter SSRTs) act cautiously and therefore miss a higher proportion of safe crossing opportunities compared to children with poorer inhibition. They inhibit the temptation to cross until they are absolutely sure it is safe to do so. This relationship is logical because those with poorer inhibitory control might be expected to have difficulty inhibiting the desire to cross and will tend to want to 'go sooner' whether it is safe to cross or not. As a result, they miss fewer opportunities than children who inhibit their desire to cross and wait until an opportunity they can be sure is safe arises. This was a finding also reported by Barton and Schwebel (2007) who also report inhibition as being linked with visual gap timing ability in young pedestrians in the same direction revealed here.

In addition, working memory predicted mean accepted gap size and mean effective gap. Children with a greater number of working memory errors (BSE) accepted smaller gaps and also had smaller effective gaps. This likely reflects the fact children with poor working memory are unable to remember and integrate the multiple variables (such as distance and speed) needed to determine whether or not enough time is available to make a safe crossing. Short term visual memory also predicted mean effective gap size, starting delay and the number of tight fits. Those with a higher percentage of correct responses on the short term visual memory task had shorter starting delays, which presumably gave rise to their having longer effective gaps and resulted in them making fewer tight fits. This further confirms the importance of memory in order to allow pedestrians to maintain and manipulate elements of the traffic environment in mind during decision making.

These findings are broadly comparable to those reported by Barton and Morrongiello (2011) who investigated the relationship between EF and visual gap timing performance. Their study reported performance on the contingency naming test (a measure of cognitive efficiency) and a parent completed BRIEF questionnaire predicted different aspects of task performance on a visual gap timing task. Specifically, the authors report cognitive efficiency scores predicted the gap size children were willing to accept. Those with good cognitive efficiency scores left more time to clear the road safely before the arrival of a vehicle at their crossing location. BRIEF scores predicted the gap sizes children were will to accept and the safety margins (or time left to spare) during crossings. These measures however are composite measures which assess multiple aspects of EF (Northam, Andreson, Jacobs, Hughes, Warne & Werther, 200, Taylor, Albo, Phebus, Sachs, & Bierl, 1987). The findings of the current study extend these findings considerably by shedding considerably more light on the nature of the relationship between cognitive function and performance on the gap timing task. Indeed, the current study is the first to examine the relationship between specific aspects of neuropsychological function and children's visual gap timing ability by decomposing aspects of EF and neuropsychological function into more specific subcomponents. This approach has made a considerable contribution to the field by revealing which aspects of cognitive function are most important.

The functions that appear to best predict performance on the gap timing task are spatial working memory and short term visual memory which, between them, predict accepted gap size, effective gap size, starting delay and the number of tight fits. Inhibitory control on the other hand was not found to predict any of these, it only predicted the number of missed opportunities. These findings highlight the particular importance of two aspects of neuropsychological function in relation to the ability to identify safe gaps between cars in a flow of traffic, namely spatial working memory and short term visual memory. The CGT measures of risk taking did not predict any aspect of performance.

As mentioned above, these findings are logical given the nature of the gap timing task, which by definition, requires participants to maintain and manipulate multiple variables in mind in order to make decisions about the estimated arrival time of a vehicle at one's location on the road. Pedestrians must for example attend to variables such as speed, distance and time and integrate these variables in an ever changing environment to be able to estimate whether they have the time necessary to complete a crossing safely.

Performance on the predicting driver intentions task was also predicted by CANTAB task performance. Specifically, spatial working memory and delayed short term visual memory appear predictive. The significant relationship between performance on the delayed short term memory task and the ability to predict the intentions of other road users shows the percentage of correct responses on the short term visual memory task positively predicted the number of correct predictions children made on the predicting road user intentions task whereby those with a higher percentage of correct responses on the short term memory task made more correct predictions on the predicting road user intentions task. The predictive relationship between working memory task performance and the ability to make correct predictions about the intentions of other road users is reflected by the fact those with a higher number of working memory errors made fewer correct predictions.

These relationships may not be entirely surprising. The predicting road user intentions task requires children to watch short traffic sequences unfolding before making predictions about the likely intentions and future actions of road users within them based upon what has been observed in each trial. It is likely that short term visual memory underpins the ability of children to remember the events they have observed across the duration of each traffic sequence. Poor short term memory likely makes it difficult for children to make accurate predictions about the intentions of road users when they are asked to do so at the end because predictions are based on events that have already unfolded which they may struggle to remember. Working memory is likely also required because pedestrians must manipulate some of the information being held in STM in order to make correct predictions. For example, if a car speeds up towards a red light, participants must attend to its speed as well as distance from the red light in order to determine whether it is likely to (or be able to) stop before reaching the crossing.

### 7.4.3 Limitations and Future Research

Although this is the first study to investigate the relationship between aspects of neuropsychological function and the ability to predict the intentions of other road users directly, we can compare the findings to other studies which have considered the relationship between neuropsychological function and other aspects of intentionality understanding in children in the broader developmental literature.

There is a wide body of literature which demonstrates clear links between aspects of neuropsychological function and social development, in particular theory of mind abilities (Hughes, 1998). These links emerge early in childhood and before school age for most children (Devine & Hughes, 2014). There also appears to be robust links between individual differences in children's false belief understanding and individual differences in EF (Moses, 2005). While the predicting road user intentions task is more than a test of theory of mind, it does require children to make judgments about other people's states of mind in terms of what their future intended actions are most likely to be. Similarly, in relation to short term memory and its contribution to the predicting road user intentions task, Gordon and Olson (1998) argue changes in capacity to hold information in mind allows for the expression of and the formation of a theory of mind. This may also explain the relationship between performance on the short term visual memory (DMtS) task and the predicting road user intentions task revealed here. The relationship between spatial working and short term memory and the ability to predict the intentions of other road users would therefore appear well supported by the social development literature and in particular, studies of ToM. It is possible that neuropsychological function predicts performance on this task via ToM but the current findings are limited so far as this cannot be confirmed. Future research should examine this possibility further.

#### 7.4.4 Summary and conclusion

The current study demonstrates similar developmental improvements in respect of three aspects of neuropsychological function across childhood. These trends demonstrate specific aspects of cognition predict the performance of discrete pedestrian skills. Children's ability to identify safe crossing locations and plan crossing routes which avoid hazards appears linked with their short term memory. The ability to identify gaps between cars in a flow of traffic on the other hand seems predicted by inhibitory control as well as short term and working memory. The ability to predict the intentions of other road users was found to be predicted by both short term and working memory.

Overall, short term visual memory would appear to be the most important aspect of neuropsychological functioning for pedestrian skill level, being predictive of performance over many of the variables measured in the current study, across all three skills. The ability to hold an item in memory over time (up to 12 seconds as measured here) would therefore appear crucial for pedestrian skill level. The need to do this whilst making a decision about a road crossing is obvious. Children must evaluate the traffic environment in terms of its features and hold this in mind whilst waiting for safe time to cross. Very often this wait is12 seconds or indeed much longer. Working memory appears important in relation to the visual gap timing task, less so in terms of predicting road user intentions, and isn't related to children's ability to navigate a safe route across the road at all. Inhibitory control was overall a much poorer predictor of performance than might have expected, predicting only missed opportunities on the visual gap timing task. Likewise, risk taking on the Cambridge Gambling Task was also a poor predictor and did not predict any performance measure for any skill.

The relative weakness of inhibition and failure of risk taking to predict pedestrian skill level in respect of any of the skills examined in this study is noteworthy given the extent to which accidents in young children are routinely attributed to impulsiveness and risk taking. The findings of the current study demonstrate however, that this does not appear to be the case and rather visual short term memory and spatial working memory are much more predictive of pedestrian skill level.

A study by Stavinros et al., (2011) revealed disinhibition did not predict the poorer pedestrian skill level of children with ADHD which was an unexpected finding. Stavrinos and colleagues suggested it was more likely that other cognitive functions that were giving rise to these results, although this study wasn't able to specify what these might be. The current study suggests that both visual short term memory and working memory are central to pedestrian skill level and appear to be neuropsychological functions that stand out as being particularly predictive of pedestrian skill level across skills. The aspects of cognition that one would have expected to be most important according to a widespread view in the literature such as risk taking (Hoffrage, Webber, Hertwig & Chase, 2003) and to some extent disinhibited, impulsive behaviour (Barton & Schwebel, 2007, Uslu, Uslu, Eksioglu & Ozen, 2007), appear to be manifestly less important.

Future research in this field ought to explore approaches that promote the development of these predictive cognitive functions as a means to enhance children's readiness to interact with the traffic environment safely. The predictive relationship between specific aspects of cognitive function and pedestrian skill level shown through this study suggests a multidimensional approach to the training of young pedestrians may be optimal in terms of improving pedestrian skill level. They also suggest screening all children on cognitive function and providing targeted intervention for those with the poorest functioning may prove to be a fruitful. Training interventions which aim to improve the safety of children's pedestrian behaviour have been previously shown to be very effective (Thomson et al., 1996). Recent studies have also begun to study the merits of training interventions for aspects of executive and neuropsychological function (see Diamond & Lee, 2011 for a discussion). Simultaneous training of pedestrian and cognitive function may therefore be beneficial in improving pedestrian skill level and the merits of this should be explored by future research.

# Chapter 8

## General Discussion of Part A

Part A of this thesis has examined the developmental profiles of three key pedestrian skills across the 5-12 year age range and has examined children's perceived difficulty of each. It has also examined the development of neuropsychological function in respect of four cognitive abilities and the relationship between these functions and children's pedestrian skill level.

The findings of part A of this thesis considerably extend the findings of previous studies examining children's developing pedestrian competence and the cognitive factors which seem to drive this. They show significant age related improvement in the performance of each skill; findings well aligned to those previously reported and which also show differences in how difficult children perceive the performance of these skills to be for the first time. In addition, the final study provides the first detailed account of the links between specific aspects of cognition and the behaviour of children by the roadside in respect of three key pedestrian skills.

### 8.1 Development of Pedestrian Skill Level

Study 1.1 showed significant developmental improvement in the ability to identify safe crossing locations and routes across the road as children grow up. It also revealed a significant improvement in children's conceptual understanding of the task of doing so. These findings align very closely to those of previous studies which have reported similar trends (Ampofo-Boateng & Thomson, 1991, Tabibi & Pfeffer, 2007, Thomson et al., 1996, Thomson et al., 2005, Tolmie et al, 2002).

Similar developmental improvements in the performance of the visual gap timing task were also revealed in study 1.2. That is, children's ability to select safe gaps to cross though, between cars in a flow of traffic, also improves significantly with age. Compared with older children, younger children accept smaller gaps, have higher starting delays and make more tight fits. Young children also much more often underestimated the time that they would need to cross the road compared with older children. These findings also closely resemble those previously reported (Barton & Schwebel, 2007, Schwebel et al., 2008, Demetre et al., 1992, Lee et al., 1984, Thomson et al., 2005).

A similar developmental profile was also revealed in respect of children's ability to accurately predict the intentions of other road users. Similar age related improvement in the number of correct predictions and the number of environmental cues children were able to identify when justifying predictions provide clear evidence that younger children are significantly less able to perform this skill than their older peers. This was the first study to investigate the developmental profile of this skill amongst children in early to mid-childhood and the findings reveal a clear developmental trajectory which extends the literature and exemplifies the difficulties young children have in respect of this social aspect of safe road use for the first time. This highlights the requirement of future research to examine children's readiness to use the road broadly and demonstrates that prospective interventions to take account of the variety of ways young pedestrians may struggle to make safe decisions by the roadside.

The findings of part A of this thesis also add to a small body of research which has highlighted some subtle gender differences in children's visual gap timing ability (e.g. Barton & Schwebel, 2007, Simpson et al., 2003). However, to the writer's knowledge such differences appear confined to the performance of the visual gap timing task and have never previously been reported in respect of other pedestrian skills. This is certainly the case compared to the other skills addressed in part A of this thesis. Study 1.2 revealed girls had higher effective gaps than boys and also made fewer tight fits. Girls on the other hand had lower estimated crossing times than boys. In contrast, no gender differences were revealed in respect of the safe place finding or predicting intentions task. These findings fit well with the literature as the studies which have investigated these other skills previously have not reported gender differences in respect of performance (Ampofo-Boateng & Thomson, 1991, 1993, Tolmie et al., 2005, Foot et al., 2006). It would therefore appear that gender differences are limited to a few specific aspects of children's visual gap timing ability rather than being a broad or characteristic feature of child pedestrian skill level.

### 8.2 Perceived Difficulty

Part A of this thesis also adds considerably to the literature through its consideration of children's perceived difficulty of these skills in early to mid-childhood for the first time. In terms of the perceived difficulty of finding a safe route across the road, it was shown that young children rate the task as being much easier than older children when asked about how difficulty they thought the task had been. As children grow up they would appear to realise the complexity of the task and update their difficulty ratings accordingly. Although older children were able to select many more safe routes than younger children, they rate the task as being *more* difficult in spite of their superior performance. This suggests that with age, comes an understanding of the complexity of the task (which is reflected by growing scores of conceptual understanding). Young children in contrast, perform much less well and yet rate the task as being much easier.

In addition, for younger children, difficulty ratings are not well justified relative to performance. In the case of older children, although they perform relatively well, they rate the task as being much more difficult. This pattern of responding demonstrates perceived difficulty increases with age and that the tendency of younger children to say the task was easy is not justified by their level of performance. The findings relating to the perceived difficulty of the visual gap timing task revealed similar trends. Thus whilst it has been known for some time that parents tend to overestimate their own child's skill level (Dunne, Asher & Rivera, 1992), the findings of this thesis suggest this is also true of young children themselves.

What is interesting is the lack of an age effect in relation to perceived difficulty of the predicting road user intentions task when compared with perceived difficulty of the other skills. A similar finding in respect of the perceived difficulty of this skill amongst adolescents has been reported previously (Tolmie et al., 2002). As discussed in chapter 6, the reasons for this are not entirely clear but are certainly worthy of further investigation.

What is also interesting is that no differences were found in respect of pre-trial difficulty ratings, across skills. That is to say when tasks were explained to children and they were asked to make difficulty estimations before engaging with them, children of all ages responded similarly. The experience of completing the tasks and deploying pedestrian skills appears to impact on how difficult older (but not younger) children rate the task to be when asked afterwards. This demonstrates an important effect of experience for older children. Younger children appear not to benefit from experience in the same manner. It would appear therefore that guided reflection on difficulty; perhaps with support from a more knowledgeable other (appreciative of the complexity of the task) could be an effective approach to addressing this issue. Interventions may wish to capitalise on the realisation of task difficulty amongst older children and make use of peer learning as an approach to addressing the tendency of younger children to underestimate the complexity of the task and its difficulty relative to their own performance.

**8.3 Cognitive Functioning and Pedestrian Skill Level**

The final study in part A of this thesis makes perhaps the most significant contribution to the field. The findings of this study revealed age related improvement in respect of three tasks assessing neuropsychological functions and showed that aspects of neuropsychological function appear to predict specific aspects of the safety of pedestrians' behaviour.

Children's ability to identify a safe place to cross the road and cross via a safe route was predicted by short term visual memory whereby superior short term visual memory allowed children to identify a higher proportion of safe routes. Performance on the visual gap timing task was predicted by spatial working memory and short term visual memory which predicted a range of performance measures showing superior working memory allowed children to cross through larger (and safer) gaps, have shorter starting delays and make fewer tight fits. Inhibitory control was also predictive of gap timing ability but to a lesser extent, predicting only the number opportunities children missed to cross between cars when it was safe to do so. In addition, short term visual memory and spatial working memory also predicted children's ability to predict the intentions of other road users.

Therefore, short term visual memory and spatial working memory appear intrinsically linked with a wide range of measures of pedestrian skill level, across a number of distinct skills. Inhibitory control was also a predictor though was comparatively less predictive than spatial working memory and delayed short term visual memory because inhibition was only related to performance on the visual gap timing task. These findings provide clear insights into the neuropsychological functions which predict children's readiness to interact with the traffic environment and pave the way for future interventions and future research which should take account of the importance of the cognitive factors which appear to underpin children's pedestrian skill level and begin to take seriously importance of examining these functions independently.

## 8.4 Conclusion

The studies reported in the first part of this thesis significantly extend our understanding of the development of children's pedestrian skill level and have shown specific and predictive relationships between aspects of neuropsychological function and children's readiness to interact with the traffic environment safely.

These relationships demonstrate the importance of studying the contribution of separable aspects of cognitive function in relation to pedestrian skill development. They also show those children who perform better on neuropsychological assessments behave more safely in respect of three key pedestrian skills. This gives rise to the question as to whether intervention aiming to improve aspects of neuropsychological function would lead to gains in children's pedestrian skill level.

This is important because the ultimate aim of all research in this field is to improve the safety of children's interaction with the traffic environment and in turn improve accident outcomes for young pedestrians. Moreover, the findings of the current study are timely given the recent and dramatic increase in the number of studies investigating the merits of training which aims to improve cognitive functions (e.g. Holmes, Gathercole & Dunning, 2009, Rueda, Rothbart, McCandliss, Saccomanno & Posner, 2005, Thorell, Lindqvist, Bergman-Nutley & Klingberg, 2009).

Whilst it has been known for some time that practical pedestrian training is effective in improving pedestrian skill level amongst children as young as 5 (Ampofo-Boateng

& Thomson, 1993, Tolmie et al., 2005, Thomson et al., 2005), what is not clear is whether simultaneous cognitive training would be even more effective. What is interesting is that the most researched approach to such cognitive training, which has repeatedly been found to be successful (Diamond & Lee, 2011), is one which targets working memory (Holmes et al., 2009). This is interesting in light of the fact working memory and short term visual memory is predictive across pedestrian skills. Although researchers have had some difficulty in showing these effects transfer to other tasks, some studies have showed they can (Holmes et al., 2009). Future research should investigate the merits of cognitive training and a joint cognitive and pedestrian training approach in terms of their impact upon children's pedestrian skill level.

Future research should aim to extend as well as apply these findings, perhaps by examining a broader range of cognitive functions than have been included in the studies in this programme of research. It is plausible that other functions too will be important. For example, it might be reasonably be expected that planning and attention switching may also be linked with children's pedestrian skill level given the need to think ahead to anticipate changes in the traffic environment and switch attention from 'right, to left and then right again' when preparing to make a road crossing.

Given the seeming importance neuropsychological functioning for children's pedestrian safety revealed in part A of this thesis, an additional and obvious next step would be to examine pedestrian skill level amongst specialist groups of children, particularly groups associated with cognitive impairment, such as those with ADHD, as will now be explored in part B.

# Chapter 9

## Introduction to Part B

Part A of this thesis examined the developmental profile of three key pedestrian skills across the 5-12 year age range and revealed clear developmental differences in the performance of these skills across childhood. Part A also examined the cognitive underpinnings of these skills and revealed clear relationships between aspects of neuropsychological functioning and children's pedestrian skill level. Part B of this thesis follows a similar format but extends part A through an examination of the abilities of children with ADHD compared with case matched control children.

As outlined in chapter 1, very few studies have studied pedestrian skill level amongst children with ADHD and fewer still have considered the relationship between pedestrian skill level and cognitive function, or indeed cognitive impairment; a characteristic of children with ADHD (Rhodes et al, 2004; Willcutt et al., 2005). This is in spite of the greater vulnerability of this group to child pedestrian injury (Transport Scotland, 2010b, UK Child Road Safety Strategy, 2007). One previous study has considered performance on a visual gap timing task amongst children with ADHD (Clancy et al., 2006) with one further study investigating the extent to which difficulties with EF predicts visual gap timing performance with an ADHD population (Stavrinos et al., 2011). These studies report significant differences in visual gap timing ability between children with and without ADHD whereby those with ADHD perform less well than typically developing children on a range of performance measures for this task. Yet little is known about which aspects of EF are predictive of pedestrian decision making and behaviour and the development of other pedestrian skills amongst children with ADHD is also unknown.

**9.1 Studies 2.1 to 2.3**

Part B will first examine differences in skill levels of children with ADHD compared with controls in respect of the same three pedestrian skills addressed in part A: i) safe place finding (chapter 11), ii) visual gap timing (chapter 12) and iii) predicting road user intentions tasks (chapter 13).

**9.2 Study 2.4**

Chapter 14 will then investigate the development of three neuropsychological functions assessed using the CANTAB's inhibition, spatial working memory and delayed short term visual memory tasks. The relationships between these functions and pedestrian skill level in respect of each of the above skills will also be examined, comparing the results of children with ADHD to those of a case matched control group.

**9.3 Study 3**

The final study reported in part B of this thesis (in chapter 15) considers developmental change in respect of performance on all of these tasks and the relations between them over the course of approximately one year. At follow up, all 31 of the children with ADHD who took part in the follow up were being treated with stimulant medication. The impact of medication on the performance of children in the ADHD group on the same tasks is therefore also considered in chapter 15.

## 9.4 Research Questions for Part B

Following the literature reviewed in chapter 1, the following research questions have been formulated for part B of this thesis:

1. What is the developmental trajectory for the ability to navigate safe crossing routes in children with ADHD and what differences are there compared to controls?

2. What is the developmental trajectory for the ability to identify gaps between cars which are safe to cross through in children ADHD compared to controls?

3. How does the ability to predict the future actions of road users develop over childhood in children with ADHD and are there differences compared to controls?

4. Does perceived difficulty of these tasks vary between children with and without ADHD?

5. What are the developmental trajectories for inhibition, working memory and delayed short term visual memory in children with ADHD and what differences are there when compared with controls?

6. To what extent do neuropsychological functions predict pedestrian performance of children with ADHD and are there differences compared with

controls?

7. How does pedestrian behaviour and neuropsychological functioning develop over time and what are the differences in development when comparing children with ADHD who have been treated with stimulant medication to controls?

# Chapter 10

## Part B General Method

### 10.1 Introduction

The studies reported in the second part of this thesis involved a number of separate tasks which were similar but assessed separable aspects of cognitive function and pedestrian skill level and the relationship between these factors amongst children with ADHD. The research design was longitudinal and took place across 2 time points approximately 14 months apart. For children in the ADHD group, the first time point allowed for an assessment of task performance shortly after receiving their ADHD diagnosis (while all children were stimulant naïve). The second, follow-up assessment which took place approximately 14 months later allowed for an assessment of performance following the participant's engagement with their clinical care package. For the vast majority of children with ADHD who returned to take part at follow up, this involved pharmacological intervention in the form of the stimulant drugs methylphenidate hydrochloride, dexamphetamine and atomoxetine. The same matched control children were also tested at both time points. This chapter will provide information about the recruitment of participants and provide details of the methodology and experimental procedure common to each of the tasks reported in the subsequent experiments.

### 10.2 Design

The programme of research reported in Part B of this thesis was conducted across 2 time points and involved two groups of children (ADHD vs. Controls). The studies are of a mixed design. Participant group (ADHD or control) and age served as between groups factors and time point (baseline vs. follow up) was a repeated measure. Data was collected through testing sessions lasting around 2 hours in total (when taking account of the consent process). All participants completed the same tasks.

The data collected at time one are reported in chapters 11-14. Participants were also invited to complete the same tasks in a follow up testing session approximately 14 months later. These findings are reported in study 3, in chapter 15.

In each testing session (baseline & follow up), participants completed 3 computer tasks from the Crossroads pedestrian software assessing the same three pedestrian skills addressed in part A of this thesis. Between group differences in respect of the Crossroads tasks are reported in chapters 11, 12 and 13. Participants also completed three subtests of the CANTAB to assess neuropsychological function. Between group differences in performance on these tasks, as well as the relationship between CANTAB task performance and pedestrian skill level are reported in chapter 14. The final empirical chapter (chapter 15) reports the follow up data.

### 10.3 Participants

Following National Health Service (NHS) ethical review and approval, participants who took part in the experiments in Part B of this thesis were recruited from two NHS Health Boards and two Scottish mainstream LEA primary schools. All participants were between the ages of 5 and 12 years old.

### 10.3.1 Baseline

A total of 122 children took part at time 1. This sample comprised 61 children with ADHD and 61 matched controls. The mean age in months at baseline is presented in Table 10.1 as a function of participant group and age group.

Table 10.1: Mean age in months (& S.D.) of Baseline Participant Age Groups for Part B

| | ADHD Group | Control Group |
|---|---|---|
| 6 Years and Under (N=15 ADHD & 15 Controls) | 76.20 (5.81) | 70.77 (4.89) |
| 7-8 Year Olds (N=30 ADHD & 30 Controls) | 93.71 (7.20) | 94.27 (6.66) |
| 9 Years and Over (N=16 ADHD & 16 Controls) | 123.47 (17.24) | 118.22 (10.10) |
| Overall (N=61 ADHD & 61 Controls) | 97.79 (10.08) | 94.42 (7.22) |

As well as being matched on age and gender, participants were matched on general verbal ability based on percentile rankings of the BPVS, data from which are presented as a function of participant group in Table 10.2 below.

Table 10.2: Percentile Rankings on the BPVS as a function of Participant Group at baseline

| | Mean (&S.D.) | Range | Minimum | Maximum |
|---|---|---|---|---|
| ADHD Group | 24.29 (19.29) | 85.00 | 2.00 | 87.00 |
| Control Group | 33.72 (23.19) | 94.00 | 2.00 | 96.00 |

Percentile rankings on the BPVS were significantly different as a function of participant group ($F[1,121]=6.43$, $p=.013$) with those in the control group having significantly higher BPVS percentile rankings than those in the ADHD group. BPVS percentile ranking was thus included as a covariate in the analyses reported herein.

Children were assigned to the ADHD group following assessment by an experienced child and adolescent psychiatrist using the ADHD section of the Kiddie-SADS Present and Lifetime (K-SADS-PL) version 1.0 (Kaufman et al., 1996). This semi-structured interview is used to assess current and past symptomology of psychopathology in children and adolescents via discussion with both children themselves and their parents/guardians. Following assessment by an NHS psychiatrist, all children in the ADHD group received a diagnosis of ADHD as defined by the DSM-V (APA, 2013) just prior to baseline testing. Full details of the diagnostic criteria are detailed in appendix 1.

As ADHD is highly comorbid with a range of other developmental disorders (see Rhodes [2014] for a discussion), participants who had received comorbid diagnoses were not excluded from participation. This ensures a representative sample of children with ADHD was recruited. Children between the ages of 5 and 12 years old who met inclusion criteria (had received a diagnosis of ADHD but had not been previously treated with stimulant medication) were invited to participate. Of the 61 medication naïve children with ADHD who took part in the current study, 4 also had a diagnosis of Autism Spectrum Disorder (ASD), 1 had a comorbid diagnosis of Tourette 's Syndrome and 5 had comorbid Oppositional Defiant Disorder (ODD). In addition, 7 had Generalised Anxiety Disorder (GAD), 9 had Developmental Coordination Disorder (DCD), 4 had dyslexia and 1 had Obsessive Compulsive Disorder (OCD). One participant had epilepsy and one had a Foetal Alcohol Spectrum Disorder (FASD). Data collected from the participants with epilepsy and FASD were excluded from all experimental analyses because these disorders are associated with cognitive impairment in respect of the cognitive functions under examination in this thesis (Parrish, Jones, Seth, Hermann & Seidenber, 2007, Slick, Lautzenhiser, Sherman & Eyrl, 2006, Green, Mihic, Nikkel, Stade, Rasmussen, Munoz & Reynolds, 2009).

At baseline, 5 children in the ADHD group had been diagnosed with ADHD-I (inattentive subtype), 7 were diagnosed with ADHD-H (hyperactive-impulsive subtype) and 49 had received a diagnosis of ADHD-C (combined subtype). The mean number of inattentive symptoms was 7 whilst the mean number of hyperactivity symptoms and impulsivity symptoms were 5 and 3 respectively. 48 of the 61 children in the ADHD group also met criteria for the ICD-10 (WHO, 1992) diagnosis of Hyperkinetic Disorder. Preliminary analyses using MANOVA with age group as the between subjects factor and symptom counts as the dependent variables revealed there were no significant differences in the total number of symptoms as a function of age group ($F[2,58]=0.57$, $p=.570$). Nor were there differences when inattentive ($F[2,58]=0.52$, $p=.598$), hyperactive ($F[2,58]=0.53$, $p=.591$) and impulsive ($F[2,58]=0.06$, $p=.938$) symptoms were examined separately. There was consequently no need to include symptom count as a covariate in the subsequent analyses including age.

Typically developing children were assigned to the control group on the basis of scoring within the typical range on a teacher completed Strengths and Difficulties Questionnaire (Goodman, 2001).

### 10.3.2 Follow up

All of the children with ADHD who took part at baseline were invited to take part in the follow up study. 35 children with ADHD (& 35 matched controls) returned to take part in a second testing session. All those who took part at baseline, who were still contactable, were invited to follow up testing. Some participants were uncontactable as they had moved out of the area or had changed telephone number and home address. Others failed to attend multiple follow up appointments resulting in a 57.37% retention of the baseline sample at time 2. All but 4 of the children in the ADHD group who consented to participate in the follow up study reported here had been titrated onto stimulant medication as part of their treatment plan. The data of those 4 children who had consented to participant but had not been treated with medication were excluded from all analyses (as were their case matches in the control group), as this small number would not allow for statistical comparisons to be drawn.

This resulted in a working sample size of 62 participants for the follow up study (31 children with ADHD and 31 matched controls). Age differences were not of interest at follow up as these have already been reported in the previous chapters. At time 2, the mean age of the ADHD group was 107.55 months (SD=18.50) and the mean age of the control group was 108.78 months (SD =18.48). These participants also took part in the studies reported in studies 2.1 to 2.4 and were retested at a mean follow up time of 13.4 months[1]. This reflects a 56.45% retention rate at follow up. Children with ADHD were matched on chronological age and gender at time 1 and the same matches were retained at time 2. There were 23 males and 8 females in each participant group. Age characteristics of the participant groups are presented in Table 10.3 below.

Table 10.3: Mean age in months (& S.D.) at Baseline and Follow-up as a function of Participant Group

| | Time 1 | Time 2 |
|---|---|---|
| ADHD Group | 93.54 (17.68) | 107.55 (18.50) |
| Control Group | 94.38 (17.68) | 108.78 (18.48) |

Participants with ADHD were matched to controls on general verbal ability based on BPVS percentile rankings at baseline. The same individual participant matches were used again at follow up. BPVS percentile rankings as a function of participant group for those who returned to take part in the follow up study are presented in Table 10.4 below.

[1] The aim was to retest children at 12 months (1 year). The slightly longer follow up time was a function of participants failing to attend initial follow up appointments which were booked exactly 12 months later (within a two week window).

Table 10.4: Percentile Rankings on the BPVS as a function of Participant Group for Follow-up Participants

| | Mean (& S.D.) | Range | Minimum | Maximum |
|---|---|---|---|---|
| ADHD Group | 25.10 (16.79) | 53.00 | 2.00 | 55.00 |
| Control Group | 32.35 (17.70) | 94.00 | 2.00 | 96.00 |

Amongst the subset of children with ADHD who took part at follow up, 3 had a comorbid diagnosis of ASD, 1 also had Tourette's Syndrome, 4 had ODD, 5 had GAD, 6 had DCD, 2 had dyslexia and 1 had comorbid OCD. Two participants in the follow up ADHD group had a diagnosis of the inattentive subtype of ADHD, 3 had been diagnosed with the Hyperactive/Impulsive subtype and 26 had the combined subtype of ADHD. At time 2, the mean number of inattentive symptoms was 8 whilst the mean number of hyperactivity symptoms and impulsivity symptoms were 4 and 3 respectively. 25 children in the follow up ADHD group met criteria for the ICD-10 diagnosis of Hyperkinetic Disorder at time 2.

The mean time children with ADHD had been prescribed their current medication and dose (unchanged) prior to follow up testing at time 2 was 7.7 months (SD=4.19). 20 of the 31 children were receiving immediate release methylphenidate (MPH-IR), 8 were receiving modified (slow) release MPH (MPH-MR) and 3 were receiving the alternative stimulant dexamphetamine (DEX). The mean mg per day (mg/day) dose for those on MPH-IR at retest was 40mg/day (SD=16.22). Those on MPH-MR were receiving a mean dose of 38mg/day (SD=15.23). The mean dose for the 3 children on DEX was 22.5mg/day (SD=12.99). These data are summarised in Table 10.5 below.

Table 10.5: Summary of Treatment Characteristics of the ADHD Group at Follow up

| Medication | Number of Participants | Mean (&SD) milligrams per day | Rage milligrams per day | Mean (& SD) months on current prescription | Range months on current prescription |
|---|---|---|---|---|---|
| Immediate Release Methylphenidate | 20 | 40.00 (16.22) | 50.00 | 8.15 (4.31) | 12.00 |
| Modified Release Methylphenidate | 8 | 38.00 (15.32) | 52.00 | 7.00 (4.84) | 13.00 |
| Dexamphetamine | 3 | 22.50 (12.99) | 22.50 | 6.67 (0.58) | 1.00 |
| Overall | 31 | 33.50 (14.84) | 41.50 | 7.27 (4.19) | 8.67 |

MPH has a behavioural half-life of 3 hours with a curvilinear time course (Phelham, Swanson, Furman & Schwindt, 1995). The half-life of DEX is much longer, varying between 8 and 22 hours (Winsberg, Press, Biale & Kupietz, 1974). Peak effects of MPH-IR are obtained approximately 2 hours after ingestion and tend to begin to dissipate 2 to 3 hours after this peak (Pelham et al., 1987, Solanto & Conners, 1982, Swanson et al., 1978). Pharmacokinetic studies of children suggest peak effects of MPH-MR will be 1.5 hours, followed by a second similar peak at 4.5 hours (see Grenhill et al., 2002). The children with ADHD in the current study were tested a mean time of 2.5 hours (S.D.=1.65) following ingestion of their most recent dose of medication suggesting the effects of medication would have been observable at time of testing.

To examine how representative those who took part at time two were of the overall sample of participants that took part at time 1 in terms of task performance, differences in task performance at time 1 were examined between those participants who returned to take part in the follow up study and those who did not. A MANOVA with follow up status (took part vs. did not) and participant group (ADHD vs. control) as the independent variables and all of the primary outcome measures from the CANTAB tasks and Crossroads tasks (upon which subsequent analyses in this study are based) as dependent variables was used for this purpose. This analysis revealed that there were no significant differences in responding at time 1 between those who did and did not return to take part at time 2 in respect of performance on any of the CANTAB or Crossroads tasks. In addition, there was no significant difference between the baseline group and follow up group of participants in respect of the overall age in months of the samples or in relation to gender. There were no differences between the baseline and follow up samples in terms of the number of inattentive, hyperactive or impulsivity symptoms. The follow up sample can therefore be said to be representative of the larger sample at time 1.

## 10.4 Materials

### 10.4.1 Participant Matching/Screening Materials

Whilst children with ADHD were case matched to typically developing control children on chronological age (within 3 months) and gender, the SDQ (Goodman, 2001) was used to screen control group children for atypical behaviours and the

BPVS was used as a measure of intellectual ability in order to control for this when examining differences between participant groups. These measures were collected at baseline used to match participants at time 1. The same matches were made at time 2.

The SDQ (Goodman, 2001) was used as a screening measure in the studies reported in part B of this thesis to ensure the typicality of the control group. The SDQ is a brief (25 item) questionnaire which assesses 5 indices of functioning including hyperactivity/inattention. Whist not a diagnostic measure, it is likely to pick up ADHD symptomology and has been used widely to screen children recruited into control groups to ensure control groups do not include children with a mental or behavioural disorder (e.g. Rhodes, Riby, Park, Fraser & Campbell, 2010; Riby, Hancock, Jones & Hanley, 2013). Teachers of children in the control group completed this measure. Only children who scored within the typical range on this measure were considered as potential matches and subsequently recruited into the control group. None of the controls scored outside the typical range. Because the SDQ was used for screening of the control group alone, no SDQ data were collected in respect of children in the ADHD group.

The British Picture Vocabulary Scale (BPVS) [3rd Edition] first developed by Dunn et al., (1997) was used as a measure of intellectual ability for participants on which children with ADHD and controls were matched. The BPVS-III has been widely used as a measure of verbal intelligence and is a quick but reliable measure designed for use with children aged 3 – 15 years (Dunn et al., 1997). It measures receptive vocabulary which has long since been described as being highly predictive of educational attainment (Dale & Reichart, 1957) and is also a significant predictor of performance on full scale tests of intelligence (Elliott, 1990). The BPVS has been used widely to match specialist groups including those with ADHD to controls (Glenn & Cunningham, 2005; Rhodes et al., 2005, 2010) and was used over a traditional full scale IQ (FSIQ) tests to avoid confounds with the aspects of cognitive function under investigation in the current study. Aspects of EF are implicated in the completion of FSIQ tests such as Raven's Coloured Progressive Matrices (Raven, 1958) that require the mental manipulation of stimuli, which is also considered an assessment of EF (Kazui, et al., 2006).

The BPVS contains 4 training plates which allow children to become familiar with the task's procedure which precede 14 sets of 12 plates (pages). Sets increase in difficulty. Each plate contains 4 colour pictures. Children are asked to select which of the 4 pictures contained on a plate best represents the meaning of a word read aloud by the test administrator. The starting plate is determined by the child's chronological age. The test is terminated when participants make 8 or more errors in the same set. The final plate from which children correctly identify an item is converted into a standardised score. Standardised scores correspond to an age-equivalent age range produced from normative data from which percentile rankings can be generated. Three children (all typically developing) were excluded from participating in the studies reported in Part B of this thesis because they failed or refused to complete the BPVS. Though given the opportunity, these participants decided they would not proceed to attempt the CANTAB and Crossroads tasks. Incomplete data from these participants was destroyed.

The same experimental materials were used for data collection time 1 and time 2. It was considered important to keep the length of testing sessions to a reasonable duration in Part B of this thesis given the target population of participants were children with ADHD. The symptoms of ADHD are such that very long testing sessions would be difficulty for children with ADHD to complete and could impact negatively on retention rates and the willingness of participants to take part in follow up studies (Hart, Rennieson & Gibson, 2005). The Cambridge Gambling Task was the longest task by duration which was included in part A of this thesis which took around 30 minutes to complete. Performance on this task did not vary significantly as a function of age in study 1.4 and was not a good predictor of pedestrian skill level (see chapter 7). These factors informed the decision to remove the Cambridge Gambling Task from the testing battery for the studies reported in part B. The table top model to assess safe place finding ability was also dropped, given the concordance in responding on both the table top model and Crossroads task reported in study 1.1 (chapter 3). All other tasks described in part A of this thesis were administered in the studies reported in part B in the same manner described in chapter 3. The sequence of task presentation was once more randomised as also described in chapter 3.

#### 10.4.2 Crossroads Pedestrian Software

The Crossroads pedestrian assessment software was selected for use in Part B of this thesis because of its ability to allow for controlled and constant testing conditions which would be impossible by the roadside as described in chapter 2. The inclusion of children with ADHD in the forthcoming studies also made the use of Crossroads assessment software particularly appropriate. Indeed, it provided an ethical and safer alternative than testing children with ADHD by the roadside. As previously discussed in this thesis, previous studies have shown performance on the Crossroads software to correspond closely to children's performance on the road (Chinn et al., 2004; Foot et al., 2006; Thomson et al., 2005).

The same three tasks from the Crossroads software as were included in the studies in part A of this thesis were selected for use in the studies reported in Part B. The Safe Place Finding, Visual Gap Timing and Predicting Road User Intentions tasks were administered to all participants in the same manner as has been previously outlined. These tasks have been described in full in Part A of this thesis (see chapter 3 for full descriptions). The same coding and scoring procedures were employed in Part B as were in part A.

#### 10.4.3 Cambridge Neuropsychological Automated Testing Battery (CANTAB)

The CANTAB was selected for use in the studies reported in Part B of this thesis once more because of its standardised administration and computerised collection and coding of data which allows for strict control of data collection between participants (Green et al., 2009). It is also a particularly popular tool for assessing neuropsychological function in the ADHD population and a wide range of studies provide normative data in relation to both typically developing control children and children with ADHD (e.g. Hughes, Russell & Robbins, 1994; Luciana & Nelson, 1998; 2000, 2002; Rhodes et al., 2004, 2005, 2006, 2012; Shur-Fen Gau & Shang, 2010).

Three subtests of the CANTAB were completed by participants. These were the Stop Signal Task (SST) assessing inhibitory control, the Spatial Working Memory Task (SWM) and the Simultaneous and Delayed Match to Sample Task (DMtS) assessing delayed short term visual memory. Full descriptions of these tasks are also provided in the general method for part A (chapter 3). These tasks were selected based on the findings reported in chapter 7 of this thesis which showed the cognitive functions these tasks assess are related to pedestrian skill level amongst typically developing children.

**10.5 Procedure**

All experimental methods and procedures were the same for testing at time 1 and time 2. Participants completed a separate consent process a second time at follow up.

Following university ethical review and sponsorship, the programme of research reported in Part B of this thesis was reviewed and approved by a panel of NHS ethics officers via a Health Board in central Scotland (see appendix 4). The project then underwent further review by business support officers from the Research and Development (R&D) department of the same health board. Following R&D approval (see appendix 5), the researcher applied for, and was granted, honorary contracts with two NHS health boards and was required to undertake NHS clinical research training prior to testing. The study was then registered with the NHS National Research Ethics Service (NRS) as required for research being undertaken across more than one NHS health board/trust when the study was expanded to and approved by a second NHS Health Board also in central Scotland (see appendix 6).

#### 10.5.1 ADHD Group

Participants and their parents were informed about the study by their NHS clinical care team (typically their Consultant Child and Adolescent Psychiatrist) or the study investigator himself during regular clinic visits. They were provided with written information (in both parent and child format) about the study during this initial face to face meeting (see appendices 7 & 8 respectively) and asked for permission to be contacted by phone or by letter after a gap of at least three days to ask whether they wish to participate.

The parents/guardians of participants were then contacted by telephone and invited to attend a research appointment at their regular paediatric or Child and Adolescent Mental Health Service (CAMHS) outpatient department. Appointment reminder letters were sent to each participant following confirmation of appointment details which detailed the purpose, date, time and location of the appointment. An appointment reminder text message was also sent the day before testing which simply contained a reminder of the date, time and appointment location.

On arrival at the clinic, participants were invited to one of the regular clinic rooms which contained a soft seating area for completion of the consent process and a desk for testing.  Parents/guardians and children were invited to ask any questions they wished to.  In accordance with the Scottish Children's Research Network operating procedures for clinical research with children (SCRN, 2012), participants were then invited to sign a consent (in the case of parents/guardians) and written (rather than verbal) assent was sought from children to confirm their willingness to take part (see Appendix 9 and 10 respectively).

### 10.5.2 Control Group

Case matched control children were recruited from mainstream LEA primary schools in Scotland.  The LEA was first contacted in writing to request permission to undertake research in primary schools within its geographic area.  Following approval from the relevant education manager, head teachers were approached to request permission to invite the families of children in their school to participate. Information sheets were distributed and consent forms were collated via school offices (see appendices 11 and 12).

All children in the control group were tested at school.  Those children whose parents retuned a signed consent form were invited to a quiet area of their school, usually an empty classroom or library where testing took place.  The purpose of the study and the procedure was explained to children and they were asked if they wished to take part.  It was explained despite their parent/guardian consenting to their participation it was up to them to decide if they wished to.  Only those children who verbally assented on the day of testing proceeded to take part.

For both the ADHD and control groups, tasks were explained to children in full and in the same way described in chapter 3.  Children again, completed practice trials for each task (data from which no data were collected) before testing began.  Children were allowed to ask any questions they wished to before testing began.  The presentation of tasks was randomised in the same manner as reported in Part A of this thesis.

# Chapter 11

## Study 2.1: Safe Place Finding Ability in Children with ADHD

### 11.1 Introduction

The skill of finding a safe crossing location and route across the road has been described as one of the most important for safe interaction with the traffic environment (Tabibi & Pfeffer, 2007) and is one which requires pedestrians to alter crossing routes to take account of hazards which would otherwise place them in danger (Tolmie et al., 2002). Study 1.1 of this thesis which examined the development of typically children's ability to distinguish safe from dangerous crossing routes revealed significant age related improvement across the 5 to 12-year age range. Young children selected significantly more unsafe crossing routes compared with older children. Younger children were also shown to have significantly poorer conceptual understanding of the task compared with their older peers. These findings are well aligned with those reported by previous studies investigating this skill which has shown similar age related improvement in the performance of this skill in the typically developing population of children (Ampofo-Boateng & Thomson, 1991, Thomson et al., 1993).

Very little however is known about the development of this skill amongst children with ADHD, who have been previously reported as being disproportionately vulnerable to pedestrian injury by both government (UK Child Road Safety Strategy, 2007, Transport Scotland, 2010b) and empirical studies alike (Clancy et al., 2006, DiScala, Lescohier, Barthel & Li, 1998, Stavrinos et al., 2011). Yet, past empirical investigation of pedestrian skill level amongst children with ADHD has focused exclusively on visual gap timing ability and the ability of children with ADHD to select safe crossing routes has been all but ignored. The abilities of children with ADHD in respect of this key pedestrian skill are therefore unknown, in spite of this skill being one of the most important for safe road use (Tabibi & Pfeffer, 2007). This is surprising given the studies which have examined pedestrian behaviour in children with ADHD (in terms of gap timing ability as described in chapter 1), demonstrate that children with ADHD perform less well than typically developing children of the same age.

The findings of study 1.1 of this thesis also revealed a relationship between perceived difficulty of the safe place finding task and behavioural performance. Although no previous studies have considered the perceived difficulty of any pedestrian skill amongst children with ADHD, the findings reported in study 1.1 demonstrate a tendency of younger children to underestimate the difficulty of the safe place finding task when asked about this after having completed crossings. Compared with older children, younger children rated the task as being less difficult at post-test than older children, in spite of a much poorer actual performance. If children with ADHD perform less well than their typically developing peers on the safe place finding task (as past research has shown they do in respect of visual timing [Stavrinos et al., 2011]) then they too, like younger children, may underestimate the difficulty of the safe place finding task relative to both older children and their own performance. Past research has shown, despite children with ADHD regularly receiving negative attention from teachers and peers (Johnston, Phelham & Murphy, 1985), rather than develop a low sense of ability at school, children with ADHD paradoxically expect to perform better than typically developing children in spite of their performance being no better or indeed worse (O'Neil & Douglas, 1991). Ohan and Johnston (2002) argue this tendency of children with ADHD to overestimate their own performance serves a self-protective function. These findings suggest it might be reasonably expected that children with ADHD will also overestimate their performance in the context of their performance as a pedestrian.

Consequently, the current study aims to investigate potential differences in safe place finding ability amongst children with and without ADHD whilst also taking account of the perceived difficulty of the task.

It is hypothesised;

1. There will be significant differences in the ability of children with and without ADHD to select safe crossing locations and routes across the road, with children with ADHD selecting significantly fewer safe crossing routes compared with typically developing children in the control group.

2. There will be corresponding differences in the conceptual understanding of the safe place finding task between children with and without ADHD, whereby children with ADHD will have significantly lower conceptual understanding of the task compared with children in the typically developing control group.

3. There will be an interaction between participant group (ADHD vs. control) and age group whereby differences in performance between those with and

without ADHD will be less pronounced among younger children (study 1.1 showed even typical children perform poorly at this age) but with age, typically developing older children will outperform children with ADHD.

4. There will be significant differences in the perceived difficulty of the safe place finding task between children with and without ADHD, with those in the ADHD group rating the task as being significantly less difficult than those in the control group.

## 11.2 Method

### 11.2.1 Participants

122 children took part in this study (61 medication naïve children with ADHD and 61 case matched control children). 98 were male and 24 were female. The mean age of the ADHD group was 97.79 months (SD=10.08). The mean age of the control group was 94.42 months (SD=7.22). Children were matched on chronological age and gender. Percentile rankings from the 3rd edition of the British Picture Vocabulary Scale; BPVS III were significantly different between groups and so this was included as a covariate in all analyses. Children were also assigned to one of three age groups: 6 years and under (15 with ADHD & 15 controls), 7-8 year olds (30 with ADHD & 30 controls) and 9 years and over (16 with ADHD & 16 controls). More information about the sample and characteristics of the age groups are provided in chapter 10.

### 11.2.2 Design

The current study is of between groups design. Participant group (ADHD or control) and age group served as between subject factors. All participants completed the same tasks.

### 11.2.3 Materials and Procedure

The procedure followed that described in chapter 4. The safe place finding task was selected from the Crossroads child pedestrian skills battery (Thomson et al., 1996), and testing was completed using a standard laptop computer. The researcher explained the task's operation verbally before testing begun. As before, participants also completed a practice trial and were given the opportunity to ask questions before beginning testing to ensure they were familiar with the operation of the software. Crossing routes were recorded using the Crossroads software and justifications, which formed conceptual understanding scores, were recorded by the researcher by hand. Data were coded using the same procedure outlined in chapter 3. Difficulty estimations were made before and after trials using the inbuilt sliding bar ranging from very easy (score of 0) to very hard (score of 100). Full details about the task and its administration have already been detailed in the general methods sections (chapters 2 & 10) and in study 1.1 (chapter 3).

## 11.3 Results

### 11.3.1 Behavioural Response

The mean proportions of each of the 4 behavioural response categories, which ranged from A (very unsafe) to D (very safe), were calculated as a function of participant group and age group. The data in Table 11.1 below show children with ADHD performed less well than controls overall (scoring more As & Bs than Cs & Ds) and that performance of both groups appears to improve with age.

Table 11.1: Mean (&S.D.) Proportion* of Response Category by Participant Group and Age Group

| | ADHD Group | | | | Control Group | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | A | B | C | D |
| 6 years and under | 0.44 (0.25) | 0.43 (0.16) | 0.13 (0.15) | 0.01 (0.03) | 0.40 (0.25) | 0.43 (0.20) | 0.16 (0.18) | 0.02 (0.04) |
| 7-8 year olds | 0.23 (0.19) | 0.61 (0.20) | 0.15 (0.18) | 0.01 (0.05) | 0.08 (0.11) | 0.44 (0.19) | 0.41 (0.15) | 0.08 (0.12) |
| 9 years and over | 0.15 (0.24) | 0.57 (0.25) | 0.28 (0.21) | 0.00 (0.00) | 0.05 (0.12) | 0.40 (0.25) | 0.44 (0.24) | 0.13 (0.14) |
| Overall | 0.26 (0.24) | 0.56 (0.22) | 0.17 (0.19) | 0.01 (0.03) | 0.16 (0.22) | 0.42 (0.21) | 0.35 (0.22) | 0.08 (0.12) |

*Any disparity in proportions is a function of rounding.

As in chapter 4 these data were next coded into two categories (safe & unsafe). Whist progression from a route coded as A (very unsafe) to B (very safe) reflects some improvement, minor shifts of this nature are not of interest because they do not reflect significant changes in the safety of children’s behaviour. As discussed in chapter 4, this approach to coding performance on this task has been used widely by studies previously investigating this skill. The mean proportion of safe routes (out of 8 trials) was computed by summing the proportion of routes coded as C or D. The proportion of unsafe routes was calculated by summing the proportion of routes coded as A or B. These data are presented in Table 11.2 below. Because the mean proportion of safe routes is the inverse of the mean proportion of unsafe routes, results herein will relate only to the proportion of safe responses.

Table 11.2: Mean (&S.D.) Proportion* of Safe and Unsafe Responses by Participant Group and Age Group

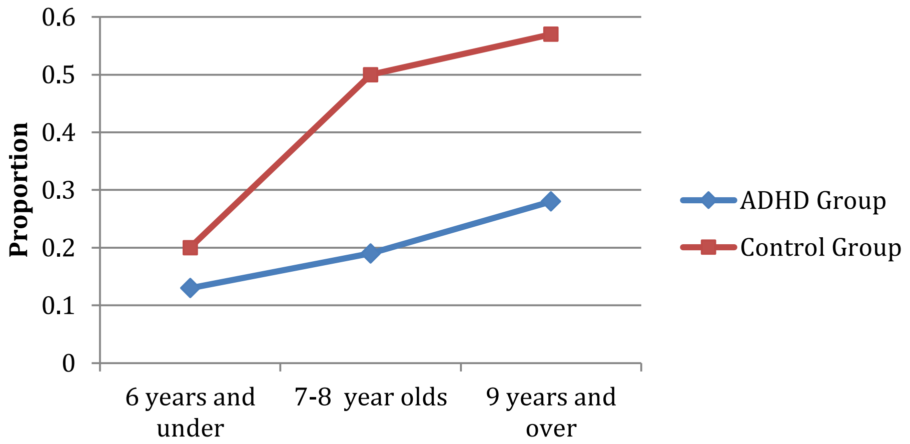
| | ADHD Group | | Control Group | |
|---|---|---|---|---|
| | Unsafe | Safe | Unsafe | Safe |
| 6 years and under | 0.88 (0.16) | 0.13 (0.16) | 0.82 (0.18) | 0.20 (0.18) |
| 7-8 year olds | 0.84 (0.19) | 0.19 (0.19) | 0.53 (0.23) | 0.50 (0.23) |
| 9 years and over | 0.70 (0.22) | 0.28 (0.22) | 0.44 (0.29) | 0.57 (0.30) |
| Overall | 0.81 (0.20) | 0.20 (0.20) | 0.59 (0.28) | 0.44 (0.28) |

*Any disparity in proportions is a function of rounding.

These data demonstrate children in the ADHD group chose fewer safe routes than control children overall. They also indicate there are little differences between those with and without ADHD who are in the youngest age group and whilst the ability to select safe routes appears to increase with age amongst control children the performance of the ADHD is effectively the same across all age groups.

A two way ANCOVA with participant group and age group as factors (and BPVS percentile rank as a covariate) revealed a significant effect of participant group ($F[1,118]=24.38$, $p<.001$, $\eta^2=.180$) whereby children with ADHD selected significantly fewer safe routes than controls across irrespective of age. A significant main effect of age was also found ($F[2,122]=10.38$, $p<.001$, $\eta^2=.158$) whereby the proportion of safe responses increases with age across both participant groups. Although the difference between children with and without ADHD appears to become more marked as children grow older, there was no significant participant group by age group interaction ($F[2,118]=2.87$, $p=.061$, $\eta^2=.049$). Planned contrasts revealed there was no effect of participant group in children aged 6 years and under ($F[1,27]=0.45$, $p=.508$, $\eta^2=.016$) whereas the effect of group at age 7-8 years old ($F[1,53]=22.64$, $p<.001$, $\eta^2=.299$) and 9 years and over ($F[1,29]=9.70$, $p=.004$, $\eta^2=.251$) was significant. Trends as a function of participant group and age group are shown in Figure 11.1 below.

Figure 11.1: Mean Proportion of Safe Routes as a Function of Participant Group & Age Group




### 11.3.2 Conceptual Response

Conceptual understanding of the safe place finding task was next examined. The mean proportion of each of the conceptual understanding response categories ranging from 0 (no conceptual understanding) to 4 (high conceptual understanding) were calculated for each participant group and age group. These data are reported in Table 11.3 below and show children with ADHD had significantly lower conceptual understanding than controls overall and that understanding of both groups also appears to improve with age.

Table 11.3: Mean (& S.D.) Proportion* of Conceptual Understanding Level on the Safe Place Finding Task by Participant Group and Age Group

| | ADHD Group | | | | | Control Group | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0s | 1s | 2s | 3s | 4s | 0s | 1s | 2s | 3s | 4s |
| 6 years and under | 0.23 (0.25) | 0.33 (0.31) | 0.36 (0.30) | 0.08 (0.14) | 0.00 (0.00) | 0.15 (0.22) | 0.34 (0.28) | 0.35 (0.32) | 0.16 (0.21) | 0.00 (0.00) |
| 7-8 year olds | 0.15 (0.24) | 0.25 (0.22) | 0.44 (0.27) | 0.17 (0.23) | 0.00 (0.00) | 0.08 (0.17) | 0.12 (0.11) | 0.28 (0.17) | 0.43 (0.24) | 0.11 (0.17) |
| 9 years and over | 0.14 (0.16) | 0.13 (0.19) | 0.43 (0.26) | 0.29 (0.19) | 0.01 (0.03) | 0.04 (0.07) | 0.06 (0.12) | 0.24 (0.21) | 0.52 (0.17) | 0.15 (0.16) |
| Overall | 0.16 (0.23) | 0.24 (0.24) | 0.42 (0.27) | 0.18 (0.21) | 0.00 (0.02) | 0.08 (0.17) | 0.16 (0.21) | 0.28 (0.23) | 0.38 (0.26) | 0.09 (0.15) |

*Any disparity in proportions is a function of rounding.

Next, the proportions of each response type were used to produce three levels of conceptual understanding: no conceptual understanding (0s), low conceptual understanding (1s and 2s) and high conceptual understanding (3s and 4s). The reason for data being coded in this way is similar to that outlined above (in relation to children's behavioural response on this task) and are described fully in chapter 4. Data are presented in this format in Table 11.4 below.

Table 11.4: Mean (& S.D.) Proportion* of Conceptual Understanding Response Categories by Participant Group and Age Group

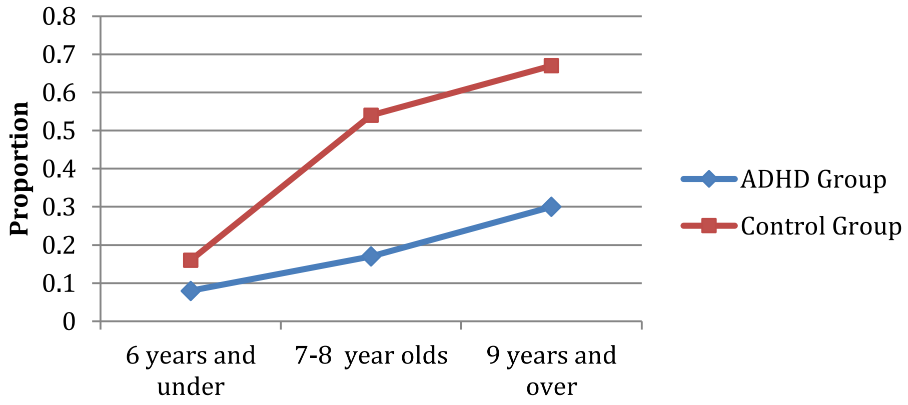
| | ADHD Group | | | Control Group | | |
|---|---|---|---|---|---|---|
| | No CU | Low CU | High CU | No CU | Low CU | High CU |
| 6 years and under | 0.23 (0.25) | 0.69 (0.27) | 0.08 (0.14) | 0.15 (0.22) | 0.69 (0.23) | 0.16 (0.21) |
| 7-8 year olds | 0.15 (0.24) | 0.69 (0.28) | 0.17 (0.23) | 0.08 (0.17) | 0.39 (0.19) | 0.54 (0.26) |
| 9 years and over | 0.14 (0.16) | 0.56 (0.25) | 0.30 (0.26) | 0.04 (0.07) | 0.29 (0.21) | 0.67 (0.23) |
| Overall | 0.16 (0.23) | 0.65 (0.27) | 0.18 (0.21) | 0.08 (0.17) | 0.44 (0.26) | 0.48 (0.31) |

*Any disparity in proportions is a function of rounding.

Table 11.4 shows children in the ADHD group had lower conceptual understanding of the task compared with children in the control group. As with the behavioural responses, although the proportion of high conceptual responses appears to increase with age for both groups, this increase is much less pronounced for children with ADHD. As with the behavioural scores, only the optimal high conceptual understanding proportions will be reported herein as this represents the level of understanding children should aim for and is the inverse proportion of the sum of the other two response types.

A further two way ANCOVA with participant group and age group as independent factors, BPVS percentile rank as a covariate and the proportion of high conceptual responses as the dependent variable revealed a main effect of participant group ($F[1,118]=38.87$, $p<.001$, $\eta^2=.259$) whereby children with ADHD had a significantly smaller proportion of high conceptual responses than did controls. A significant main effect of age was also found ($F[2,118]=21.63$, $p<.001$, $\eta^2=.280$) whereby conceptual understanding improves with age across both groups. There was also a significant interaction between participant group and age group ($F[2,118]=4.14$, $p=.018$, $\eta^2=.069$), whereby the gap between children with and without ADHD appears to increase with age. Planned contrasts revealed this was because there was no effect of participant group at age 6 years and under ($F[1,27]=2.60$, $p=.118$, $\eta^2=.088$) but an effect of group emerges amongst children aged 7-8 ($F[1,53]=24.62$, $p<.001$, $\eta^2=.317$) and remains at age 9 years and over ($F[1,29]=24.97$, $p<.001$, $\eta^2=.463$). Trends in conceptual understanding are demonstrated in Figure 11.2 below.

Figure 11.2: Mean Proportion of High Conceptual Responses as a Function of Participant Group & Age Group



### 11.3.3 Perceived Difficulty

Children's perceived difficulty of the safe place finding task was next examined. The findings relating to how difficult participants found the task to be are reported through two variables. Pre-trial estimations were made before the completion of trials when children were asked how difficult they thought the task would be prospectively after it had been explained but before undertaking it. Post-trial estimations were made immediately after a trial had been completed before participants proceeded to the next. Post-trail ratings recorded how difficult children had found the task to be on reflection. Mean perceived difficulty ratings are presented in Table 11.5 below.

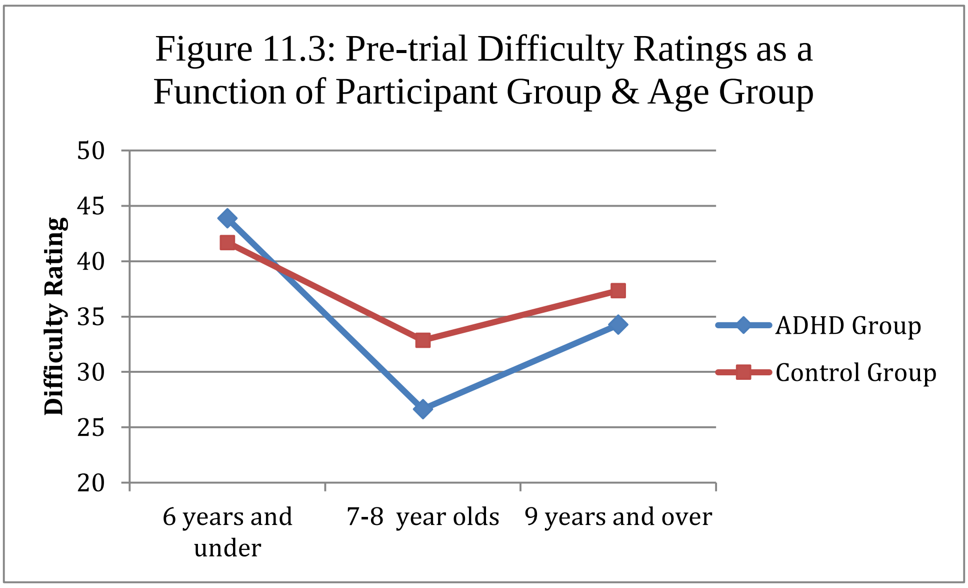
Table 11.5: Mean (& S.D.) Pre & Post-trial Perceived Difficulty rating* by Participant Group and Age Group

| | ADHD Group | | Control Group | |
|---|---|---|---|---|
| Age Group | Pre-trial | Post-trial | Pre-trial | Post-trial |
| 6 years and under | 43.86 (30.56) | 37.04 (27.30) | 41.67 (29.37) | 18.49 (16.71) |
| 7-8 year olds | 26.63 (20.45) | 23.07 (23.05) | 32.86 (19.89) | 23.42 (17.41) |
| 9 years and over | 34.26 (15.16) | 20.13 (13.80) | 37.34 (12.76) | 32.31 (16.57) |
| Overall | 32.74 (23.05) | 25.78 (22.97) | 36.61 (21.52) | 24.41 (17.51) |

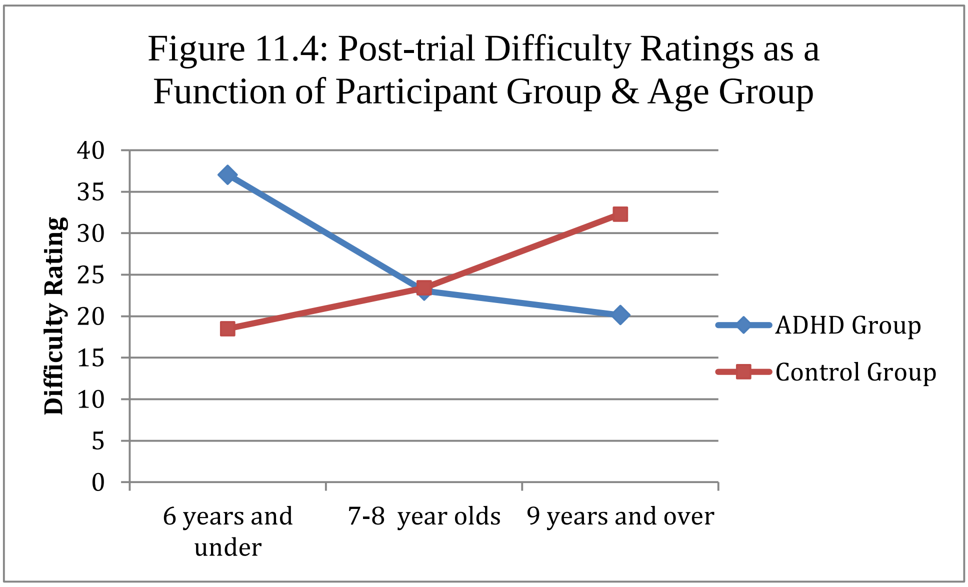
*Maximum Score=100.

Two two-way ANCOVAs (one for pre-trial and one for post-trial ratings) with participant group and age group as factors (and BPVS percentile ranks as a covariate) were used to examine data relating to perceived difficulty. Findings relating to pre-trial difficulty revealed there was no effect of participant group ($F[1, 109]=0.41$,

$p$=.525, $\eta^2$=.004) but there was an effect of age group ($F[2, 113]$=4.32, $p$=.016, $\eta^2$=.073). No interaction between participant group and age group was found ($F[2, 109]$=0.03, $p$=.975, $\eta^2$=.000). These data are presented in Figure 11.2 below.




In respect of post-trial difficulty ratings, there was no main effect of participant group ($F[1, 109]$=0.02, $p$=.881, $\eta^2$=.000) or of age group ($F[2, 109]$=0.28, $p$=.757, $\eta^2$=.005). A significant interaction between participant group and age group was revealed for post-trial difficulty estimations ($F[2, 109]$=4.16, $p$=.018, $\eta^2$=.071). In terms of post-trial difficulty ratings, control children rate the task as being more difficult with age while children with ADHD in contrast, rate the task as being less difficult as they grow up, as shown in Figure 11.4 below.




### 11.4 Discussion

The findings of the current study support the first and second hypotheses, that children with ADHD would perform significantly less well than controls in terms of the proportion of safe routes they selected and also in terms of their conceptual understanding of the task. Children with ADHD perform much less well and as a consequence are at much greater risk than are case matched control children of the same age in respect of finding a safe crossing location and planning a safe route across the road.

The current study provides the first empirical evidence to demonstrate differences in the ability of children with ADHD compared with controls in respect of the performance of the key pedestrian skill of identifying and planning a route across the road. Children with ADHD appear significantly less able to distinguish safe from dangerous crossing locations and unlike control children, there is very little age related improvement in this ability. Children with ADHD appear to struggle to plan a safe route across the road which avoids dangerous locations and do not modify crossing routes to take account of hazards as do control children. The data pertaining to conceptual understanding demonstrate children with ADHD have much poorer conceptual understanding of the task of doing so as well. Together, these findings represent broad difficulties with what has been previously described as one of the most important pedestrian skills of all (Tabibi & Pfeffer, 2007).

These findings extend the literature considerably, which so far, has focused exclusively on the ability of children with ADHD to perform a different pedestrian skill. The findings of the present study demonstrate clearly that the difficulties experienced by children with ADHD in the traffic environment extend beyond the one skill which has previously received research attention with an ADHD population and pervade into the domain of another skill central to the safe navigation of the traffic environment.

The findings relating to age are novel and so the current study also extends the literature by providing insights into the developmental trajectory of pedestrian skill of children with ADHD for the first time. The current study demonstrates clearly that the natural age related development of the ability to perform this important skill is markedly different for children with ADHD compared with controls. Children with ADHD demonstrate much less improvement in terms of the safety of their crossing routes and very little improvement indeed in respect of their conceptual understanding compared with controls. In contrast, typically developing children demonstrate marked improvement in respect of both of these measures of performance as they grow older. That being said, it is also clear that there is little difference between participant groups amongst children of the youngest age. This is very likely because even control children perform poorly at this age (because of their limited experience to traffic and undeveloped skills). In contrast, even in the middle age group, a large gap has opened in the skill level of children with and without ADHD and this remains amongst older children. Thus whilst there is significant age related improvement in the performance of this skill for typically control children, the skill level of children with ADHD widens with age and lags much further behind in comparison overall.

Although these findings reported here are novel so far as no previous studies have investigated this specific pedestrian skill amongst children with ADHD, in broad terms, the findings of the current study compare well to previous findings which have shown differences in the pedestrian skill level of children with ADHD and controls in respect of a different skill. The previous studies in this area have focused on children’s visual gap timing ability in which children with ADHD also appear to show impairment. Studies by Stavrinos et al. (2011) and Clancy et al. (2006) both reported children with ADHD were much less able to identify safe gaps between cars in a flow of traffic. Clancy and colleges reported children with ADHD made poor use of gaps between cars and were hit by vehicles twice as often as were control children because of difficulties in respect of visual timing. The findings of the current study suggest that children with ADHD are also likely to be struck by a vehicle because they struggle to identify a safe crossing location and fail to take account of hazards that may for example obstruct their view of the road before stepping out to begin a crossing.

The findings of the current study suggest that the difficulties experienced by children with ADHD when interacting with the traffic environment are broader than has been previously reported and difficulties generalise across multiple pedestrian skills. The current study shows children with ADHD are significantly less able to identify safe from dangerous crossing locations and have difficulties planning safe crossing routes across the road which take account of hazards compared with controls.  Children with ADHD also have correspondingly poor conceptual understanding of the task of doing so as reflected in their justifications for route selections.

The similarities in the trajectories of the behavioural and conceptual data are not surprising.  It has been argued for some time that gains in conceptual understanding likely drive improvement in terms of behavioural response in relation to this and similar pedestrian tasks (Thomson et al., 2005).  Similarities in terms of developmental profiles of both conceptual and behavioural responses suggests concordance exists between conceptual understanding and behavioural response for this group of children also.  Whilst typically developing children had relatively high levels of conceptual understanding (and a correspondingly higher level of behavioural performance), those with ADHD had poor conceptual understanding and poor behavioural performance as a result.  This alignment between behaviour and underlying conceptual understanding was also revealed in study 1.1 reported earlier in this thesis and carries implications for the design of prospective interventions for this group, which should address conceptual understanding as well as behavioural decision making.

The significant age by participant group interaction in respect of conceptual understanding shows clearly that the gap in performance between those with and without ADHD appears to widen with age. The performance of typically developing children appears to improve much more than does the performance of children with ADHD. The difference in age related improvement is such that children with ADHD even by age 11 to 12 years do not attain the conceptual understanding of the safe place finding task that control children do by age 7-8. It is both possible and likely that this is a result of children with ADHD not being able to benefit from experience because of underlying cognitive impairment. It may also be a result of the parenting practices of children with ADHD, who may be cautious in allowing children to gain experience by exposing them to traffic in the first place. Future research may wish to examine these possibilities further.

These findings carry implications for both children with ADHD and their caregivers. While by the age of 9 years, typically developing children are approaching adult levels of performance, those with ADHD lag much further behind. Differences in performance of this skill emerge at age 7-8 and remains at age 9 and over. Even the oldest children with ADHD in the present sample perform below the level of typical 7-8-year-olds. In relation to the supervision of children with ADHD, these findings suggest those with ADHD remain much less ready to interact with the traffic environment compared to control children. This finding also carries implications for educators, clinicians and public health practitioners who ought to address the vulnerability of children with ADHD in the context of the traffic environment with the parents and carers of children with ADHD.

The findings relating to the perceived difficulty of the safe place finding task are also interesting and partially support the third hypothesis; that children with ADHD would rate the safe place finding task as being less difficult than control children. This was the first study to consider the perceived difficulty of any pedestrian skill amongst children with ADHD. The findings relating to perceived difficulty show no significant differences between children with and without ADHD for pre or post-trial difficulty ratings. Nor are differences significant as a function of age. The lack of differences in respect of age for pre-trial ratings are not surprising given the findings of study 1.1 revealed little difference in in this regard, amongst a larger sample of typically developing children.

The significant age by participant group interaction showed in respect of post-trial difficulty estimations (made immediately after participants completed trials) shows control children rate the safe place finding task as being more difficult as they grow older whereas those with ADHD actually rate the task as being easier with age. At age 6 and under, children in the control group actually rate the task as being easier than those in the ADHD group. At age 7-8, there are no differences between groups and by age 9 years trends have reversed whereby older children in the control group rate the task as being much harder than children with ADHD. Thus as they grow up, typically developing children appear to develop an appreciation of the intricacy of the task and rate the task as being more difficult at post trial as a result. Children with ADHD on the other hand, rate the task as being less difficult with age at post-trial, despite their much less safe performance. Older children with ADHD perceive safe place finding task difficulty (at post-trial) in a way which resembles much younger typically developing children. In stark contrast to the typical group, who with age appear to foster an appreciation of the complexity of the task and update their (post-trial) difficulty ratings accordingly, those with ADHD actually downgrade their difficulty ratings at post trial as they age. This tendency is completely unjustified relative to their performance.

Children with ADHD therefore not only perform less well than control children, but also appear unaware of their own poor performance. This pattern of responding resembles the pattern reported in study 1.1 whereby children with ADHD respond in a way similar to much younger typically developing children in respect of how difficult they perceive the task of finding a safe crossing route to be. The tendency of children with ADHD to rate the task as being less difficult with age probably reflects the significantly poorer conceptual understanding of this group (as shown by their much lower conceptual scores). It is likely children with ADHD, in the same manner as young typically developing children, rate the task as being easy because they fail to see hazards and the need to modify crossing routes in the first place. It would appear that they 'miss the point' and rate the task as being easy because from their perspective, it is. Future interventions targeting those with ADHD should take account of the apparent failure of even older children with ADHD (who are approaching adolescence) to realise the complexity of the task and their tendency to overestimate their own ability relative to their poor performance.

In summary, the current study provides the first evidence of differences in the ability of children with and without ADHD to select safe crossing locations and navigate safe routes across the road. This study thus extends the emerging literature suggesting that children with ADHD have poorer pedestrian skills than typically developing control children. It shows the difficulties children with ADHD experience when interacting with traffic are more diverse than had been previously demonstrated. Until now, past research had focused exclusively on visual gap timing ability and showed children with ADHD are impaired in respect of this skill. The current study shows this impairment extends to safe place finding ability as well. It also suggests that children with ADHD may have less insight into their own skill level compared with typically developing children, particularly as they grow older.

# Chapter 12

## Study 2.2: Visual Gap Timing Ability in Children with ADHD

### 12.1 Introduction

Study 1.2 of this thesis explored the development of children's ability to identify gaps which were safe to cross between cars in a flow of traffic. The findings of study 1.2 demonstrate significant age related improvement in performance of this task, in terms of a wide range of outcome measures, and that there are also distinct differences in relation to the perceived difficulty of this task whereby after completing the task, children rated it as being more difficult with age. The current study examines the ability of children with ADHD to make such visual gap timing judgements relative to matched control children. This skill has been the focus of only two past studies of pedestrian skill in children with ADHD. Both of these studies reported significant differences in visual gap timing ability amongst children with ADHD compared with controls. Clancy et al. (2006) recruited participants with ADHD aged 13-17 years who completed a visual gap timing task using a virtual reality simulator. Participants were required to identify gaps between cars that they thought were large enough to cross through safely. Those with ADHD performed significantly less well than control children across a range of variables. The ADHD group walked slower than control children and spent more time on the road. They made poor use of gaps as a result of higher starting delays which resulted in smaller safety margins amongst children with ADHD compared to controls who in contrast left much more time to spare. Those with ADHD were also struck by vehicles twice as often as those without ADHD. These findings represent very unsafe performance of this skill amongst adolescents with ADHD, across a range of measures of performance.

Extending these findings is a study by Stavrinos and colleagues (2011) that also studied the performance of 7 to 10 year old children with ADHD on a visual gap timing task. The findings demonstrated those with ADHD were more willing to initiate crossings when vehicles were closer, selected smaller gaps to cross through and left less time between initiating their crossing and the arrival of an approaching vehicle.

Neither of these studies considered age as a factor in terms of the performance of children with ADHD. Thus, these studies reveal nothing about the developmental trajectory of this skill amongst children with ADHD or how the performance of children with ADHD changes across childhood relative to control children. Whether or not performance increases as a function of age in those with ADHD in the same manner as controls is an important question, the answer to which would be of significance for prospective interventions targeting this vulnerable group. Indeed, while the findings of these previous studies suggest intervention is needed, the developmental trajectory of the skill has not yet been reported and thus the optimal age for intervention would be difficult to determine given the lack of data surrounding the natural development of this skill across childhood for children diagnosed with ADHD.

The findings reported in chapter 5 of this thesis also revealed age differences in the perceived difficulty of the visual gap timing task amongst typically developing children. Younger children judged the task as being much less difficult than older children, in spite of their much poorer performance. Whilst no previous studies have considered how difficult children with ADHD perceive the visual gap timing task to be compared with control children, it might reasonably be expected that such differences also exist in respect of visual gap timing since such differences have already been reported with respect to safe place finding earlier in this thesis. As such, the current study will also address perceived difficulty of visual gap timing amongst children with ADHD for the first time.

In summary, the current study aims to examine visual gap timing ability in children with and without ADHD, and establish whether age-related improvement in performance is observed for children with ADHD, as has been previously reported amongst typically developing children. It also aims to establish how difficult children with ADHD perceive the gap timing task to be compared with controls by examining perceived difficulty via ratings made both before and after participants have undertaken crossings.

It is hypothesised that:

1. Children with ADHD will perform significantly less well than typically developing control children of the same age such that;
   i) The size of gaps children with ADHD are willing to attempt to cross through will be significantly smaller than those in the control group

ii) the starting delays of children with ADHD will be larger than those without ADHD

iii) Children with ADHD will miss more safe opportunities to cross than controls, and

iv) Children with ADHD will have a significantly higher number of tight fits compared to controls.

2. There will be an interaction between participant group and age group. Participant group differences are not anticipated between children in the youngest age group because even typically developing children perform poorly at this age. It is expected that differences between groups will emerge with age.

3. There will be significant difference in how difficult children with ADHD perceive the task to be compared to controls, such that children with ADHD will perceive the task as being less difficult than will children in the control group. Children with ADHD will also be less likely to rate the difficulty of the task has greater after having had the opportunity to make crossing decisions.

## 12.2 Method

### 12.2.1 Participants

The same 122 children took part in this study (61 medication naïve children with ADHD and 61 case matched control children). 98 participants were male and 24 were female. The mean age of the ADHD group was 97.79 months (SD=10.08) and the mean age of the control group was 94.42 months (SD=7.22). Children with ADHD were matched to typically developing control children on chronological age and gender. Percentile rankings from the 3rd edition of the British Picture Vocabulary Scale; BPVS III were significantly different between groups and so this was included as a covariate in all analyses. Participants were again assigned to one of three age groups: 6 years and under (15 children with ADHD & 15 controls), 7-8 year olds (30 children with ADHD & 30 controls) and 9 years and over (16 children with ADHD & 16 controls). Further information about the sample can be found in the general method section for part B (chapter 10).

#### 12.2.2 Design

The design was between groups with participant group (ADHD vs. control) and age group as between subjects factors.

#### 12.2.3 Materials and Procedure

The task used to assess visual (gap) timing ability in this study was the same as that used and described in study 1.2 in part A of this thesis. This task and its operation are also described in the general methods sections. Data was also coded following the same procedure described in study 1.2 and the general methods sections. Participants completed this task individually under the guidance of an experimenter using a laptop computer. Following three practice trials, participants completed 24 experimental crossing trials split between four different road scenes. Perceived difficulty was measured once more via the software's inbuilt sliding bar which participants were instructed to move on a scale ranging from very easy to very difficult in the same manner described in chapter 3.  Participants made difficulty ratings both before (pre-trial rating) and after trials had been completed (post-trial rating).

## 12.3 Results

### 12.3.1 Behavioural Measures

The mean scores for each of the main behavioural outcome variables were calculated as a function of participant group and age group.  These data are presented in Table 12.1 below.

Table 12.1: Mean (& S.D.) for Performance Measures on the Visual Gap Timing Task as a function of Participant Group and Age Group

| | ADHD Group | | | | | | Control Group | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age Group | Accepted Gap | Effective Gap | Start Delay | Est. Cross Time | Missed Opportunities | Tight Fits | Accepted Gap | Effective Gap | Start Delay | Est. Cross Time | Missed Opportunities | Tight Fits |
| 6 years and under | 5.37 (0.31) | 3.36 (0.51) | 2.02 (0.55) | 3.27 (0.68) | 0.91 (0.48) | 3.21 (1.01) | 5.38 (0.50) | 3.55 (0.67) | 1.70 (0.51) | 3.25 (0.63) | 1.34 (0.74) | 2.69 (1.02) |
| 7-8 year olds | 5.46 (0.38) | 3.63 (0.59) | 1.84 (0.48) | 3.22 (0.74) | 1.10 (1.12) | 2.96 (0.84) | 5.73 (0.38) | 4.30 (0.60) | 1.40 (0.48) | 3.33 (0.44) | 1.36 0.72) | 2.02 (1.14) |
| 9 years and over | 5.39 (0.71) | 3.95 (0.88) | 1.44 (0.37) | 2.88 (0.11) | 1.20 (1.14) | 2.43 (1.23) | 5.86 (0.39) | 4.79 (0.62) | 1.04 (0.32) | 3.37 (0.77) | 1.49 (0.85) | 1.28 (1.04) |
| Overall | 5.42 (0.46) | 3.64 (0.67) | 1.79 (0.51) | 3.15 (0.83) | 1.08 (1.00) | 2.89 (1.00) | 5.65 (0.48) | 4.25 (0.77) | 1.37 (0.51) | 3.32 (0.60) | 1.39 (0.75) | 1.98 (1.19) |

A two way ANCOVA with participant group and age group as independent factors and mean accepted gap size as the dependent variable revealed the mean accepted gap time (in seconds) varied significantly between participant groups ($F[1,111]=6.43$, $p=.013$, $\eta^2=.055$) and age groups ($F[2,111]=4.43$, $p=.014$, $\eta^2=.074$). Children with ADHD accepted significantly smaller gaps than did control children. There was also a significant interaction between participant group and age group ($F[2,111]=3.36$, $p=.038$, $\eta^2=.057$). Figure 12.1 shows this is because there was no difference between participant groups in the youngest age group whereas, in the two older groups it was substantial. This was confirmed by planned contrasts which revealed whilst there were no differences between children with ADHD and controls at age 6 years and under ($F[1,27]=0.61$, $p=.441$, $\eta^2=.022$) there were significant participant group differences amongst 7-8 year olds ($F[1,57]=6.16$, $p=016$, $\eta^2=.104$) and children aged 9 years and over ($F[1,29]=5.70$, $p=.024$, $\eta^2=.164$).

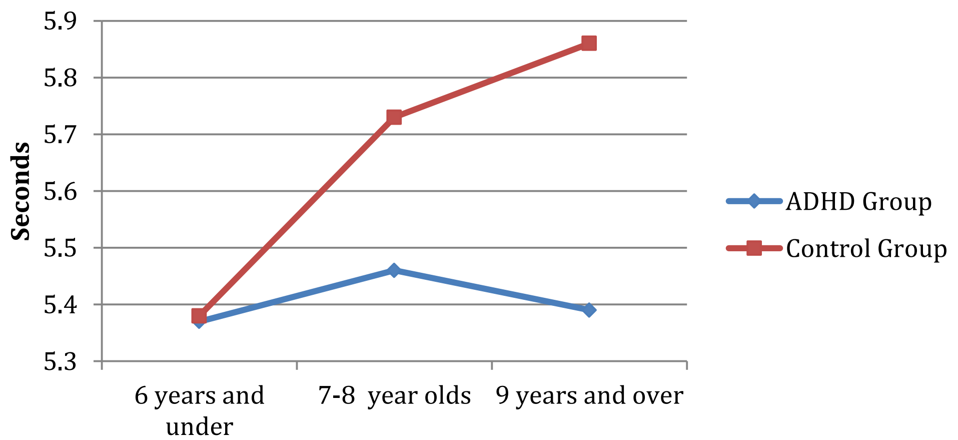
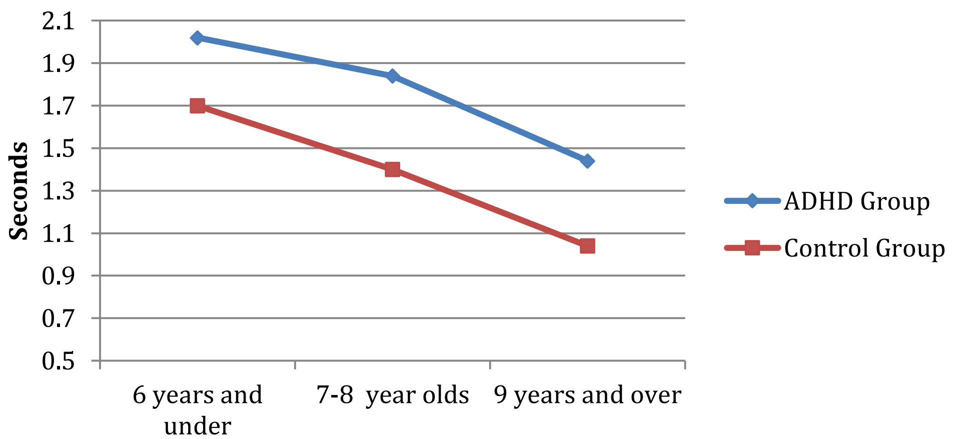



Figure 12.1: Mean Accepted Gap Size as a Function of Participant Group & Age Group

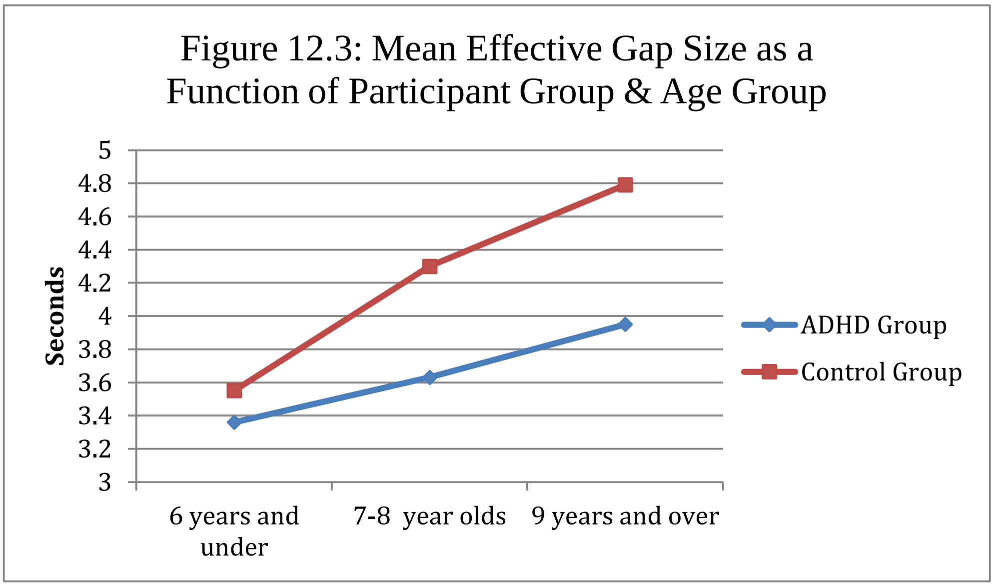
Starting delay was also examined as a function of participant group and age group, by means of a two way ANCOVA with participant group and age group as independent variables and starting delay as the dependent factor. The mean starting delay also varied significantly between participant groups ($F[1,111]=16.04$, $p<.001$, $\eta^2=.128$) and age groups ($F[2,111]=16.25$, $p<.001$, $\eta^2=.230$). There was no interaction between participant group and age group in relation to starting delay ($F[2,111]=0.09$, $p=.916$, $\eta^2=.002$). Children with ADHD had significantly larger starting delays compared with controls. Findings relating to starting delay are displayed in Figure 12.2 below.

Figure 12.2: Mean Starting Delay as a Function of Participant Group & Age Group




A further two way ANCOVA with participant group and age group as independent variables and mean effective gap size as the dependent factor revealed the mean effective gap time varied significantly between both the participant groups ($F[1,111]=19.27$, $p<.001$, $\eta^2=.148$) and age groups ($F[2,111]=16.37$, $p<.001$,

$\eta^2$=.227). There was no significant interaction between participant group and age group (F[2,111]=1.74, $p$=.180, $\eta^2$=.030). The mean effective gap size increased with age across both participant groups but children with ADHD had smaller effective gaps than control children overall. Participant group and age group effects are shown in Figure 12.3 below.

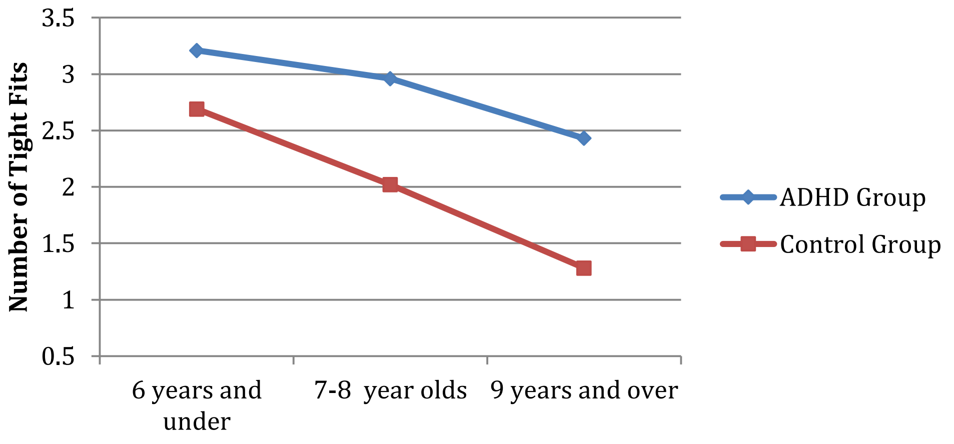



In contrast to the findings reported above, a further two way ANOVA revealed that the mean estimated crossing time did not vary as a function of participant group (F[1,111]=0.91, $p$=.343, $\eta^2$=.008) or age group (F[2,111]=0.14, $p$=.873, $\eta^2$=.002) with no interaction between participant group and age group (F[2,111]=2.13, $p$=.124, $\eta^2$=.037). Similarly, when the same analysis was conducted for the number of missed opportunities, there were no significant differences as a function of participant group (F[1,111]=2.89, $p$=.092, $\eta^2$=.025) or age group (F[2,111]=0.57,

$p$=.567, $\eta^2$=.010) and there was no interaction between participant group and age group (F[2,111]=0.34, $p$=.710, $\eta^2$=.006).

However, a further two way ANOVA with participant group and age group as independent variables revealed the number of tight fits was significantly different between participant groups (F[1, 111]=17.98, $p$<.001, $\eta^2$=.139) and age groups (F[2, 111]=8.86, $p$<.001, $\eta^2$=.138). Children in the ADHD group made significantly more tight fits than did controls across all age groups and the number of tight fits also reduced with age. There was no interaction between participant group and age group (F[2,111]=0.63, $p$=.536, $\eta^2$=.011). The findings relating to the number of tight fits are summarised in Figure 12.4 below.

Figure 12.4: Mean Number of Tight Fits as a Function of Participant Group & Age Group



### 12.3.2 Perceived Difficulty

Finally, the mean perceived difficulty estimations for pre-trial and post-trial ratings were calculated as a function of participant group and age group. These are shown in Table 12.2 below.

Table 12.2: Mean (& S.D.) Pre & Post-trial Perceived Difficulty rating* for the Visual Gap Timing Task as a function of Participant Group and Age Group

| | ADHD Group | | Control Group | |
|---|---|---|---|---|
| | Pre-trial | Post-trial | Pre-trial | Post-trial |
| 6 years and under | 39.74 (31.54) | 34.20 (25.56) | 24.03 (21.07) | 20.34 (16.24) |
| 7-8 year olds | 35.46 (27.26) | 27.74 (21.99) | 42.42 (25.07) | 36.21 (27.23) |
| 9 years and over | 35.43 (19.83) | 30.33 (16.72) | 46.78 (20.68) | 49.36 (18.14) |
| Overall | 36.47 (26.44) | 29.89 (21.59) | 38.76 (24.20) | 35.92 (24.39) |

*Maximum Rating=100

A two way ANCOVA with participant group and age group as factors and BPVS percentile rank as a covariate revealed there were no significant differences for either pre-trial ($F[1, 111]=0.07$, $p=.791$, $\eta^2=.001$) or post-trial estimations ($F[1, 111]=1.31$, $p=.254$, $\eta^2=.012$) as a function of participant group. There were also no significant differences in either pre-trial ($F[2, 111]=1.19$, $p=.309$, $\eta^2=.021$) or post trial ratings ($F[2, 111]=2.43$, $p=.093$, $\eta^2=.042$) as a function of age. No participant group by age group interaction was found in respect of pre-trial estimations, although the p-value was close to significance ($F[2, 111]=2.89$, p=.060, $\eta^2=.049$). However, a significant interaction between participant group and age group was found for post-trial estimations (F[2, 111]=4.67, *p*=.011, $\eta^2$=.077). Figure 12.5 shows that, on post-trial ratings, children in the control group rated the task as being more difficult with age, whereas there was no such age effect for those with ADHD. This was confirmed by planned contrasts which revealed whilst children with ADHD actually rated the task as being more difficult than controls aged 6 years and under (F[1,27]=4.95, p=.035, $\eta^2$=.155), there were no differences at age 7-8 years (F[1,57]=0.59, *p*=.445, $\eta^2$=.011) and by age 9 years and over, children with ADHD rated the task as being much simpler than controls (F[1,29]=9.52, *p*=.004, $\eta^2$=.247).

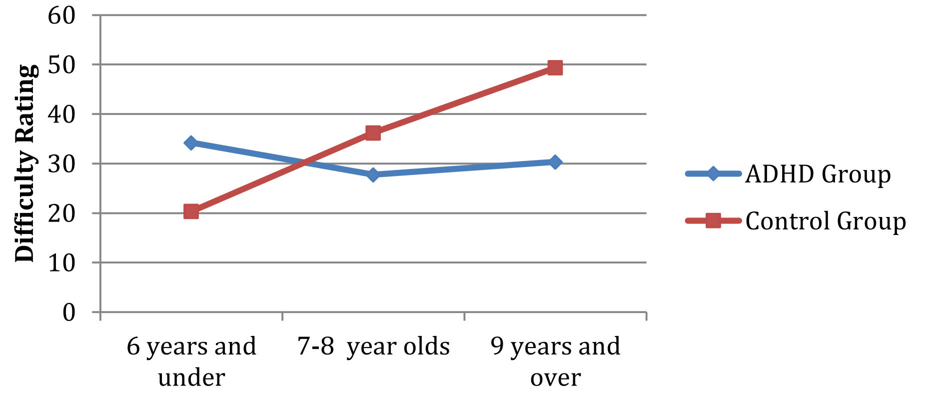


Figure 12.5: Mean Post-trial Difficulty Estimations as a Function of Participant Group & Age Group

## 12.4 Discussion

### 12.4.1 Behavioural Measures

In support of the first hypothesis, the results of the current study suggest there are significant differences between children with ADHD compared with controls in relation to visual gap timing ability. These findings yield support for the few previous studies which have examined this ability amongst children with ADHD and reported similar differences (Clancy et al., 2006, Stavrinos et al., 2011). The findings also provide significantly greater insights into these differences because they demonstrate different developmental profiles in the acquisition of these skills between children with ADHD and typically developing control children. In general, across performance measures, typically developing children show a fairly linear improvement with age whereas for children with ADHD, there is very little (almost no) such improvement in comparison. Thus, the differences between children with and without ADHD is small at age 6 and under but becomes increasingly marked with age because children with ADHD do not improve in the same manner controls do with development.

The findings relating to the mean accepted gap size demonstrate significant differences in the size of gaps children with ADHD were willing to accept compared to controls. Children with ADHD were willing to cross through much smaller gaps than were controls. In addition, there is no age related improvement in the gaps children with ADHD are willing to cross through whereas accepted gap size increased significantly with age for typically developing control children. These effects are such that even by age 9 and over, those with ADHD still performed similarly to a typically developing 6 year-old. There is no meaningful age related improvement for the ADHD group in respect of accepted gap size. Thus while the performance of typically developing children becomes safer across childhood, for those with ADHD there is no such improvement in accepted gap size with age.

Children with ADHD had also significantly longer starting delays than did control children. Starting delay is strategically important in the completion of the gap timing task because having short starting delays allows pedestrians to ‘make the most’ of the gaps available to them and having shorter starting delays consequently improves other (related) aspects of the safety of the crossing. The long starting delays of children with ADHD revealed in the current study, implies they are unfocused and do not make crossing decisions effectively or efficiently. They likely have poor anticipation because they fail to look ahead for gaps that may shortly appear as traffic approaches their location and as a result do not initiate crossings promptly when a suitable gap does open. As a consequence, children with ADHD delay their initiation of a crossing once it is safe to go which explains the similar findings revealed in respect of the size of effective gaps which were also significantly shorter amongst children with ADHD.

A number of previous studies in the literature highlight the importance of starting delay as a measure of children’s developing skill level in respect of visual gap timing (Plumert & Kearney, 2014, Schwebel et al., 2008). These and similar studies unanimously report starting delays reduce with age across childhood and as starting delay decreases, effective gap size increases accordingly (Thomson et al., 2005). The current study shows some improvement in both starting delay (and effective gap size as a result) in children with ADHD, but they remain significantly below the performance level of typically developing controls across age groups, with no indication that children with ADHD are catching up with age and experience. The current findings therefore demonstrate not only do children with ADHD accept smaller gaps to start with but they also squander part of these gaps before initiating a crossing as reflected in their longer starting delays, which in turn also leads to smaller effective gaps in this group as well.

The findings relating to estimated crossing time revealed performance in respect of this outcome measure did not vary as a function of age or participant group. That is, the total time participants estimated it would take them to get from the near side of the road to the far side was not found to be significantly different between children with ADHD compared with controls or between children of different ages. This finding is interesting because it suggests the reason children with ADHD accept smaller gaps is not because they think they need less time to cross the road than do controls. Thus the overall poorer performance of the ADHD group on the visual gap timing task cannot be attributed to perceptual differences in respect of the time needed to get from one side of the road to the other. In contrast, this finding suggests children with ADHD experience processing difficulties or problems in coordinating information from multiple sources, using this to reach a decision and then undertake a safe crossing. The findings reported in chapter 7 of this thesis highlight predictive relationships between aspects of cognitive function and the performance of typically developing children on the visual gap timing task. Children with ADHD have been previously shown to be impaired in respect of these same functions (Rhodes et al., 2005), which suggests differences in the performance of children with ADHD compared with controls revealed here, may be attributable to processing difficulties arising from problems with cognitive function. This possibility will be explored in chapter 14.

The number of missed opportunities to cross when it was safe to do so was not significantly different as a function of age or participant group meaning there were no differences in the number of chances missed to cross when it was safe to do so between age groups or between children with and without ADHD. This lack of age difference is not a surprise. This corresponds well to the findings reported in chapter 5 which also showed no significant age related differences in performance according to this outcome measure in a larger sample of typically developing children. Some studies even report no differences in the number of missed opportunities between children and adults (Demetre et al., 1992).

The reasons for the non-significant difference the number of missed opportunities between those with ADHD and controls is that very few children across the sample as a whole missed very opportunities. This can be interpreted in two ways. One possibility is that most children were choosing gaps that were 'short'. By being willing to cross through smaller gaps, it follows that children will miss few opportunities because they are willing to cross through even small gaps. The other possibility is that this is a function of the definition of what constitutes a 'missed opportunity'. In the current study, this was defined as one and a half times of the total time needed to cross. Previous studies have defined a missed opportunity in a less conservative manner (Lee et al., 1984, Young & Lee, 1985) whereby, missing much smaller gaps counted as missed opportunities and therefore more likely to occur. The fact the current study only included larger missed gaps as missed opportunities means participants are less likely to miss many in the first place.

However, the definition adopted by the current study is well aligned with the definitions used by more recent studies (e.g. Thomson et al., 2005) which also report the number of missed opportunities to be a poorly discriminating measure of performance.

The mean number of tight fits was significantly different as a function of both age and participant group. The number of tight fits reduced significantly with age whereby older children were much less likely than younger children to still be on the road when a car arrives at their crossing line. This finding is well aligned to those of previous studies which have reported similar age related findings (Thomson et al., 2005). Whilst there was some age-related improvement in children with ADHD too, those with ADHD continued to make a much higher number of tight fits than did control children across all age groups. Whilst the literature against which this finding can be compared is limited, the findings reported here relating to the performance of children with ADHD align well with those of Clancy et al. (2006) who also reported children with ADHD perform much less well than controls of the gap timing task. The also resemble those reported recently by Nikolas et al., (2016) in respect of the ability of adolescents with ADHD to time gaps between cars whilst cycling. Nikolas and colleagues reported those with ADHD accepted smaller gaps whilst cycling and report similar findings in relation to the efficiency of children's use of gaps as reported here through the findings pertaining to starting delay and effective gap size.

### 12.4.2 Perceived Difficulty

Findings also reveal the developmental profile of the perceived difficulty of the gap timing task in the ADHD population for the first time. At pre-trial, there were no differences in difficulty estimations offered by children with ADHD and controls. At post-test however, typically developing children appear to have revised their ratings after attempting the task and rate it as being more difficult with age. Thus as they grow up, the experience of having completed the task allows typically developing children to gain appreciation of its complexity. This was not observed amongst children with ADHD.

Whilst it is clear the extent to which typically developing children revise their difficulty judgements in this way is age dependent, children with ADHD do not make such revised judgements at any age. This in spite of the fact that their actual performance was significantly poorer than that of typically developing controls and they therefore had, in this sense, much greater scope to see that the task, for them, was difficult and that they were not performing well, yet failed to see this and update their post-trial difficulty ratings accordingly. Thus the overarching ability of children with ADHD to see the difficulties posed by the task and their awareness of their ability to complete the task is poor and does not improve with age, as is the case for the controls. The significantly easier difficulty ratings made by children with ADHD are not justified in terms of their actual performance.

### 12.4.3 Summary and Conclusions

In summary, the current study provides further evidence of significant differences in the abilities of children with and without ADHD to perform a key pedestrian skill which is central to the safe navigation of the traffic environment. The current study shows children with ADHD are willing to accept smaller gaps, have longer starting delays, smaller effective gaps and significant more tight fits than do control children. These findings represent a significantly less safe performance of the ADHD group overall.

The findings of the current study add significantly to those of past studies which have made similar conclusions about the abilities of children with ADHD in relation to the performance of this pedestrian skill (Clancy et al., 2006, Stavrinos et al., 2011) through its consideration of age. This study has shown very little age related improvement in performance of children with ADHD. The gap in performance between groups either remains constant or actually increases with age.

In addition, the findings relating to the perceived difficulty of the gap timing task at post-trial reveal further differences between children with and without ADHD in respect of the visual gap timing task and also provide further evidence for a tendency of children with ADHD to underestimate the difficulty relative to the safety of their performance (which do not appear correlated). Those with ADHD do not upgrade difficulty estimations with age in the same manner typically developing children do following the experience of undertaking the task. Post-trial difficulty estimations offered by children with ADHD do not increase with age but rather remain static in spite of the significantly poorer overall performance of those with ADHD compared with case matched control children.  Thus not only are children with ADHD less skilled when it comes to the visual gap timing task, but they are also unaware of their difficulties and continue to rate the task as being easy after completing it, despite not doing so in a safe manner.

# Chapter 13

## Study 2.3: The ability to Predict Road User Intentions in children with ADHD

### 13.1 Introduction

The ability to predict the intentions and future actions of other road users is a key ability central to safe road use which reflects the interactive and participatory nature of the traffic environment. This will be the final pedestrian skill examined amongst children with ADHD in this thesis. As discussed in chapter 6, it is crucial that pedestrians are able recognise and interpret the actions of other road users and understand what these reveal about their intentions. As part of this process, pedestrians must identify environmental cues in order to anticipate future vehicle movements and modify their own movements and behaviour accordingly (Tolmie et al., 2002). Like previous studies of this skill (Foot et al., 2006, Tolmie et al., 2002), study 1.3 of this thesis demonstrated this is something younger children are much less able to do compared with older children but that this ability improves significantly between the ages of 5 and 12 years of age.

Recent studies have demonstrated children with ADHD are much less safe as pedestrians compared with control children in respect of visual gap timing ability (Clancy et at., 2006, Stavrinos et al., 2011) and as shown in chapter 11, also in respect of safe place finding ability. Yet the ability of children with ADHD to predict the intentions and future actions of other road users has never been previously studied. This is surprising for a number of reasons.

The additional social component implicit in the skill under current investigation suggests children with ADHD might be even less competent in their ability to perform this skill than their typically developing peers. The ability to predict the intentions and future actions of other road users would seem to at least partly require pedestrians to infer the states of minds of others. They must use cues in the environment and the observed actions of others to determine the most likely future course of action individuals will take. A range of studies have shown children with ADHD are impaired in terms of social cognition, including conversational interaction (Green et al., 2014), emotion regulation (Sinzig, 2008), social adjustment (Huang-Pollock et al., 2009) and the perception and understanding of social behaviour (Parker & Asher, 1987, Tseng & Gau, 2013).

It has been suggested that these social difficulties may at least in part be attributable to the profile of cognitive deficit common amongst children with ADHD (Perner et al., 2002). Indeed, neuropsychological (and in particular executive) functions have been previously linked with Theory of Mind (see review by Devine & Hughes, 2014). Research suggests executive functions influence the emergence rather than the expression of ToM whereby intact executive functions appear necessary for the development of ToM even in early childhood (Carlson, Claxton & Moses, 2015; Carlson, Mandell & Williams, 2002; Hughes, Dunn & White 1998). There is also recent evidence that the relationship between executive functions and ToM extends into later childhood (Bock et al., 2014) and adulthood as well (Uzefovsky, Allison, Smith & Baron-Cohen, 2016). Although most research in this field has focused on children with Autism Spectrum Disorders (ASD) (e.g. Baron-Cohen, Leslie & Frith, 1985), difficulties with ToM amongst those with ADHD might be reasonably expected given the comorbidity of ADHD and ASD and some studies have reported ToM impairment in ADHD. Perner and colleagues for example reported 'hard to manage' children suspected of having ADHD have difficulties with higher order Theory of Mind (ToM) tasks (Perner, Kain & Barchfeld, 2002). Nyden et al. (2010) compared adults with ADHD to those with comorbid ADHD and Autism Spectrum Disorder (ASD), and those with ASD alone and reported no differences in ToM abilities between the groups. Charman, Carroll and Sturge, (2001) showed children with ADHD were impaired on a task assessing ToM and inhibitory control. Whilst measures of inhibitory control and ToM scores were correlated for typically developing children, these were not correlated for children with ADHD. Thus aspects of neuropsychological functioning commonly impaired in children with ADHD (Rhodes et al., 2005), have been linked with ToM in both pre-schoolers and children in middle childhood (Bock et al., 2014, Hughes, 1998) but these relationships seem absent in children with ADHD (Charman, Carroll & Sturge, 2001).

Therefore, in addition to the likely difficulties children with ADHD will experience because of the cognitive underpinnings of the predicting road user intentions task revealed in chapter 7, the additional social component of the predicting road user intentions task may add an additional layer of difficulty for children with ADHD. Yet no previous studies have investigated this possibility and the ability of children with ADHD to make such pedestrian judgements is unknown. The current study aimed to provide the first data in this regard.

Whilst no past research has considered how difficult children with ADHD perceive the task of predicting the intentions of other road users to be, the findings relating to perceived difficulty reported in the preceding two chapters demonstrate children with ADHD underestimated the difficulty of the safe place finding and visual gap timing tasks at post-test relative to controls. It might be reasonably expected that this tendency will pervade the final pedestrian skill under current examination.

It was hypothesised that:

1. Children with ADHD will be significantly less able to predict the intentions of other road users compared with children in the control group.

2. Children with ADHD will be significantly less able to identify cues specifying other road user intentions and use these to justify the predictions they make compared with children in the control group.

3. There will be an interaction between participant group (ADHD vs. control) and age group such that differences in performance between those with and without ADHD will become more apparent with age.

4. Perceived difficulty will vary significantly between participant groups, with children with ADHD rating the task as being significantly less difficult than children in the control group.

## 13.2 Method

### 13.2.1 Participants

61 medication naïve children with ADHD and 61 case matched typically developing control children took part in the current study, providing a total sample size of 122 participants. Children with ADHD were matched to control children on chronological age, verbal ability (percentile rankings of the BPVS III) and gender. The mean age of the ADHD group was 97.79 months (SD=10.08). The mean age of the control group was 94.42 months (SD=7.22). Children were also assigned to one of three age groups (6 years and under, 7-8 year olds & 9 years and over). More information about the sample and its recruitment as well as characteristics of the age groups are provided in chapter 10.

### 13.2.2 Design

The study design was between groups with participant group (ADHD or control) and age group as the between group factors.

### 13.2.3 Materials and Procedure

The predicting road user intentions task used in the current study is the same task used in chapter 6 of this thesis. This was selected from the Crossroads pedestrian training and assessment software (Thomson et al., 2005). It was administered in exactly the same manner reported in chapter 6. The task and its administration are described in more detail in chapters 3, 6 and 9.

## 13.3 Results

### 13.3.1 Behavioural Measures

The mean number of correct predictions made on the task was first calculated as a function of participant group and age group. These data are presented in Table 13.1 below.

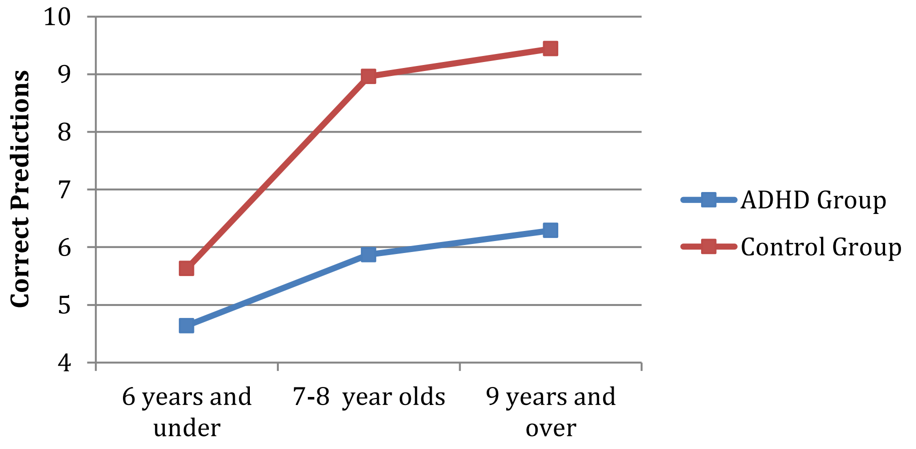
Table 13.1: Mean (& S.D.) Number of Correct Predictions* as a function of Participant Group and Age Group

| Age Group | ADHD Group | Control Group |
|---|---|---|
| 6 years and under | 4.64 (1.95) | 5.63 (2.73) |
| 7-8 year olds | 5.87 (2.11) | 8.96 (1.93) |
| 9 years and over | 6.29 (2.40) | 9.44 (1.38) |
| Overall | 5.68 (2.19) | 8.20 (2.03) |

* out of 11

A two way ANCOVA with participant group and age group as independent variables (and BPVS percentile rank as a covariate) revealed the number of correct predictions varied significantly as a function of both participant group ($F[1,111]=34.61$, $p<.001$, $\eta^2=.238$) and age group ($F[2,111]=15.46$, $p<.001$, $\eta^2=.218$). Children in the control group made significantly more correct predictions than did children with ADHD across all age groups. The number of correct predictions increased with age for both children with and without ADHD. The participant group by age group interaction did not reach levels of statistical significance ($F[2, 111]=2.62]$, $p=.077$, $\eta^2=.045$). Planned contrasts revealed whilst there was no effect of group amongst children in the youngest age group ($F[1,27]=0.78$, $p=.384$, $\eta^2=.000$) there were significant effects of group for the middle (F [1,53]=19.79, $p$<.001, $\eta^2$=.259) and oldest age groups ([1,29]=22.36, $p$<.001, $\eta^2$=.422). These findings are shown in Figure 13.1 below.

Figure 13.1: Mean Number of Correct Predictions as a Function of Participant Group & Age Group



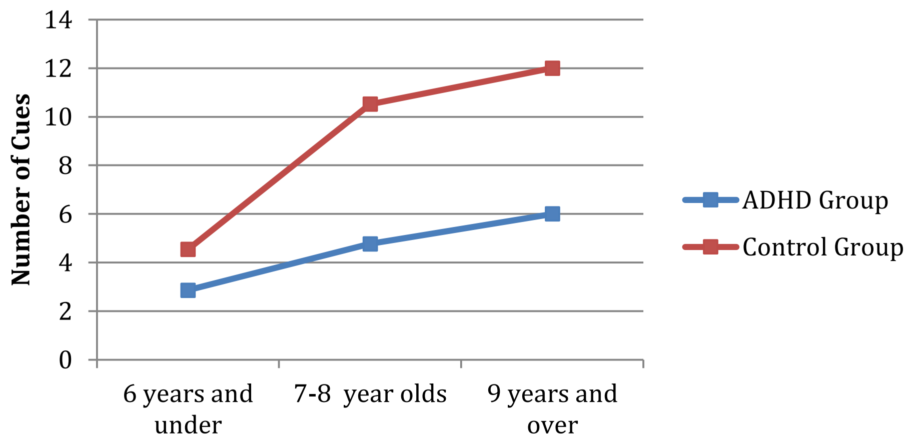

Next, the mean number of cues children identified and used as a justification for predictions were calculated by participant group and age group. These data are displayed in Table 13.2 below.

Table 13.2: Mean (and S.D.) Number of Correct Predictions on the Predicting Road User Intentions Task as a function of Participant Group and Age Group

| | ADHD Group | Control Group |
|---|---|---|
| 6 years and under | 2.86 (2.35) | 4.54 (2.54) |
| 7-8 year olds | 4.77 (3.17) | 10.52 (3.36) |
| 9 years and over | 6.00 (2.60) | 12. 00 (2.72) |
| Overall | 4.61 (3.03) | 9.54 (4.16) |

A further two way ANCOVA with participant group and age group as factors (and BPVS percentile ranking as a covariate) revealed the number of environmental cues identified also varied significantly as a function of both participant group ($F[1,111]=58.47$, $p<.001$, $\eta^2=.360$) and age group ($F[2,111]=25.76$, $p<.001$, $\eta^2=.331$). Children in the control group identified more environmental cues than did children with ADHD across age groups. Children also identify more cues with age across both participant groups. These findings are shown in Figure 13.2 below.

Figure 13.2: Mean Number of Cues Identified as a Function of Participant Group and Age Group




A significant interaction between participant group and age group was also found ($F[2,111]=2.62$, $p=.009$, $\eta^2=.087$). The findings displayed in Figure 13.2 suggests this is because the difference between the ADHD and control groups was small in the youngest age group but is larger in the older groups. Individual planned contrasts for each age group confirmed this. There was no significant effect of participant group amongst children aged 6 and under ($F[1, 27]=3.42$, $p=.077$, $\eta^2=.125$) but significant differences as a function of participant group were revealed amongst 7-8 year olds ($F[1, 53]=30.37$, $p<.001$, $\eta^2=.383$) and aged 9 years and over ($F[1,32]=38.59$, $p<.001$, $\eta^2=.570$). These results confirm that typically developing children make larger gains with age than do those with ADHD. The difference between children with ADHD and controls in respect of the ability to identify environmental cues appears to widens as children develop.

### 13.3.2 Perceived Difficulty

Next, the mean perceived difficulty estimations for pre and post-trial ratings were calculated by participant group and age group. These data are presented in Table 13.3 below.

Table 13.3: Mean (& S.D.) Pre & Post-trial Perceived Difficulty rating* for the Predicting Road User Intentions Task by Participant Group and Age Group

| | ADHD Group | | Control Group | |
|---|---|---|---|---|
| | Pre-trial | Post-trial | Pre-trial | Post-trial |
| 6 years and under | 34.55 (32.03) | 35.77 (27.55) | 40.14 (19.93) | 35.40 (15.59) |
| 7-8 year olds | 43.27 (25.17) | 32.63 (19.07) | 35.08 (23.44) | 37.21 (20.32) |
| 9 years and over | 42.14 (29.14) | 36.75 (22.03) | 47.94 (12.70) | 45.78 (17.57) |
| Overall | 40.94 (27.59) | 34.35 (21.69) | 40.38 (20.19) | 39.40 (18.57) |

*Maximum Rating=100

A two-way ANCOVAs revealed there were no significant participant group ($F[1, 111]=0.04$, $p=.844$, $\eta^2=.000$) or age group ($F[2, 111]=0.89$, $p=.415$, $\eta^2=.016$) differences in difficulty rating for pre-trial estimations and there was no interaction

(F[2, 111]=1.12, *p*=.331, $\eta^2$=.020). Similarly, there were no differences for post-trial estimations in respect of participant group (F[1, 111]=1.37, *p*=.245, $\eta^2$=.012) or age group (F[2, 111]=0.89, *p*=.414, $\eta^2$=.016) and there was no interaction (F[2, 111]=0.44, *p*=.647, $\eta^2$=.008).

## 13.4 Discussion

### 13.4.1 Behavioural Measures

The findings pertaining to the number of correct predictions reveal those with ADHD were significantly less able to correctly predict the intentions and future actions of other road users. Younger children also performed significantly less well than did older children across groups whereby performance appears to increase with age. However, the findings also show the performance of children with ADHD lags behind typically developing control children to the extent that those with ADHD at age 11 perform at the same level as a typical 5-year-old.

Although the current study is the first to examine this pedestrian skill amongst children with ADHD, this finding is well aligned with results in earlier chapters in this thesis and with previous studies which have reported similar findings in respect of others skills (Clancy et al., 2006, Stavrinos et al., 2011) and the present findings suggest the difficulties children with ADHD experience in respect of pedestrian skill level are broader than has previously been shown. The findings also align well with the broader developmental literature, in which a number of studies have shown children with ADHD have problems with aspects of social cognition (Devine & Hughes, 2014, Perner et al., 2002, Tseng & Gau, 2013). The current study provides evidence that these difficulties impact negatively in the applied context of decision making about the intentions and future actions of other road users.

Findings relating to the number of cues children were able to identify and use when asked to justify their predictions reveal the judgments of children with ADHD are predicated far less on cues which can explicitly reveal the likely course of action of other road users. Thus children with ADHD are less likely to correctly anticipate what is going to happen because they are not sensitive to the cues in the traffic environment that provide information about what is likely to happen.

A possible explanation of these findings is that children with ADHD cannot focus their attention on relevant cues, perhaps because they cannot filter out or inhibit other irrelevant stimuli which capture their attention and are thus unable to distinguish cues from other irrelevant features of road. This would seem plausible given the well documented difficulties children with ADHD have been shown to experience in respect of inhibitory control (Barkley, 1997; Kempton et al., 1999; Willcutt et al., 2005) which were also revealed in the current sample. This finding may also reflect difficulties with visual search amongst children with ADHD which is likely to be less structured and logical than it is in control children. This would seem likely given past research has shown children with ADHD have difficulties with visual search compared with control children in other domains (Mason, Humphreys & Kent, 2004). Mason and colleagues reported children with ADHD use the same visual search mechanisms as typically developing children but those with ADHD made more errors and failed to inhibit irrelevant items during searches. At present it cannot be said with certainty whether or not this is what underpins the poorer performance of children with ADHD in relation to the identification of cues on the predicting road user intentions task, but future research might address this possibility, for example through eye tracking studies to explore the visual search of young pedestrians with ADHD in context of the traffic environment.

The findings reported here also broadly fit with the wider ADHD literature which has demonstrated children with ADHD experience difficulties with aspects of social cognition, in particular, ToM tasks (Perner, Kain & Barchfeld, 2002). The findings revealed in the current study demonstrate these difficulties extend into the domain of road user behaviour and show children with ADHD are much less able to make judgements about the intentions of other road users. The extent to which these difficulties might be underpinned by underlying problems with ToM as previously reported in the ADHD population is not clear from the current study and future research may wish to examine this possibility also.

### 13.4.2 Perceived Difficulty

The findings relating to the perceived difficulty of the task did not support the third hypothesis. Children with ADHD rated task difficulty in a way similar to control children. This was surprising given the findings in respect of the other pedestrian skills examined in this thesis. It was shown that neither pre-trial nor post-trial difficulty estimations varied between children with and without ADHD or indeed between children of different ages. Thus children with ADHD appear to perceive the difficulty of the predicting road user intentions task in a way similar to typically developing control children.

The reason for this disparity in contrast to differences revealed in respect of the other skills investigated in this thesis is not clear but as discussed in chapter 6, may reflect the different ways humans make judgements about the future actions of others (Frith & Frith, 2006, Schultz et al., 2004) or may reflect views about error making in this context whereby prediction errors are often used to improve future decisions (Frith & Frith, 2006).

Alternatively, despite there being age-related improvement in the number of correct predictions, the sample still performed poorly overall. Those with ADHD on average made 5 correct predictions whilst controls made an average of 8 out of a possible 11 correct predictions. There is therefore still room for improvement across the sample as a whole which would suggest that this skill slow in developing and so perhaps less surprisingly none of the participants had a well developed sense of task difficulty.

### 13.4.3 Summary and Conclusions

This study is the first to demonstrate significant differences in the ability of children with ADHD compared with controls to predict the intentions and future actions of other road users. It appears children with ADHD are much less able to perform this pedestrian skill than are age matched typically developing control children but respond similarly to controls in terms of perceived difficulty of the task. Whilst there is some developmental improvement amongst those with ADHD, this improvement is much less marked compared to the gains made by typically developing children. Even by age 9 years, children with ADHD do not perform as well as a typically developing 6-year-old. Similar trends were observed in relation to the ability to identify cues in the environment when children were asked to justify their predictions.

# Chapter 14

# Study 2.4: Neuropsychological Function & Pedestrian Skill Level in Children with ADHD

## 14.1 Introduction

Study 1.4 of this thesis demonstrated relationships between aspects of executive functioning and typically developing children's pedestrian skill level in respect of three key pedestrian skills, namely safe route planning, visual gap timing and the ability to predict the intentions and future actions of other road users. Typically developing children who performed well on tasks assessing short term visual memory and spatial working memory, and to a lesser extent inhibitory control, also tended to perform well on tasks assessing pedestrian skill level. Part B of this thesis has then shown significant differences in skill level between children with and without ADHD in respect of the same three pedestrian skills. A recent study has suggested the profile of cognitive deficit associated with ADHD may account for this difference (Stavrinos et al., 2011) yet very few studies have set out to examine this empirically. An examination of these relationships will be the focus of the current study.

It has long been argued children with ADHD exhibit impairment in terms of a number of cognitive abilities compared with typically developing children, including delay aversion (Sonuga-Barke et al., 2002), temporal information processing (Toplack & Tannock, 2005) and aspects of executive function (Barkley, 1997; Coghill et al., 2014; Fair, Bathula, Nikolas & Nigg, 2012; Sonuga-Barke et al., 2010; Rhodes et al., 2005), as discussed in chapter 1. Most researchers today agree upon a multicomponent account of executive function (Lehto et al., 2003; Miyake et al., 2000; Wu et al., 2011) and impairment in multiple impairments in EF amongst those with ADHD (Coghill et al., 2013).

Some recent studies have postulated that aspects of cognitive function may be related to the ability of children to behave safely as pedestrians (e.g. Barton & Morrongiello, 2011). Others too have suggested there are key cognitive underpinnings to the development of safe pedestrian behaviour and skill level, highlighting inhibitory control (Tabibi & Pfeffer, 2003), working memory, selective attention and visual search (Barton et al., 2010) as well as executive functioning more broadly, assessed using composite measures (Barton, 2006). However, these studies have focused exclusively on the ability to time gaps between cars in a flow of traffic using a relatively restricted range of behavioural measures. They have not considered the wider range of skills that form the focus of the present thesis which reflects the range of ways children make decisions by the roadside and very few studies indeed have considered pedestrian skill level or its relationship to cognitive impairment in children with ADHD.

One study by Clancy et.al. (2006) demonstrated behavioural differences in the safety of children with and without ADHD when completing a visual gap timing task on a virtual reality simulator. Those with ADHD had much less time left to spare, walked slower, made poor use of the gap available between cars (wasting time before beginning to cross) and were hit twice as often as were controls. In a similar study, Stavrinos et al. (2011) report children with ADHD who had suspended medication for 24 hours before testing crossed through smaller gaps and had less time to spare compared with control children.  Unlike Clancy et al., Stavrinos and colleagues go on to argue that problems with EF explain the relationship between ADHD and unsafe pedestrian behaviour.  However, Stavrinos and colleagues were unable to specify which aspects of EF are predictive because EF was not comprehensively examined in that study and was reported via a composite measure which was a significant limitation.  This study also failed to take account of impairment in more basic cognitive processes such as non-executive delayed short term memory, which is also impaired in ADHD (Dovis et al., 2013; Kempton et al., 1999; Rhodes et al., 2004, 2005, 2012).  The findings of study 1.4 reported in chapter 7 of this thesis showed delayed short term visual memory, spatial working memory and inhibitory control were related to pedestrian skill level amongst typically developing children. These functions have also been shown impaired amongst children with ADHD (Castellanos et al., 2006; Kempton et al., 1999; Martinussen & Tannock, 2006; Willcutt et al., 2005; Toplak et al., 2008).  The current study aims to examine the extent to which the relationship between these functions and child pedestrian skill level are similar or different amongst children with ADHD.

Stavrinos et al. also tested children with ADHD who were being treated with stimulant medication and had suspended medication for 24 hours before testing. This is a methodological limitation because medication has been shown to significantly improve ADHD symptoms even 12 months after medication has been suspended (Aggarwal & Lilystone, 2000; Guang et al., 2012).  The current study will address these limitations by i) identifying which specific aspects of cognitive function predict aspects of pedestrian skill level in children with ADHD and ii) undertake to determine these relationships in a medication naive sample of children with ADHD for the first time.

In summary, the performance of children with ADHD in relation to visual gap timing ability has been previously shown to be impaired and it has been argued this may reflect impairment of cognitive functions important for the performance of this skill. It is also possible that impaired cognitive functioning may underpin the poorer performance of children with ADHD on the safe place finding and predicting road user intentions tasks as reported in chapters 11 and 13 respectively.

The aim of the current study is to investigate these relationships amongst medication naive children with ADHD. Differences in performance of each of the tasks assessing aspects of cognitive function will therefore be examined before the relationship between neuropsychological function task performance and pedestrian skill level will be compared.

The following experimental hypotheses have been formulated:

1. There will be significant differences in the performance of children with ADHD and controls in respect of both executive and non-executive aspects of cognition such that;
    i) Children with ADHD will be impaired on the Stop Signal Task assessing inhibitory control,

ii) Children with ADHD will also be impaired on the Spatial Working Memory Task and,

iii) Children with ADHD will be impaired on the Delayed Match to Sample Task assessing delayed short term visual memory

2. There will be significant effect of age whereby older children will perform better on tasks assessing cognitive function compared with younger children but there will also be an interaction between participant group and age group. Differences between the performances of children with and without ADHD on tasks assessing cognitive function and pedestrian skill level will become more marked as children develop.

In addition, this study aims to explore the cognitive predictors of pedestrian skill level for children with ADHD and controls separately, to establish the pattern of relationships for each participant group.

## 14.2 Method

### 14.2.1 Participants

122 children took part in this study (61 medication naïve children with ADHD and 61 case matched control children). The mean age of the sample was 7 years 9 months. 98 were male. Children with ADHD were matched to typically developing control children on chronological age and gender. Differences in general verbal ability were controlled for by including percentile rank on the BPVS as a covariate. The mean age of the ADHD group was 97.79 months (SD=10.08) and the mean age

of the control group was 94.42 months (SD=7.22). Once again, children were assigned to one of three age groups (6 years and under, 7-8 year olds & 9 years and over). See chapter 10 for further information about the sample.

### 14.2.2 Design

The design was between groups. Participant group (ADHD or control) and age group served as between group factors.

### 14.2.3 Materials and Procedure

All participants first completed the BPVS-III which provided a measure of general verbal ability which was used for control and matching purposes. Controls were screened by a teacher rating on the SDQ (Goodman et al., 1997). Participants then completed three tasks assessing pedestrian skill level from the Crossroads pedestrian training and assessment software (the safe place finding, visual timing and predicting road user intentions tasks) and three tasks from the CANTAB battery (the Stop Signal Task assessing inhibitory control, Spatial Working Memory Task assessing visuo-spatial working memory and the Simultaneous and Delayed Match to Sample Task assessing delayed short term visual memory). Full verbal instruction was provided before tasks were completed on a standard laptop computer and touch screen tablet respectively. More information about the materials and procedure can be found in chapter 10 and a summary of the outcome measures for each task in Chapter 7.

### 14.3 Results

#### 14.3.1 Spatial Working Memory

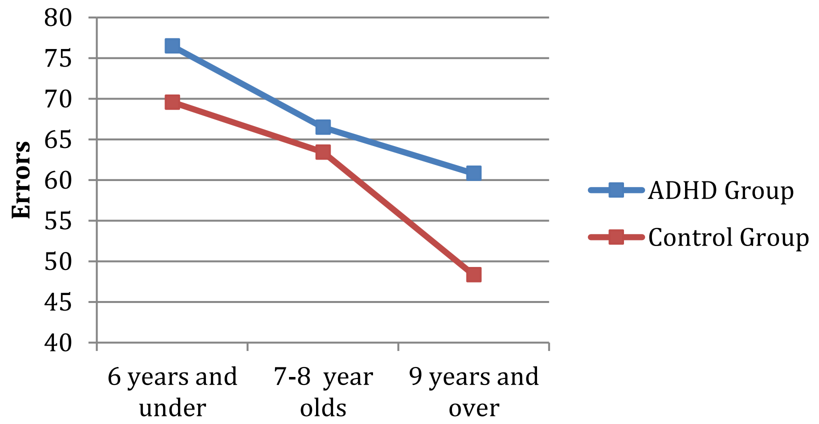
The mean number of between search errors (BSE) on the spatial working memory task was calculated for the task as a whole as well as for each of the three difficulty levels as a function of participant group and age group. BSE reflects the number of times a participant returned to check a box where a token had already been found in a previous search and is the primary outcome measure of the SWM task. BSE are also examined as a function of trial complexity and are thus subdivided into 4, 6 and 8 box trials (as well as overall BSE) to allow for comparison of performance at varying task difficulty levels reflecting working memory load. These data are presented in Table 14.1 below.

Table 14.1: Mean (& S.D.) Number of Between Search Errors as a function of Participant Group and Age Group

| | ADHD Group | | | | Control Group | | | |
|---|---|---|---|---|---|---|---|---|
| | Total Between Search Errors | BSE 4 Box Trials | BSE 6 Box Trials | BSE 8 Box Trials | Total Between Search Errors | BSE 4 Box Trials | BSE 6 Box Trials | BSE 8 Box Trials |
| 6 years & under | 76.47 (20.28) | 6.93 (3.77) | 25.13 (8.72) | 44.40 (10.25) | 69.59 (15.08) | 6.24 (4.01) | 22.47 (8.10) | 40.88 (9.47) |
| 7-8 Year Olds | 66.48 (19.88) | 4.42 (4.01) | 21.58 (8.18) | 40.48 (10.52) | 63.42 (14.83) | 4.69 (3.61) | 18.58 (7.29) | 40.15 (7.04) |
| 9 Years & Over | 60.80 (19.23) | 4.93 (4.06) | 18.93 (7.38) | 36.93 (12.09) | 48.33 (13.28) | 2.44 (2.97) | 13.89 (6.08) | 32.00 (8.57) |
| Overall | 67.54 (20.29) | 5.16 (4.03) | 21.80 (8.29) | 40.57 (10.10) | 60.69 (16.54) | 4.46 (3.79) | 18.28 (7.80) | 37.95 (8.97) |

A two way ANCOVA with participant group and age group as factors, BPVS percentile rankings as a covariate and overall between search errors as the dependent variable revealed children with ADHD made significantly more BSEs overall than did controls ($F[1,115]=3.95$, $p=.049$, , $\eta^2=.029$). ANCOVA also revealed overall BSE varied significantly between age groups ($F[2,115]=9.97$, $p<.001$, $\eta^2=.124$) whereby the number of errors reduced with age across both participant groups. There was no significant interaction between participant group and age group ($F[2,115]=1.57$, $p=.213$, $\eta^2=.028$). These findings are presented in Figure 14.1.

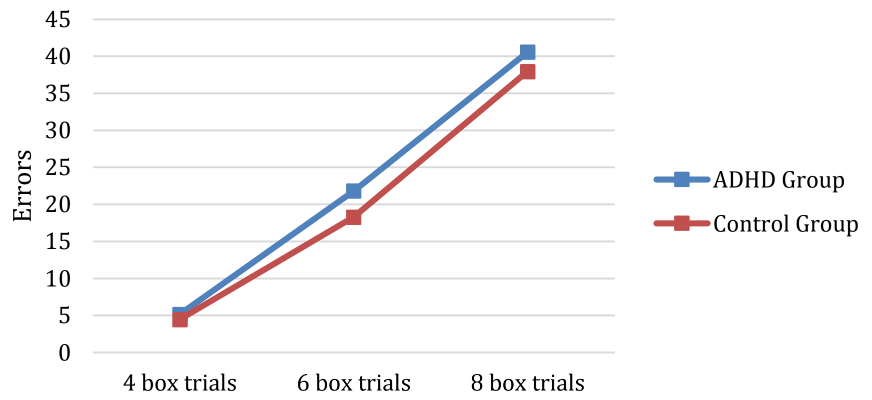
Figure 14.1: Overall Between Search Errors as a Function of Participant Group & Age Group




Although the interaction effect between participant group and age group was not significant, Figure 14.1 above demonstrates that the differences between children with and without ADHD appears to increase with age such that the difference between participant groups is more marked amongst the children aged 9 and over but less marked amongst younger children. Planned contrasts revealed there was no difference between children with and without ADHD at age 6 and under ($F[1,27]=0.52$, $p=.478$, $\eta^2=.019$) or at age 7-8 years ($F1,53]=0.04$, $p=.833$, $\eta^2=.001$) but differences between children with and without ADHD at age 9 years and over were significant (F[1,29]=5.14, *p*=.031, $\eta^2$=.151). Caution is needed however as the interaction effect was not congenitally significant.

Next, differences in responding for each difficulty level of the task (4, 6 or 8 box trials) were examined separately. A mixed MANCOVA with difficulty level as a repeated measure, participant group and age group as between group factors (and BPVS percentile ranking as a covariate) showed a main effect of age group (F[2,115]=4.18, p=.043, $\eta^2$=.036) and difficulty level (F[2,230]=331.92, *p*<.001, $\eta^2$=.031). The number of errors increased with trial difficulty as shown in Figure 14.2 below.

Figure 14.2: Between Search Errors as a function of Participant Group and Difficulty Level




There was no significant interaction between difficulty level and participant group (F[2,230]=1.34, *p*=.263, $\eta^2$=.010). Both children with and without ADHD made a greater number of errors as task difficulty increased. There was an interaction between trial difficulty level and age group ($F[4, 230]=2.57$, $p=.021$, $\eta^2=.067$) whereby the number of errors reduced more significantly for the most difficult level for those children in the oldest age group. There was no interaction between difficulty level, participant group and age group ($F[4, 230]=0.99$, $p=.913$, $\eta^2=.008$).

### 14.3.2 Inhibitory Control

Next, performance on the SST assessing inhibitory control was examined. The mean stop signal reaction time (SSRT) was calculated for each participant group and age group. SSRT is the mean time in milliseconds between the appearance of the go stimulus and presentation of the stop signal at which participants successfully inhibited their response during the last 50% of trials (i.e. the processing time required to inhibit a pre-potent response). These data are presented in Table 14.2 below.

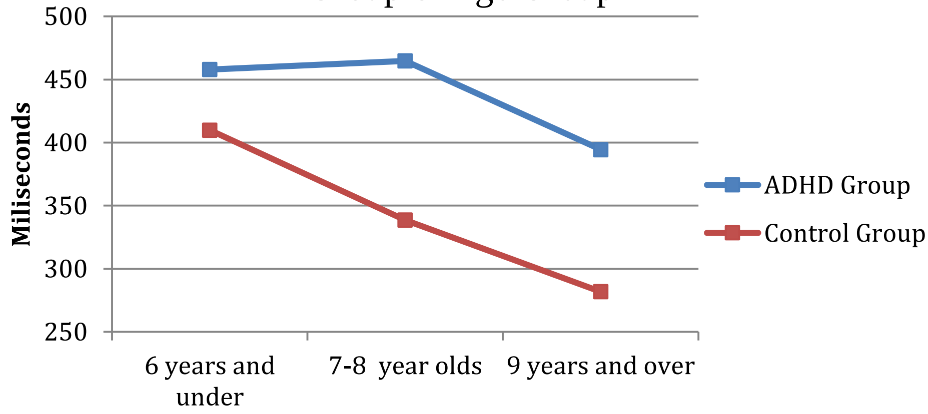
Table 14.2: Mean (& S.D.) Stop Signal Reaction Time* as a function of Participant Group and Age Group

| | ADHD Group<br>Stop Signal Reaction Time<br>(milliseconds) | Control Group<br>Stop Signal Reaction Time<br>(milliseconds) |
|---|---|---|
| 6 years & under | 457.93<br>(112.32) | 409.97<br>(89.87) |
| 7-8 Year Olds | 464.75<br>(88.53) | 338.60<br>(112.87) |
| 9 Years & Over | 394.50<br>(119.68) | 281.91<br>(106.79) |
| Overall | 445.80<br>(105.29) | 341.77<br>(114.41) |

*in milliseconds.

ANCOVA revealed stop signal reaction time varied significantly between participant groups (F[1,115]=21.76, $p$<.001, $\eta^2$=.156) and age groups (F[2, 115]=7.52, $p$=.001, $\eta^2$=.094). SSRT reduces with age, representing an improvement in performance as children grow older. Children with ADHD had higher SSRTs than controls across all ages, reflecting an overall poorer performance. There was no interaction between participant group and age group (F[2,115]=0.92, $p$=.400, $\eta^2$=.026). The effects of participant group and age group on SSRT are shown in Figure 14.3.

Figure 14.3: Stop Signal Reaction Time as a Function of Participant Group & Age Group




Although the interaction between participant group and age group was not significant, planned contrasts revealed the gap in performance between children with ADHD and controls widens with age. There was no significant difference between children with and without ADHD in the 6 years and under age group (F[1, 27]=1.04, $p$=.317, $\eta^2$=.037) but there were significant differences between children with and without ADHD at age 7-8 (F[1, 57]=13.69, $p$=.001, $\eta^2$=.205) and 9 years and over

($F[1,29]=8.17$, $p=.008$, $\eta^2=.220$). These findings suggest the gap between the performance of children with and without ADHD increases with age but this must be interpreted with caution as the interaction was not conventionally significant.

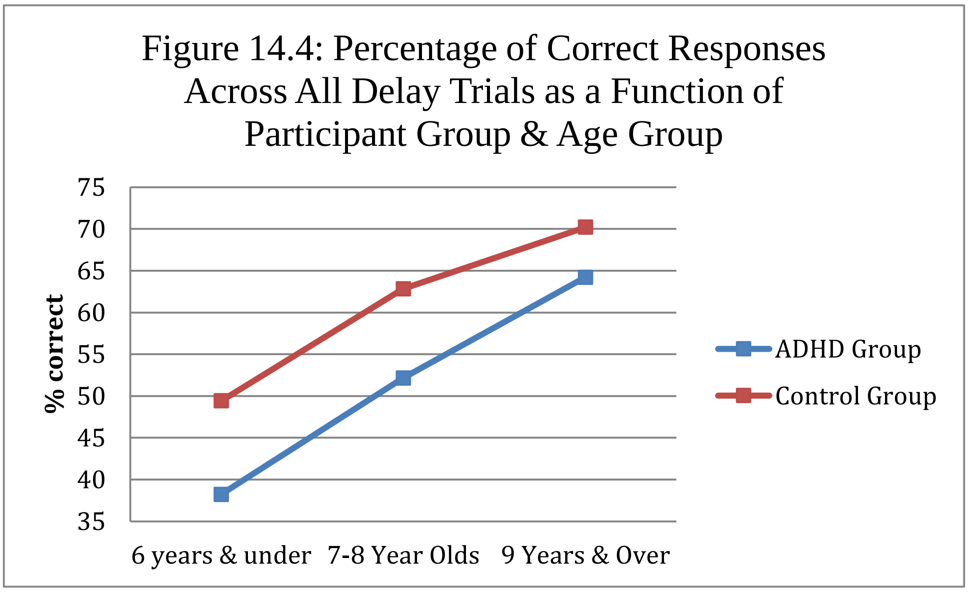
### 14.3.3 Delayed Short Term Visual Memory

Performance on the DMtS assessing short term visual memory was next examined. The total percent of correct responses across all delay conditions (% correct all delays) was calculated as a function of participant group and age group. This is the primary outcome measure which reflects overall performance on the task, across all conditions. The percent of correct responses on simultaneous trials without a delay condition (% correct simultaneous) and then for each of the (increasing) delay conditions was also calculated separately, as a function of participant group and age group to provide insight into performance as a function of difficulty as delay demands on short term memory increased. These data are presented in Table 14.3 below.

Table 14.3: Mean (& S.D.) Percentage of Correct Responses on Delayed Match to Sample Task as a function of Participant Group and Age Group

| | ADHD Group | | | | Control Group | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 second delay | 4 second delay | 12 second delay | All Delays | 0 second delay | 4 second delay | 12 second delay | All Delays |
| 6 years & under | 41.33 (29.73) | 46.67 (27.95) | 26.67 (19.52) | 38.22 (18.25) | 48.24 (21.28) | 57.65 (28.62) | 35.00 (22.29) | 49.41 (20.52) |
| 7-8 Year Olds | 46.77 (21.20) | 60.97 (25.87) | 48.71 (27.42) | 52.15 (15.70) | 71.54 (16.90) | 60.39 (20.49) | 56.54 (20.58) | 62.82 (12.92) |
| 9 Years & Over | 54.67 (11.87) | 76.00 (27.46) | 62.22 (23.05) | 64.21 (14.00) | 80.00 (10.29) | 72.22 (20.16) | 58.33 (26.62) | 70.19 (10.63) |
| Overall | 47.38 (22.05) | 61.15 (28.29) | 46.61 (27.41) | 51.59 (18.20) | 67.54 (20.71) | 63.12 (23.35) | 53.12 (23.63) | 61.26 (16.69) |

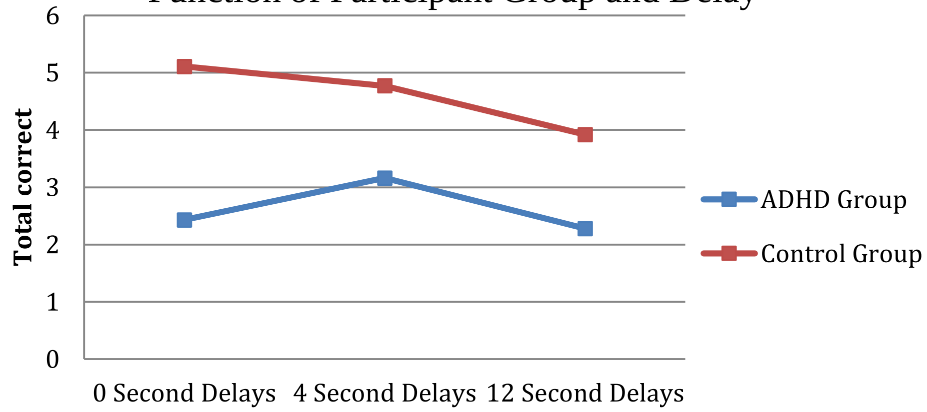
ANCOVA revealed the total percent of correct responses overall, across all delay conditions (% correct all delays), varied significantly between participant groups ($F[1,115]=8.74$, $p=.004$, $\eta^2=.072$) whereby the performance of children with ADHD was poorer than that of controls. There was also a main effect of age group whereby performance improved with age ($F[2,2115]=18.99$, $p<.001$, $\eta^2=.221$). There was no interaction between participant group and age group ($F[2,115]=0.32$, $p=.730$, $\eta^2=.004$). Differences in responding as a function of age and participant group are shown in Figure 14.4 below.




Planned contrasts revealed the percentage of correct responses was not significantly different between children with and without ADHD at age 6 years and under ($F[1,29]=2.19$, $p=.150$, $\eta^2=.075$), for children aged 7-8 years ($F[1,57]=3.41$, $p=.070$, $\eta^2=.060$) or for children aged 9 years and over ($F[1,29]=2.19$, $p=.150$, $\eta^2=.070$).

Next, performance according to trial difficulty (delay condition) was investigated using a mixed ANCOVA with participant group as a between subjects factor and difficulty level as a repeated measure (BPVS percentile ranks were covaried). There was no main effect of delay (F[2,230]=0.57, $p$=.576, $\eta^2$=.035). There was however an interaction between delay and participant group (F[2,230]=6.88, $p$<.001, $\eta^2$=.087) whereby differences between children with and without ADHD were apparent for the 0 second delay condition with differences in responding between groups becoming less marked as difficulty increased as shown below in Figure 14.5. This was confirmed by planned contrasts which revealed significant differences between participant groups (ADHD vs. control) for 0 second delay trials (F[1,119]=23.94, $p$<.001, $\eta^2$=.172) but not 4 second (F[1,119]=0.02, $p$=.891, $\eta^2$=.000) or 12 second delays (F[1,119]=2.25, $p$=.137, $\eta^2$=.019). There was no significant interaction between delay and age group (F[2,230]=1.97, $p$=.144, $\eta^2$=.011).

Figure 14.5: Percentage of Correct Responses as a Function of Participant Group and Delay



In summary, these findings demonstrate children with ADHD are impaired in terms of inhibitory control, spatial working memory and delayed short term visual memory compared with controls. Although the performance of children with ADHD across these tasks improves with age, it remains significantly below that of typically developing control children.

### 14.3.4 Summary of Child Pedestrian Task Performance

Clear differences between children with ADHD and controls has already been reported in relation to the behavioural outcome measures of each of the tasks assessing pedestrian skill level have been reported in chapters 11, 12 and 13 of this thesis. Because some of these data will act as the dependent variables in the subsequent analyses in this chapter, these have been summarised in Table 14.4 below. The data demonstrate children with ADHD performed less well than control children on the safe place finding, visual (gap) timing and predicting intentions tasks.

As a reminder, the children with ADHD performed in the following way on the pedestrian tasks.

Table 14.4: Summary of the Mean (& S.D.) scores for Tasks assessing Pedestrian Skill level as a function of Participant Group and Age Group

| | ADHD Group | | | | Control Group | | | |
|---|---|---|---|---|---|---|---|---|
| | 6 years & under | 7-8 year olds | 9 years & over | Overall | 6 years & under | 7-8 year olds | 9 years & over | Overall |
| **Safe Place Finding Task** | | | | | | | | |
| Proportion of Safe Routes | 0.13 (0.16) | 0.53 (0.23) | 0.44 (0.29) | 0.20 (0.20) | 0.18 (0.18) | 0.47 (0.23) | 0.56 (0.30) | 0.44 (0.28) |
| Proportion of High Conceptual Responses | 0.08 (0.14) | 0.17 (0.23) | 0.30 (0.26) | 0.18 (0.21) | 0.08 (0.17) | 0.54 (0.26) | 0.67 (0.23) | 0.48 (0.31) |
| **Visual Gap Timing Task** | | | | | | | | |
| Mean Accepted Gap (secs) | 5.33 (0.35) | 5.46 (0.38) | 5.41 (0.46) | 5.42 (0.46) | 5.33 (0.42) | 5.72 (0.30) | 5.82 (0.39) | 5.64 (0.41) |
| Effective Gap (secs) | 3.29 (0.54) | 3.63 (0.59) | 3.94 (0.85) | 3.62 (0.68) | 3.57 (0.57) | 4.30 (0.58) | 4.79 (0.62) | 4.24 (0.75) |
| Start Delay (secs) | 2.03 (0.54) | 1.84 (0.48) | 1.48 (0.39) | 1.80 (0.51) | 1.76 (0.55) | 1.42 (0.48) | 1.04 (0.32) | 1.40 (0.53) |
| Estimated Crossing Time (secs) | 3.31 (0.68) | 3.32 (0.74) | 2.86 (1.07) | 3.16 (0.83) | 3.33 (0.68) | 3.29 (0.45) | 3.32 (0.72) | 3.31 (0.60) |
| Number of Missed Opportunities | 0.98 (0.54) | 1.10 (1.12) | 1.17 (1.11) | 1.09 (1.00) | 1.38 (0.74) | 1.37 0.74) | 1.49 (0.85) | 1.41 (0.76) |
| Number of Tight Fits | 3.30 (1.03) | 2.96 (0.84) | 2.50 (1.22) | 2.93 (1.02) | 2.66 (1.00) | 2.00 (1.13) | 1.28 (1.04) | 1.97 (1.18) |
| **Predicting Road User Intentions Task** | | | | | | | | |
| Number of Correct Predictions | 4.46 (1.95) | 5.87 (2.11) | 6.29 (2.40) | 5.68 (2.19) | 5.63 (2.73) | 8.96 (1.93) | 9.44 (1.38) | 8.20 (2.03) |
| Number of Environmental Cues | 2.86 (2.35) | 4.77 (3.17) | 6.00 (2.60) | 4.61 (3.03 | 4.54 (2.54) | 10.52 (3.36) | 12.00 (2.72) | 9.54 (4.16) |

### 14.3.5 Relationship between Cognitive Function and Child Pedestrian Skill Level

The relationship between CANTAB task performance and child pedestrian task performance was next examined. Multiple regression analyses were used to determine the extent to which performance on tasks assessing neuropsychological function predicted performance on each of the tasks assessing pedestrian skill level by examining relationships between the primary outcome measures for each of the tasks assessing pedestrian skill level and the primary outcome measures of each of the tasks assessing cognitive functioning.

### 14.3.6 Safe Place Finding

To examine the relationships between, group membership (ADHD vs. control), cognitive function and performance on the safe place finding task, a two-step hierarchical multiple regression analyses was conducted. First, to examine predictors of performance on the safe place finding task, multiple regression analyses were used to determine the predictors of children's ability to identify safe crossing locations and routes across the road. In the first step, participant group was regressed on the proportion of safe routes. This accounted for a statistically significant proportion of the variance ($R^2$ =.19, $p$<.001). In the second step, the CANTAB outcome variables were added to the model which accounted for an increment to $R^2$ ($R^2$ =.24, Rchange2 =.05, $p$<.001) yet the standardised beta weights (in Table 14.5 below) revealed only group membership was a significant independent predictor.

Table 14.5: Predicting the Proportion of Safe Routes on the Safe Place Finding Task from Participant Group and CANTAB Outcome Measures

| Predictor Variables | $R^2$ | F | $\beta$ |
|---|---|---|---|
| **Step1** | .185 | 26.41 | |
| Group (ADHD vs. Control) | | | -.431*** |
| **Step 2** | .494 | 9.10 | |
| Group | | | -.324** |
| SSRT (Stop Signal Task) | | | -.125 |
| BSE (Spatial Working Memory Task) | | | -.093 |
| % correct all delays (Delayed Match to Sample Task) | | | .133 |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

To determine the cause of the increment to $R^2$ between the first and second steps and because these findings are different to those revealed in study 1.4 of this thesis, further analyses were conducted for the ADHD and control groups separately. The same analysis was once again used to regress the primary outcome variables from each of the CANTAB tasks on the proportion of safe routes, but this time for each participant group separately. When this analysis was conducted for children in the control group alone, the regression model accounted for a significant proportion of the variance ($R^2$ =.13, $p<.05$). The standardised beta weights in Table 14.6 show that performance on the simultaneous and delayed match to sample task (assessing short term visual memory) was an independent predictor of the performance of typically developing children on the safe place finding task. In contrast, when the same analysis was performed for the ADHD group, the model was not significant and no outcome measures of the CANTAB were predictors of performance. These findings are summarised in Table 14.6 below.

Table 14.6: Predicting the Proportion of Safe Routes on the Safe Place Finding Task from CANTAB Outcome Measures for each Participant Group Separately

| Predictor Variables | ADHD Group | | | Control Group | | |
|---|---|---|---|---|---|---|
| | $R^2$ | F | $\beta$ | $R^2$ | F | $\beta$ |
| Predictors | .06 | 1.21 | | .13 | 2.8<br>3 | |
| SSRT (Stop Signal Task) | | | -.10 | | | -.15 |
| BSE (Spatial Working Memory Task) | | | -.22 | | | 0.5 |
| % correct all delays (Simultaneous & Delayed Match to Sample Task) | | | -.02 | | | .32* |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

Thus it would appear for typically developing children, short term visual memory predicts the ability to identify safe crossing locations and routes across the road, whereas this relationship does not exist amongst children with ADHD. This likely explains the significantly poorer performance of children with ADHD in respect of the proportion of safe routes they select as reported in chapter 11.

### 14.3.7 Visual Gap Timing

Regression analyses were once again used to examine the relationship between participant group, CANTAB task performance and performance on the visual gap timing task. Predictors of performance on each of the outcome variables on the visual gap timing task were examined by regressing participant group and each of the primary outcome measures of the CANTAB onto each of the outcome variables for visual timing. In the first step of these analyses, participant group was regressed onto each outcome variable and in the second, CANTAB task outcome measures were added to the model. In the first steps, participant group accounted for a significant proportion of the variance in respect of accepted gap ($R^2$ =.06, $p$<.001), effective gap ($R^2$ =.15, $p$<.001), starting delay ($R^2$ =.14, $p$<.001) and the number of tight fits ($R^2$ =.15, $p$<.001). In the second steps of these analyses, the addition of the CANTAB outcome variables to the model resulted in an increment to $R^2$ in each analysis (see Table 14.7). In the second steps of these analyses, when controlling for participant group, SSRT on the SST and the percentage of correct responses across all delay conditions on the DMtS predicted effective gap size and starting delay. The percentage of correct responses on the DMtS also predicted the number of tight fits. The directions of these relationships reveal those with higher SSRTs (poorer inhibitory control) had smaller effective gaps and those with a higher percentage of correct responses on the DMtS had larger effective gaps and fewer tight fits.

These findings reveal different relationships to those revealed in respect of the predictors of this skill reported in chapter 7 based on a larger sample of typically developing children. In light of these differences, analyses were next conducted for children with and without ADHD separately.

When the same analyses were conducted for typically children in the control group alone, CANTAB task performance measures accounted for a significant proportion of the variance in respect of accepted gap size ($R^2$ =.18, $p$<.001) with beta weights showing BSE on the SWM task negatively predicting accepted gap size whereby those children who made fewer working memory errors accepted larger gaps. When this analysis was repeated for the ADHD group, no such relationship was revealed.

Similarly, CANTAB outcome variables accounted for a significant proportion of the variance in respect of effective gap size for typically developing children ($R^2$ =.26, $p$<.001) with the percentage of correct responses on the DMtS task positively predicting effective gap size: typically developing children who had a high percentage of correct responses on the DMtS assessing short term visual memory had larger effective gaps. This relationship prevailed when the same analysis was conducted for the ADHD group ($R^2$ =.25, $p$<.001).

When the same CANTAB outcome variables were regressed onto starting delay for typically developing children, it was shown once more that this accounted for a significant proportion of the variance for the control group ($R^2$ =.26, $p$<.001). Beta weights demonstrate the percentage of correct responses on the DMtS negatively predict starting delay whereby those with a high percentage of correct responses on the short term visual memory task, had shorter starting delays. This relationship also prevailed when the same analysis was conducted for the ADHD group ($R^2$ =.27, $p$<.001). In addition, SSRT on the SST was also found to be an independent predictor of starting delay for the ADHD group whereby for children with ADHD SSRT positively predicted starting delay: those with higher SSRTs (and poorer inhibitory control) had longer starting delays.

No relationships were revealed between CANTAB task performance and estimated crossing time for children in the control group, but when CANTAB outcome variables were regressed onto the estimated crossing time for children with ADHD, it was revealed that this accounted for significant proportion of the variance with standardised beta weights showing SSRT on the SST was a negative predictor of the estimated crossing times of children with ADHD. Thus for children with ADHD, higher SSRTs (poorer inhibitory control) predicted lower estimated crossing times.

CANTAB outcome variables did not predicted number of missed opportunities neither for children with ADHD nor for those in the control group. That said, SSRT for control group children was approaching significance ($R^2$ =.25, *p*=.066).

Finally, the CANTAB outcome measures were regressed onto the number of tight fits once more for children with and without ADHD separately. For children in the control group, none of the CANTAB task outcome measures were predictors of the number of tight fits, though the percentage of correct responses on the DMtS was approaching significance as a negative predictor suggesting those who made more correct responses made fewer tight fits ($R^2$ =.26, *p*=.077). For children in the ADHD group the model accounted for a significant proportion of the variance ($R^2$ =.15, *p*<.001) and the percentage of correct responses on the DMtS was a significant negative predictor of the number of tight fits.

The output of each of the regression analyses conducted for the visual timing task are presented in Tables 14.7, 14.8 and 14.9 below.

Table 14.7: Predicting Performance on the Visual Gap Timing Task from Participant Group and CANTAB Outcome Measures

| | Accepted Gap | | | Effective Gap | | | Start Delay | | | Estimated Crossing Time | | | Missed Opportunities | | | Tight Fits | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Steps/Predictors | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta |
| **Step1** | .06 | 6.81 | | .15 | 20.48 | | .14 | 18.96 | | .01 | 1.61 | | .03 | 3.79 | | .15 | 20.47 | |
| Participant Group | | | .24* | | | .39*** | | | -.38*** | | | .12 | | | .18 | | | -.39* |
| **Step 2** | .37 | 4.42 | | .60 | 16.14 | | .37 | 16.10 | | .06 | 1.87 | | .09 | 2.65 | | .27 | 10.52 | |
| Participant Group | | | .14 | | | .19* | | | -.16 | | | .04 | | | .108 | | | -.24** |
| SSRT (SST) | | | -.04 | | | -.21* | | | .26** | | | -.04 | | | -.01 | | | .16 |
| BSE (SWM) | | | -.15 | | | -.05 | | | -.01 | | | -.08 | | | -.13 | | | -.02 |
| % correct all delays (DMtS) | | | .19 | | | .37*** | | | -.38*** | | | .16 | | | .15 | | | -.31** |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

Table 14.8: Predicting Performance on the Visual Gap Timing Task from CANTAB Outcome Measures for Children with ADHD

| | Accepted Gap | | | Effective Gap | | | Start Delay | | | Estimated Crossing Time | | | Missed Opportunities | | | Tight Fits | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Predictors | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta |
| | .05 | 1.04 | | .25 | 6.20 | | .27 | 6.85 | | .12 | 2.46 | | .06 | 1.15 | | .16 | 3.56 | |
| SSRT (SST) | | | .10 | | | -.14 | | | .28* | | | -.27* | | | -.02 | | | .16 |
| BSE (SWM) | | | -.03 | | | .01 | | | -.04 | | | -.05 | | | -.18 | | | -.13 |
| % correct all delays (DMtS) | | | .22 | | | .45* | | | -.40** | | | .137 | | | .10 | | | -.36** |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

Table 14.9: Predicting Performance on the Visual Gap Timing Task from CANTAB Outcome Measures for Typically Developing Children

| | Accepted Gap | | | Effective Gap | | | Start Delay | | | Estimated Crossing Time | | | Missed Opportunities | | | Tight Fits | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Predictors | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta | $R^2$ | F | Beta |
| | .18 | 4.08 | | .26 | 6.59 | | .26 | 6.14 | | .11 | 2.18 | | .26 | 1.29 | | .15 | 3.23 | |
| SSRT (SST) | | | -.12 | | | -.24 | | | .22 | | | .25 | | | -.02 | | | .13 |
| BSE (SWM) | | | -.29* | | | -.13 | | | .05 | | | -.20 | | | -.03 | | | .11 |
| % correct all delays (DMtS) | | | .13 | | | .32* | | | -.37** | | | .14 | | | .23 | | | -.26 |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

In summary, these findings reveal group significantly predicts a range of performance measures (all but estimated crossing time and the number of missed opportunities). When the primary outcome measures of the CANTAB tasks were added to the model the effect of group remained but was reduced and short term visual memory and to a lesser extent inhibitory control, were predictive. When the analyses were conducted separately for each group, short term visual memory was predictive of effective gap size and starting delay for both groups. For typically developing children, working memory predicted accepted gap size whereby typical children made comparatively few working memory errors which predicted their accepting larger gaps but this was not found for children with ADHD. In contrast whilst inhibitory control was not predictive of performance for typically developing children, this was positively predictive of starting delay and negatively predictive of estimated crossing time such that high SSRTs (and thus poorer inhibitory control) predicted longer starting delays and smaller crossing time estimates.

In contrast, working memory was not predictive of accepted gap size for children with ADHD in the manner revealed for control children. Whereas it would appear the relatively good performance of typically developing children in respect of the SWM task results in typically developing children crossing through larger gaps but this is not true for children in the ADHD group. As shown earlier in this thesis, children with ADHD cross through significantly smaller gaps than control children. The findings revealed here demonstrate this is at least partly because of difficulties with spatial working memory. In addition, for children with ADHD poor inhibitory control (evidenced by higher SSRTs) positively predicts starting delay and negatively predicts estimated crossing times. For children with ADHD poor inhibitory control results in their delaying for longer before initiating a crossing and estimating significantly less time being needed to complete a crossing.

The findings relating to the number of tight fits also demonstrate an importance of short term visual memory. Although the findings were not significant for children in the control group (as was shown in chapter 7), the relationship was approaching significance and was significant for those in the ADHD group. This further demonstrates the importance of short term visual memory for the performance of this aspect of the task. Children with better short term visual memory made fewer tight fits.

### 14.3.9 Predicting Road User Intentions

Regression analyses were once again used to examine the relationships between group membership (ADHD vs. control), CANTAB task performance and performance on the safe predicting road user intentions task. In the first step, participant group was regressed onto the number of correct predictions.

This accounted for a significant proportion of the variance ($R^2$ =.22, $p$<.001). In the second step, the CANTAB outcome variables were added to the model which accounted for an increment to $R^2$ ($R^2$ =.38, Rchange2 =.16, $p$<.001). The standardised beta weights (in Table 14.10 below) show group, performance on the simultaneous and delayed match to sample task and spatial working memory task predicts performance on the road user intentions task. BSE negatively predicts performance whereby, fewer errors predicts a greater number of correct predictions. Performance on the DMtS assessing short term visual memory is positively predictive whereby a higher percentage of correct responses also predicts a greater number of correct predictions. A summary of the regression is presented in Table 14.10 below.

Table 14.10: Predicting the Number of Correct Predictions on the Predicting Road User Intentions Task from Participant Group and CANTAB Outcome Measures

| Predictors | $R^2$ | F | *β* |
|---|---|---|---|
| **Step1** | .47 | 33.05 | |
| Group (ADHD vs. Control) | | | .47*** |
| **Step 2** | .62 | 17.46 | |
| Group | | | .33*** |
| SSRT (Stop Signal Task) | | | -.09 |
| BSE (Spatial Working Memory Task) | | | -.20* |
| % correct all delays (Delayed Match to Sample Task) | | | .26** |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

Given the differences revealed above between children with and without ADHD in respect of the safe place finding task, separate analyses were again conducted for the ADHD and control groups. First when the primary outcome measures from each of the CANTAB tasks were regressed onto the proportion of safe routes for typically developing children, the regression model accounted for a significant proportion of the variance ($R^2$ =.31, $p$<.001). Standardised beta weights shown in Table 14.11 below show that performance on the spatial working memory task and simultaneous and delayed match to sample task independently predicted the number of correct predictions typically developing children made on the predicting road user intentions task. When this analysis was repeated on the data of children with ADHD, the regression model again accounted for a significant proportion of the variance ($R^2$

=.13, *p*<.05), but beta weights show only performance on the simultaneous and delayed match to sample task was predictive for children with ADHD as shown in Table 14.11.

Table 14.11: Predicting the Number of Correct Predictions on the Predicting Road User Intentions Task from CANTAB Outcome Measures for each Participant Group Separately

| | ADHD Group | | | Control Group | | |
|---|---|---|---|---|---|---|
| Predictor Variables | $R^2$ | F | $\beta$ | $R^2$ | F | $\beta$ |
| | .13 | 2.82 | | .31 | 8.18 | |
| SSRT (Stop Signal Task) | | | .04 | | | .16 |
| BSE (Spatial Working Memory Task) | | | -.16 | | | -.29* |
| % correct all delays (Simultaneous & Delayed Match to Sample Task) | | | .29* | | | .27* |

*=*p*<.05, **=*p*<.01, *** *p*<.=001

Therefore, for typically developing children both spatial working memory and short term visual memory are predictive of the ability to predict the intentions of other road users. For children with ADHD on the other hand, only short term visual memory was predictive and the model accounted for much less of the variance than was the case for the controls. This may explain the finding reported in chapter 13 which revealed children with ADHD were much less able to predict the intentions of other road users compared with children in the control group.

## 14.4 Discussion

### 14.4.1 Findings relating to Neuropsychological Functioning

The findings relating to spatial working memory (SWM) task performance show that although performance improves with age for both children with and without ADHD, children with ADHD perform significantly poorer than controls overall. While those in the oldest age group improved most significantly in relation to 8 box trials, children with ADHD made more errors on the performance of this task in terms of the number of between search errors across all difficulty levels. This represents broad impairment in performance of children with ADHD compared with control children irrespective of age and the difficulty of trials. This finding is well aligned with those of other previous studies which have reported similar findings in relation to the impairment of working memory task performance amongst children with ADHD (Kempton et al., 1999; Rhodes et al., 2004; 2005; 2012).

Similar findings were revealed in relation to performance on the stop signal task (SST) assessing inhibitory control. Indeed, once more while performance on this task improves with age for both those with and without ADHD, children with ADHD performed less well overall than did matched controls in relation to the primary outcome measure, stop signal reaction time.

These findings demonstrate broad impairment in inhibitory control amongst children with ADHD compared with matched control children and also align closely with those of previous studies which have also reported significant differences in inhibitory control between children with and without ADHD (Barkley, 1990; Coghill et al., 2014; Nigg, 1999).

The findings relating to performance on the third and final task from the CANTAB battery, the simultaneous and delayed match to sample task (DMtS) revealed in respect of the percent of correct trials, that while performance improved with age for both groups, children with ADHD once more scored significantly below control children overall.  Furthermore, an interaction effect showed the greatest difference between groups was observed for the shortest, 0 second delay trials.  On these trials, children in the control group performed very well but children with ADHD performed much less well.  Indeed, children with ADHD performed less well even on simultaneous trials, without any delay at all.  These findings demonstrate significant differences in respect of short term visual memory which are observable and indeed most pronounced, for the shortest delay trials.  The overall percentage of correct responses reported here reflect significant impairment in respect of delayed short term visual memory amongst children with ADHD, a finding which has also been previously reported by amongst children with ADHD using similar tasks (Chelonis, et al, 2002; Kempton et al., 1999; Rhodes et al., 2005).

Considered together, findings relating to performance on subtests of the CANTAB provide clear evidence of impairment in a range of aspects of cognition amongst children with ADHD.  The findings of previous studies which have also suggested children with ADHD are impaired in terms of inhibitory control, working memory and delayed short term memory (e.g. Coghill et al., 2014; Kempton et al., 1999;

Rhodes et al., 2004). The findings reported in this study therefore demonstrate the areas of impairment shown by children with ADHD who took part, are broadly comparable to those reported previously. This was an important prerequisite to the examination of the relationships between CANTAB task performance and children's pedestrian skill level, the results of which will now be discussed.

### 14.4.2 The relationship between Cognitive Functioning & Pedestrian Skill Level

The results relating to the relationship between aspects of neuropsychological function and child pedestrian skill level broadly support the arguments forwarded by Clancy et al., (2006) as well as that of Stavrinos et al. (2011) which suggest deficits in aspects of cognition may account for differences in pedestrian skill level between children with and without ADHD. The findings of this study add significantly to this argument by demonstrating more specific links between neuropsychological function and pedestrian skill level than has previously been reported.

Results relating to the first pedestrian skill show participant group was a strong predictor in the first step, but this reduced when the measures of neuropsychological function were added to the model. For children in the control group, delayed short term visual memory positively predicted the number of safe routes children were able to identify on the safe place finding task. Good short term visual memory likely helps typically developing children remember hazards and hold features of the environment in mind before making a decision about where to cross the road. No such relationship however was revealed amongst children with ADHD. This likely explains the significantly poorer performance of the ADHD group on the safe place finding task revealed in chapter 11 and further highlights a specific importance of delayed short term visual memory for the safe place finding task.

The relationships between neuropsychological function and visual gap timing performance when comparing participant groups are interesting. In the first analysis, once again participant group predicted a range of performance measures such that typically developing status was predictive superior performance and ADHD status to poorer performance. The strength of participant group as a predictor once more reduced when the CANTAB outcome measures were added to the regression models, though remaining a significant predictor of some aspects of performance. Starting delay, effective gap size and the number of tight fits were predicted by participant group. Accepted gap size is predicted by group but this effect is lost completely when the CANTAB variables are added in the second step of the model. This suggests that group is, in part, a proxy for these cognitive functions. When added to the model, measures of short term visual memory and inhibition become predictors of starting delay, effective gaps and (in the case of short term visual memory) tight fits. Spatial working memory was not shown to be predictive of any outcome measures whilst the number of missed opportunities and estimated crossing time were not predicted by participant group or any of the cognitive measures.

When the analyses were conducted separately for the ADHD and control groups, some aspects of cognitive function were predictive of performance on the visual gap timing task for both children with ADHD in much the same way as was revealed for controls. Short term visual memory for example was predictive of effective gap size and starting delay for both groups in the same direction. Those with better short term visual memory had smaller starting delays and as a consequence, larger effective gap sizes. Yet there are also a number of interesting differences between groups.

Spatial working memory task performance predicted the accepted gap size for control children, but not those with ADHD. Control children who performed well on the spatial working memory task attempted to cross through larger gaps. In contrast, this relationship did not exist in the ADHD group. For children with ADHD, high stop signal reaction times (reflecting poor inhibitory control) positively predicted starting delay and negatively predicted estimated crossing time. Poor inhibitory control in the ADHD group was thus associated with longer starting delays and children estimating a small amount of time was needed to complete a crossing. These findings were not revealed amongst children in the control group.

Thus whilst spatial working memory appears to help typically developing children select larger gaps to cross through, this is not true for children with ADHD. The problems with inhibitory control shown amongst children with ADHD group appear to lead them to estimate less time is needed to complete a crossing and delay for a longer period of time before initiating a crossing.

Interestingly, some of the cognitive variables were slightly stronger predictors in the ADHD group than the control group. For example, DMtS task performance was a stronger predictor of effective gap size and starting delay for those with ADHD compared with controls. In addition, DMtS task performance also predicted the number of tight fits for children with ADHD but not amongst controls. A possible explanation of this might be that for control group children, age is a proxy for experience which their intact cognitive abilities have allowed them to benefit from in a way children with ADHD cannot. For children with ADHD, by contrast, the cognitive variables may be strong predictors because in some cases problems with cognitive functions cause difficulties that has limited their ability to learn from experience resulting in a greater dependence on cognitive processes rather than experience.

These findings significantly extend those reported by Stavrinos et al. (2011) which reported a relationship between cognitive function and the safety of the performance of children with ADHD on a visual gap timing task. Stavrinos and colleagues selected three subtests of the Attention and Executive Function domain of the NEPSY (Korkman, Kirk & Kemp, 1997) which were combined to provide an overall measure of EF. This was then compared with performance on a further aggregate score relating to performance on the visual gap timing task. The authors concluded that problems with EF mediate the relationship between ADHD and unsafe performance on the visual gap timing task. The findings of the current study go some way beyond this by demonstrating that impairment in the more basic (non-executive) cognitive process of delayed short term visual memory is also implicated which exemplifies the importance of considering children's wider cognitive function, beyond EF alone. In addition, the findings highlight a specific importance of inhibitory control in explaining the poorer performance of children with ADHD on the gap timing task.  These functions together impact upon starting delays and also impact both effective gap size and the number of tight fits.

In respect of the final skill (that of predicting road user intentions), participant group was a significant predictor but this reduced when the cognitive variables were added to the model (Beta reduced from .47 to .33) and spatial working memory and short term visual memory task performance became predictive but inhibition was not.

When the analyses were conducted separately for the two groups, both short term visual and spatial working memory were predictive of performance amongst controls but only short term visual memory was predictive for those with ADHD.  These findings suggest the relatively well-developed spatial working memory capacity of children in the control group children results in the comparatively superior performance of the control group on the predicting road user intentions task.  For children with ADHD, performance on the short term visual memory task also predicted a greater number of correct predictions, but working memory task performance did not.  The relative difficulties children with ADHD experience with short term visual memory and spatial working memory compared with control children appears to at least partly explain the difficulties those with ADHD experience in relation to the predicting road user intentions task.  It is likely difficulties with both short term visual memory and spatial working memory prevent children with ADHD from maintaining and manipulating events in the traffic environment as they unfold.  For example, it will likely be difficult for children with ADHD, who have poor working memory compared with control children, to maintain in mind the appearance of an indicator signally the intentionality of a driver to turn off, whilst manipulating speed and distance as required to make the correct prediction that the car is travelling too fast to be able to make the first turning, has indicated too early and actually intends to take the second exit.

The fact spatial working memory was predictive of performance on this task for children in the control group but not those with ADHD is interesting and may also be related to the social nature of this task. Whilst the predicting road user intentions task is more than a test of ToM, it does require children to make judgements about the states of mind of other road users and so can be said to have a social cognitive component. A number of studies have shown a relationship between aspects of neuropsychological (particularly executive) functions and theory of mind ability (Ozonoff, Pennington & Rogers, 1991, Devine & Hughes, 2014) with some arguing working memory specifically to be important for ToM (Carlson, Moses & Brenton, 2002). The current study showed a relationship between working memory and children's ability to predict the intentions of other road users for control children but not those with ADHD who performed less well on the SWM task. Given the social-cognitive nature of the predicting road user intentions task, it is possible one of the mechanisms by which children with ADHD perform less well on this task compared with controls is because of the impact difficulties with working memory has on ToM. Whilst this interpretation is not clear from the findings of the current study, future research should address this possibility and examine the relationship between cognitive function, ToM and the ability to predict intentionality in the context of pedestrian decision making amongst children with ADHD and other specialist populations associated with cognitive and social cognitive impairment.

### 14.4.3 Summary and Conclusion

In summary, the current study showed that inhibitory control, working memory and short term visual memory task performance to be impaired in children with ADHD compared with matched control children. In line with past research reviewed in the introduction, this confirms the sample of children in the current study exhibit the profile of cognitive deficit common amongst children with ADHD. These impairments were then shown to impact upon the relationship between aspects of cognition and pedestrian skill level when comparing these relationships for children with and without ADHD.

Participant group (ADHD vs. control) was a strong predictor of a number of dependent variables across the three tasks assessing pedestrian skill level but generally became less of a predictor when the cognitive variables were added to the regression models. This suggests that participant group is in part a proxy for cognitive ability which further emphasises the importance of studying children's cognitive abilities relative to their readiness to interact with the traffic environment. The role of cognitive functions was most marked for the visual gap timing task, followed by the intentions task and then safe place finding task. In addition, the findings of the current study suggest more basic (non-executive) cognitive processes are also important. Indeed delayed short term visual memory was the function most often implicated across all pedestrian tasks but inhibition and working memory were also important in some tasks, but not others. These findings exemplify the notion that global measures of cognitive function are not sufficient when studying the cognitive underpinnings of the development of children's pedestrian skill development, as are global measures of pedestrian skill level. They also extend the literature by demonstrating specific links between aspects of cognitive function and pedestrian skill level in much more detail than has been previously reported. This finding also serves to demonstrate the importance of considering non-executive, more basic cognitive processes in ADHD and adds to a small but growing literature which demonstrates this (Dovis et al., 2013; Kempton et al., 1999; Rhodes et al., 2004, 2005, 2012).

While adding considerably to the literature, the findings reported here must also be considered against the study's limitations. An omission of the current study was to examine potential subtype differences amongst children in the ADHD group. Future research should seek to examine the possibility of between group differences amongst children with different subtypes of ADHD to determine whether children with some subtypes are more impaired and more vulnerable as pedestrians compared to others. This would appear prudent given past studies have reported subtype differences in relation to cognitive impairments in ADHD (Nigg, Blaskey, Haung-Pollock & Rappley, 2002). Most children (N=49) in the current study had combined subtype ADHD but as described in chapter 10, 7 had been diagnosed with the hyperactive-impulsive subtype and 5 with the inattentive subtype meaning insufficient numbers of each subtype were recruited to allow for statistical comparisons in terms of task performance. Future research with sufficient numbers of children with ADHD may wish to explore such differences. This might be considered important as research has suggested children with the hyperactive-impulsive subtype may be less impaired cognitively (Nigg, Willcutt, Doyle & Sonuga-Barke, 2005).

Given the widespread use of medication in the treatment of children with ADHD, an obvious next step would be to examine the effects of medication on the pedestrian competence of children with ADHD. A range of studies have previously reported stimulant medication improves driving performance of adults with ADHD (Cox, Lawrence, Kovatchev & Steward, 2000, Barkley & Cox, 2007). In light of the emerging difficulties those with ADHD have in respect of their performance of a range of pedestrian skills, many of which overlap with the skills underpinning driving performance, it would appear logical to examine the impact medication may have on the skill level of children with ADHD as pedestrians. This will now be considered in the final study of this thesis.

# Chapter 15

# Study 3: The impact of stimulant medication on the Neuropsychological Function and Pedestrian Skill Level of Children with ADHD

## 15.1 Introduction

Part B of this thesis has so far revealed differences in skill level in respect of each of the three pedestrian skills examined in this thesis when comparing the performances of children with and without ADHD and suggests that difficulties with neuropsychological function amongst children with ADHD may at least partly account for much lower pedestrian skill level of children with ADHD.

An important factor to be considered in relation to the readiness of children with ADHD to safely interact with traffic is the approach to treatment or management of ADHD. Approaches to treating ADHD vary significantly between patients depending on a range of factors including individual differences in symptom severity and patient choice. Common approaches include behavioural interventions targeting those diagnosed with the disorder, their parents and teachers, pharmacological interventions using stimulant medication as well as multimodal interventions combining these. The most common approach to the management of ADHD is pharmacological: according to the UK's National Institute for Clinical Excellence (NICE), pharmacological intervention is the first line approach to intervention for children and young people with severe symptoms (NICE, 2015). Indeed, stimulant medication has been used to treat ADHD for over 60 years (Bradley, 1937) and converging evidence continues to support the use of medication as an effective approach to treatment (Greenhill, Findling & Swanson, 2002, Rowland, Lesesne & Abramowitz, 2002), which significantly improves cognition (Coghill et al., 2007, 2013; Rhodes et al., 2004, 2006).

The use of stimulant medication to treat ADHD is widespread and has been supported by the findings of a large number of empirical and clinical studies, which have shown pharmacological intervention to have a positive impact on ADHD symptoms and to have an ameliorating effect on cognitive impairment common to this group (Coghill et al., 2013; Muston, Firestone, Pisterman, Bennett & Mercer, 1997; Rhodes et al., 2004, 2006). For example, Firestone et al., (1978) demonstrated Methylphenidate (MPH) leads to improved behaviour (in respect of impulsivity and motor control) as rated by both parents and teachers of children with ADHD. Similarly, Rhodes et al. (2004) showed MPH has an ameliorating effect on short term visual memory and in other studies, has been shown to improve aspects of more basic memory processes as well (Chelonis et al., 2002; Rhodes et al., 2006). A recent meta-analytic review of 25 studies reported MPH has small to moderate effect on inhibition, working memory and sustained attention (Tamminga, Reneman, Huizenga & Geurts, 2016). Coghill, Seth, Pedroso, Usala, Currie and Gagliano (2014) report similar findings in a review of 36 studies but also that MPH has an ameliorating effect on non-executive memory as well. Another meta-analytic review of 26 randomised controlled trial studies investigating the effects of MPH in children with ADHD reported large mean weighted effect sizes for the effects of MPH on ADHD symptoms and academic functioning in children aged 6-12 years, compared with only moderate effect sizes for psychosocial intervention (Van der Oord, Prins, Oosterlaan & Emmelkamp, 2008). Prasad, Brogan, Mulvaney, Grainge, Stanton and Sayal, (2013) reported similar findings in respect of on-task behaviour at school and the completion of academic work.

In the UK there are currently four medications licenced for the treatment of ADHD: dexamfetamine, lisdexamfetamine, atomoxetine and the most common; methylphenidate (NHS Choices, 2015). Methylphenidate hydrochloride (MPH), a derivative of piperidine which began to be marketed as Ritalin in the 1960s (Diller, 1996), remains the most commonly prescribed stimulant drug used to treat ADHD today (Barkley & Cox, 2007). Though the safety and suitability of MPH for the treatment of ADHD has been questioned repeatedly (Gross-Tsur, Manor, Van der Meere & Shalev, 1997; Wigal et al., 2006) MPH continues to be the most common medication used to treat ADHD in the UK (NHS Choices, 2016) and modern slow or modified release (MR) versions of the medication have also been formulated which are designed to produce a similar rapid onset therapeutic effect to traditional immediate release (IR) versions (typically taken three times per day). Its effects have a longer duration than the traditional immediate release (IR) versions which removes the need for a midday dose at school (Greenhill et al., 2002) and it can be effectively used to treat children who achieve suboptimal symptom control with the first line MPH-IR treatment (Coghill, Banaschewski, Zuddas, Pelaz, Gagliano & Doepfner, 2013).

In spite of the repeated and continuing study of its safety, MPH has been described as a cornerstone of pharmacological intervention to treat the symptoms of ADHD in childhood (Rhodes et al., 2004). It has a long history with decades of research demonstrating a positive impact on cognitive functions (Berridge et al., 2006; Knights, 1974; Rapport, Carlson, Kelly & Pataki, 1993, Rhodes et al., 2005) and examining its side effects. Though some side effects are common such as a reduction in appetite and associated weight loss (David, Levitan, Kaplan, Carter, Reid, Curtis, Patte & Kennedy, 2007; Karabekiroglu, Yazgan & Dedeoglu, 2008) and insomnia (Sangal, Owens, Allen, Sutton, Schu & Kelsey, 2006), countless studies have reported MPH as being safe and effective in managing the behavioural symptoms of ADHD (Biederman, Quinn, Weiss, Markabi, Weidenman, Edson, Karlson, Pohlmann & Wigal, 2003; Godfrey, 2008; Wigal, Greenhill, Chuang, McGough, Vitiello, Skrobala, Swanson, Wigal, Abikoff, Kollins, McCracken, Riddle, Posner, Ghuman, Davies, Thorp & Stehli, 2006) and studies highlight no negative effects of medication on cognition or behaviour (Rhodes et al., 2004, 2006).

MPH has also been shown to be effective in normalising some aspects of cognitive function which are commonly impaired in children with ADHD, including inhibitory control when taken chronically (Coghill et al., 2007) and delayed short term visual memory with acute or chronic administration (Coghill et al., 2007; Rhodes et al., 2004, 2006). These studies report variance in the impact of medication on aspects of cognitive functioning depending on whether administration of MPH is acute (Rhodes et al., 2005) or chronic (Coghill et al., 2007). This thesis has revealed links between both of these functions and aspects of pedestrian skill using the same tasks as Coghill et al. and Rhodes et al. in 2005 and 2007 respectively. In addition, Rhodes et al. (2005) reported significant improvements on a short term visual memory task amongst children with ADHD following treatment with medication but reported no impact of acute MPH administration (one dose) on tasks assessing inhibitory control or working memory. Findings reported by Coghill et al. (2007) suggest a 4 week chronic administration is needed to see improvement in inhibition. This suggests there may be important differences in terms of the effectiveness of MPH in relation to improving aspects of cognition depending on the duration of administration, with chronic administration improving a wider range of cognitive functions. Thus a longitudinal approach to assess the impact of stimulant medication on cognitive function would appear appropriate in order to encapsulate the impact this has on cognitive function in the long term.

Previous studies would therefore appear to suggest MPH is effective in improving some aspects of cognitive function, some of which this thesis has linked with the pedestrian skill level of children with ADHD. It would thus appear prudent to examine the impact of medication on both children's cognitive functioning and their pedestrian decision making. Given the effects medications have been shown to have on aspects of cognitive function, it might be reasonably hypothesised that this in turn may improve the pedestrian judgements of children with ADHD. This hypothesis would derive some support from some previous studies which have examined the impact of stimulant medication on the performance of drivers with ADHD. Jerome and Segal (2001) for example report significant improvements in driving performance in a large sample of adults with ADHD following titration onto stimulant medication. Self and spouse reports of a range of negative driving behaviours including speeding, distractibility at the wheel and irritability revealed MPH had a positive impact.

Similarly, Cox, Humphrey, Merkel, Penberthy, and Kovatchev (2004), focussing on adolescent drivers with ADHD, observed 17-year-old drivers over a 16 mile route comprising a variety of rural and urban roads. Participants had either taken or abstained from taking MR-MPH on the day of testing. Safer performance was observed when MPH had been taken on the day of testing whereby significantly fewer inattentive driving errors were made according to a blind rater. Barkley, Murphy, O'Connell and Connor (2005) built on these findings and implicated attention and inhibitory control in the MPH-driving performance relationship. In a placebo controlled study investigating the impact of MPH (10mg versus 20mg) on the performance of adults on a driving simulator and continuous performance test (CPT) assessing attention and inhibition, Barkley and colleagues reported that a high dose of MPH has a significant impact on both CPT and driving simulator performance in respect of the variability of steering. Nada-Raja, Langley, McGee, Williams, Begg and Reeder (1997) also reported an association between problems with attention and crashes involving injury in adolescent drivers. Furthermore, a review of over 15 years of research by Barkley and Cox (2007) concluded that stimulant medications have a positive impact on the driving performance of both adults and adolescents with ADHD whereby stimulant medication has been shown to reduce inattentive driving errors (Cox, Humphrey, Merkel, Penberthy & Kovatchev, 2004) and reduce speeding (Cox, Merkel, Moore, Thorndike, Muller & Kovatchev, 2006). Whilst these studies demonstrate clear improvement in driving behaviour amongst those with ADHD treated with stimulant medication, the effects of medication on children's road use is currently unknown. This will be investigated in the context of children's pedestrian skill level in the current study.

Given the overlap of driving and pedestrian skills, which appear underpinned by similar aspects of cognition and the findings of past research pertaining to the positive impact of MPH on the behaviour of drivers with ADHD it might be reasonably expected that medication may also lead to improvements in the pedestrian behaviour of children with ADHD by allowing children with the disorder to deploy skills in a more appropriate and controlled manner. However, no previous research has addressed this explicitly. That said, it is known that medication improves cognition amongst children with ADHD as discussed above. The previous chapters of this thesis have also demonstrated children with ADHD are impaired in respect of inhibitory control, working memory and delayed short term visual memory as well as in terms of the three pedestrian skills under investigation in this thesis. Chapter 14 also revealed links between these cognitive functions and pedestrian skill level amongst controls but that relationships were quite different for those with ADHD. The current study is a longitudinal, follow up study of performance on tasks assessing both neuropsychological function and pedestrian skill level in children with ADHD which aims to examine the impact of medication on both cognitive functioning and pedestrian skill level.

It is hypothesised that:

1. Medication will improve the neuropsychological functioning of children with ADHD in respect of both executive and more basic non-executive aspects of functioning such that;
    i) Medication will improve the performance of children with ADHD on the Stop Signal Task assessing inhibitory control and,
    ii) Medication will improve the performance of children with ADHD on the Simultaneous and Delayed Match to Sample Task assessing delayed short term visual memory, but not working memory.

2. Medication will also improve pedestrian skill level such that children with ADHD will perform better at follow up than at baseline and in a manner more comparable to controls whereby;
    i) Medication will improve the ability of children with ADHD to identify safe crossing routes on the safe place finding task
    ii) Medication will improve the performance of children with ADHD on the visual gap timing task
    iii) Medication will improve the ability of children with ADHD to predict the intentions of other road users.

## 15.2 Method

### 15.2.1 Participants

31 children with ADHD and 31 matched controls took part in the current study. These participants also took part in the studies reported in studies 2.1 to 2.4 and were retested at a mean follow up time of 13.4 months. Children with ADHD were

matched on chronological age and gender at time 1 and the same matches were retained at time 2. There were 23 males and 8 females in each participant group. Verbal ability (based on percentile rankings of the BPVS) was included as a covariate in all analyses to control for general verbal ability. More information about the sample at both time 1 and time 2 as well as matching criteria are reported in the general method section for part B of this thesis (chapter 10).

### 15.2.2 Design

The current study had a mixed design. Time point (Time 1 vs. Time 2) served as a within groups factor. Participant group (ADHD vs. control) served as a between groups factor. The dependent variables were the primary outcome measures of the safe place finding, visual timing and predicting road user intentions tasks from the Crossroads battery assessing pedestrian skill level and the stop signal, spatial working memory and simultaneous and delayed matching to sample tasks from the CANTAB battery assessing inhibitory control, spatial working memory and short term visual memory respectively.

### 15.2.3 Materials and Procedure

The materials and procedure used at follow up testing were exactly the same as those employed at baseline which have already been described. Participants completed the safe place finding, visual gap timing and predicting road user intentions tasks from the Crossroads software as well as the Stop Signal Task (assessing inhibitory control), the Spatial Working Memory Task and the Delayed Match to Sample Task (assessing short term memory) from the CANTAB battery. The sequence of task presentation was once more randomised in the same manner previously described. More information about the materials and procedure can be found in chapter 10.

## 15.3 Results

All baseline data reported herein are based on the data from those participants who took part at follow up, rather than from the larger baseline sample as a whole as reported in the previous chapter.

### 15.3.1 Inhibitory Control

The mean (and standard deviation) stop signal reaction times were calculated for baseline and follow up testing as a function of participant group. These are presented in Table 15.1 below.

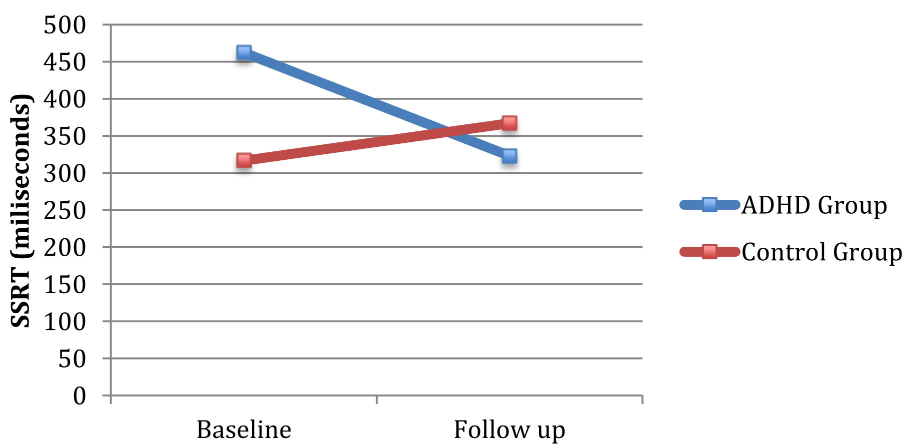
Table 15.1: Mean (& S.D.) Stop Signal Reaction Time* as a function of Participant Group and Time Point

| | ADHD Group | Control Group |
|---|---|---|
| Baseline | 462.16<br>(95.61) | 316.78<br>(110.84) |
| Follow up | 322.95<br>(110.79) | 367.28<br>(119.63) |

*in milliseconds

Differences in responding between time one and time two in respect of the primary outcome measure of the stop signal task (SSRT) was examined by means of a two way mixed ANCOVA with time point (baseline vs. follow up) as a repeated measure and participant group (ADHD vs. control) as a between subjects factor (with BPVS percentile rank as a covariate). ANCOVA revealed there was a main effect of participant group ($F[1,55]=5.39$, $p=.024$, $\eta^2=.089$) but no main effect of time point ($F[1,55]=1.22$, $p=.274$, $\eta^2=.002$). There was an interaction between participant group and time point ($F[1,55]=22.69$, $p<.001$, $\eta^2=.292$) whereby stop signal reaction time reduced markedly for children in the ADHD between baseline and follow up. These effects are shown in Figure 15.1 below and confirmed by planned contrasts which revealed whilst there were significant differences between the ADHD group and controls at baseline ($F[1,59]=30.38$, $p<.001$, $\eta^2=.35$) there was no such difference at follow up ($F[1,59]=2.26$, $p=.138$, , $\eta^2=.04$). Children in the ADHD group had improved much more so than had those in the control group whereby at follow up there were no longer significant differences between groups.

Figure 15.1: Stop Signal Reaction Time as a Function of Participant Group & Time point



### 15.3.2 Spatial Working Memory

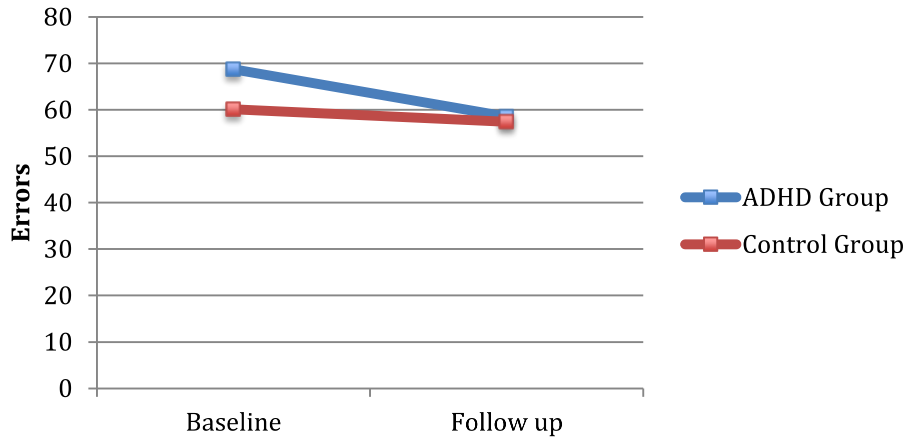
The mean number (and standard deviation) of overall between search errors was calculated for baseline and follow up as a function of participant group. These are presented in Table 15.2 below.

Table 15.2: Mean (& S.D.) Overall Between Search Errors as a function of Participant Group and Time Point

| | ADHD Group | Control Group |
|---|---|---|
| Baseline | 68.76 (23.73) | 60.14 (14.82) |
| Follow up | 58.52 (17.36) | 57.45 (13.63) |

Differences in responding between baseline and follow up in respect of the primary outcome measure of the spatial working memory task (overall BSE) was examined by means of a mixed ANCOVA with time point (baseline vs. follow up) as a repeated measure and participant group (ADHD vs. control) as a between subjects factor (with BPVS percentile rank as a covariate). ANCOVA revealed there was a main effect of time point (F[1,55]=4.44, $p$=.040, $\eta^2$=.075) but no main effect of participant group (F[1,55]=2.26, $p$=.141, $\eta^2$=.039). There was no significant interaction between participant group and time point (F[1,55]=0.90, $p$=.346, $\eta^2$=.024). These effects are shown in Figure 15.2 below.

Figure 15.2: Overall Between Search Errors as a Function of Participant Group & Time point




### 15.3.3 Delayed Short Term Visual Memory

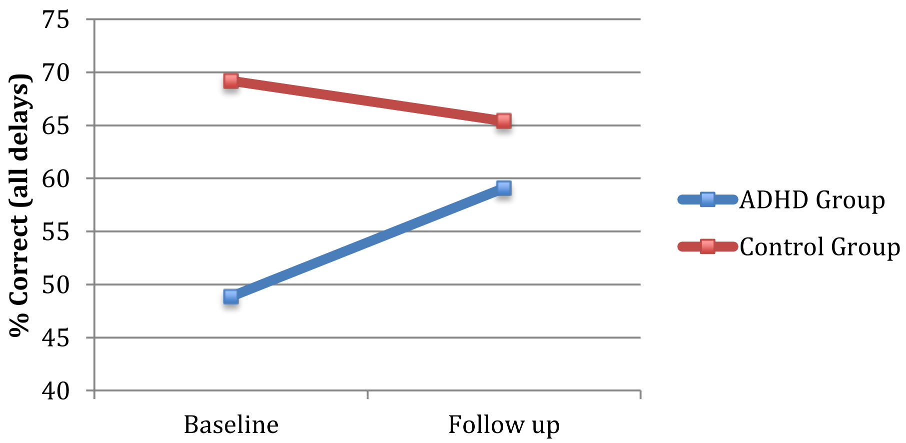
The mean percentage (and standard deviation) of correct responses on the simultaneous and delayed match to sample task (DMtS) across all delay conditions was calculated for baseline and follow up tests as a function of participant group. These are presented in Table 15.3 below.

Table 15.3: Mean (& S.D.) Percentage of Correct Responses on the Delayed Match to Sample Task overall as a function of Participant Group and Time Point

| | ADHD Group | Control Group |
|---|---|---|
| Baseline | 48.85 (17.55) | 59.08 (14.42) |
| Follow up | 69.19 (20.73) | 65.40 (16.07) |

Responding between time one and time two in respect of the primary outcome measure of the short term visual memory task (% correct all delays) was examined by means of a mixed ANCOVA with time point (baseline vs. follow up) as a repeated measure and participant group (ADHD vs. control) as a between subjects factor (with BPVS percentile rank as a covariate). ANCOVA revealed there was a main effect of time point (F[1,58]=4.59, $p$=.037, $\eta^2$=.087) but no main effect of participant group (F[1,58]=0.75, p=.390, $\eta^2$=.013). There was however a significant interaction between participant group and time point (F[1,58]=5.58, $p$=.002, $\eta^2$=.092) whereby the gap between the ADHD and control groups had reduced at time 2. There is marked improvement in the ADHD group, as shown in Figure 15.3 below. This was confirmed by planned contrasts which revealed whist there was a significant difference between children with ADHD compared to controls at baseline (F[1,59]=6.34, $p$=.015, $\eta^2$=.10) there was no significant difference at follow up (F[1,59]=0.73, $p$=.397, $\eta^2$=.01).

Figure 15.3: Percentage of Correct Responses as a Function of Participant Group & Time point



### 15.3.4 Safe Place Finding

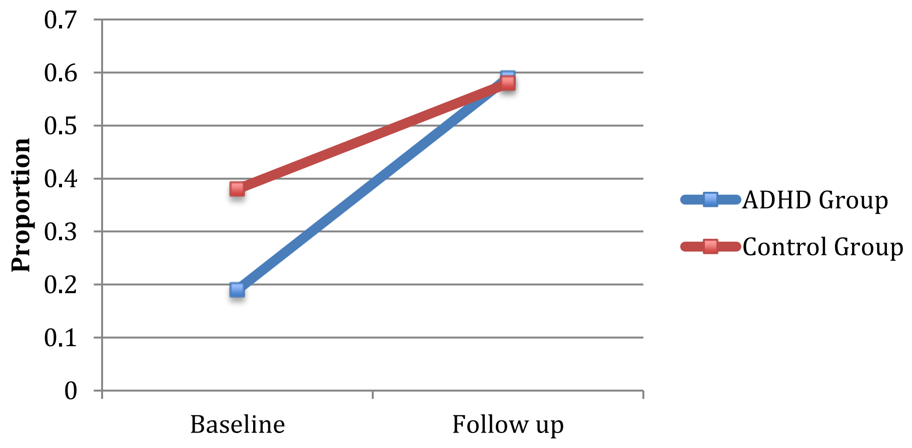
Mean (and standard deviation) proportion of safe routes was calculated for baseline and follow up testing as a function of participant group. These are presented in Table 15.4 below.

Table 15.4: Mean (& S.D.) Proportion of Safe Routes on the Safe Place Finding Task as a function of Participant Group and Time Point

| | ADHD Group | Control Group |
|---|---|---|
| Baseline | 0.19 (0.29) | 0.38 (0.29) |
| Follow up | 0.57 (0.33) | 0.58 (0.28) |

Differences in performance on the safe place finding task between baseline and follow up were examined by means of a mixed ANCOVA with participant group as a between groups factor and time point as a repeated measure. Percentile rankings on the BPVS were a covariate. The proportion of safe routes was the dependent variable. ANCOVA revealed a main effect of time point ($F[1,58]=14.43$, $p<.001$, $\eta^2=.211$) but no main effect of participant group ($F[1,58]=1.98$, $p=.166$, $\eta^2=.035$). There was however an interaction between participant group and time point ($F[1,58]=4.06$, $p=.049$, $\eta^2=.070$) whereby by time 2, those in the ADHD improved much more than did controls as shown in Figure 15.4 below. These effects are shown in Figure 15.4 below and confirmed by planned contrasts which revealed whilst there were significant differences between the ADHD group and controls at baseline ($F[1,59]=6.74$, $p=.012$, $\eta^2=.110$) there was no such difference at follow up ($F[1,59]=0.03$, $p=.867$, , $\eta^2=.000$).

Figure 15.4: Proportion of Safe Routes as a Function of Participant Group & Time point



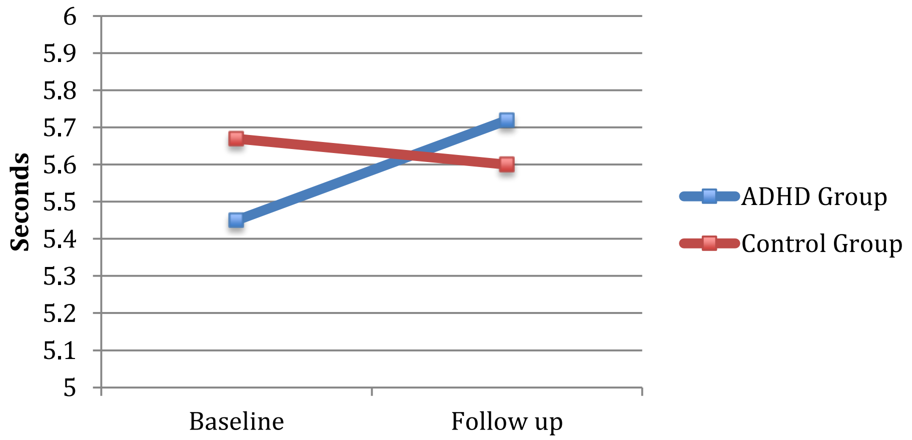

### 15.3.5 Visual Gap Timing

The mean (and standard deviation) for each of the outcome measures of the visual gap timing task were calculated as a function of time point and participant group. These data are presented in Table 15.5 below.

| Table 15.5: Mean (and SD) for Performance Measures on the Visual Gap Timing Task as a function of Participant Group and Time point | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ADHD Group | | | | | | Control Group | | | | | |
| | Accepted Gap | Effective Gap | Start Delay | Est. Cross Time | Missed Opportunities | Tight Fits | Accepted Gap | Effective Gap | Start Delay | Est. Cross Time | Missed Opportunities | Tight Fits |
| Baseline | 5.45 (0.36) | 3.66 (0.57) | 1.80 (0.37) | 3.07 (0.74) | 1.02 (0.91) | 2.90 (0.93) | 5.67 (0.41) | 4.25 (0.68) | 1.41 (0.49) | 3.18 (0.66) | 1.42 (0.79) | 1.82 (1.08) |
| Follow up | 5.72 (0.24) | 4.34 (0.61) | 1.39 (0.45) | 3.09 (0.53) | 0.61 (0.49) | 1.92 (0.89) | 5.60 (0.37) | 4.49 (0.66) | 1.12 (0.38) | 3.46 (0.71) | 1.53 (1.13) | 1.87 (1.12) |

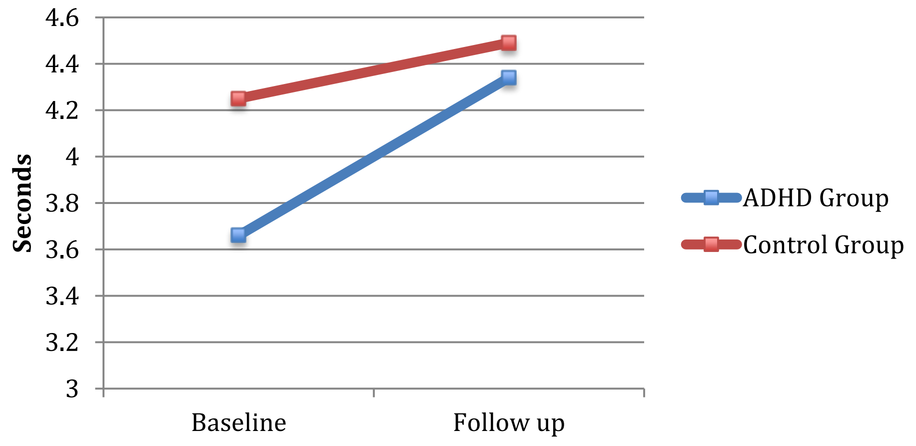
Differences in mean accepted gap time at time one and time two were examined via a mixed ANCOVA with participant group as a between subjects factor and time point as a repeated measures. This revealed no main effect of time point (F[1,58]=1.07, *p*=.306, $\eta^2$=..019) and no effect of participant group (F[1,58]=0.78, *p*=.382, $\eta^2$=.014). There was an interaction between participant group and time point whereby mean accepted gap time increased for those in the ADHD group between baseline and follow up whereas this decreased slightly but remained fairly static in comparison for those in the control group (F[1,58]=7.51, *p*=.008, $\eta^2$=.122). Planned contrasts revealed whist there was a significant difference between the ADHD and control groups at baseline (F[1,59]=5.29, *p*=.025, $\eta^2$=.072), there was no significant difference at follow up (F[1,59]=1.64, *p*=.206, $\eta^2$=.031).

Figure 15.5: Accepted Gap Time as a Function of Participant Group & Time point



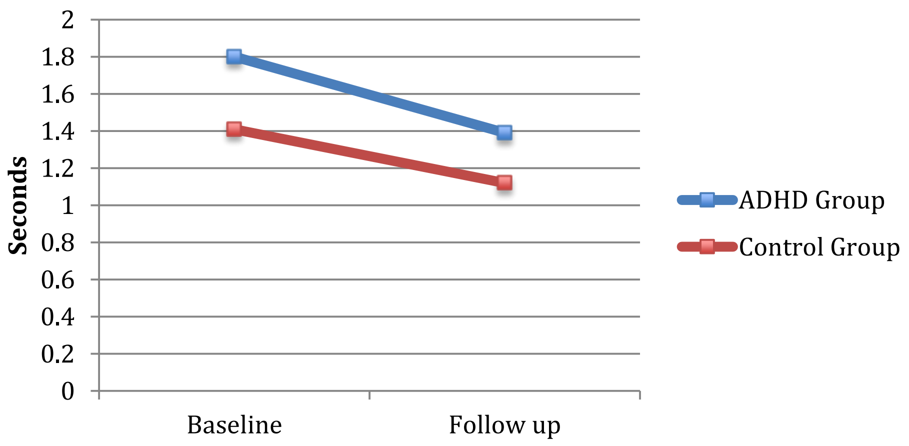

A mixed ANCOVA with participant group as a between subjects factor and time point as a repeated measure revealed a main effect of time point (F[1,58]=4.06, *p*=.049, $\eta^2$=..070) and a main effect of group (F[1,58]=9.98, *p*=.003, $\eta^2$=.156). This also revealed an interaction effect between time point and group was approaching significance (F[1,58]=3.24, *p*=.077, $\eta^2$=.057). Planned contrasts revealed a significant effect of group at baseline (F[1,59]=13.97, *p*<.001, $\eta^2$=.201) but not at follow up (F[1,59]=0.65, *p*=.424, $\eta^2$=.011) which reflects the increase observed in the ADHD group as shown in Figure 15.6 below.

Figure 15.6: Effective Gap Time as a Function of Participant Group & Time point



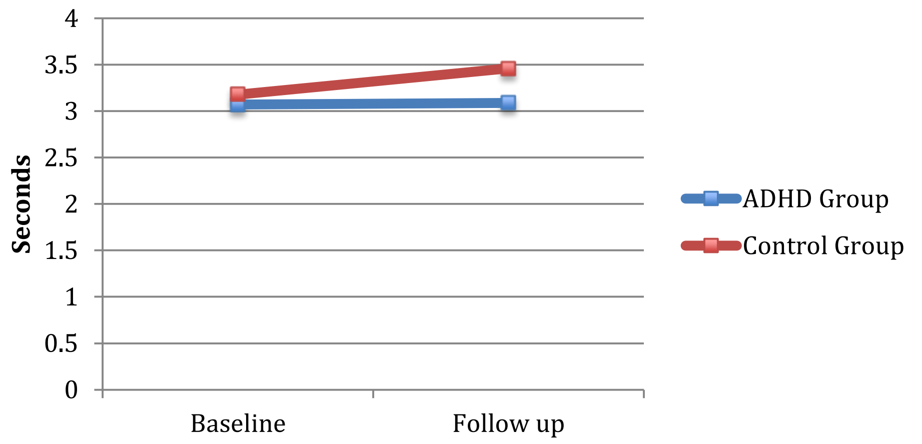

A mixed ANCOVA with participant group as a between subjects factor, time point as a repeated measure and BPVS percentile rankings as a covariate revealed a main effect of participant group (F[1,58]=17.09, *p*<.001, $\eta^2$=.240) and of time point (F[1,58]=4.48, *p*=.039, $\eta^2$=.077). There was no interaction between time point and participant group (F[1,58]=0.60, *p*=.443, $\eta^2$=.011). Planned contrasts revealed there were differences between children with and without ADHD at both baseline ($F[1,59]=12.71$, $p<.001$, $\eta^2=.180$) and at follow up ($F[1,59]=4.88$, $p=.031$, $\eta^2=.081$) as shown in Figure 15.7 below thus whilst medication appears to have had some impact on starting delay, there were still significant differences between children with ADHD and controls at follow up.

Figure 15.7: Starting Delay as a Function of Participant Group & Time point



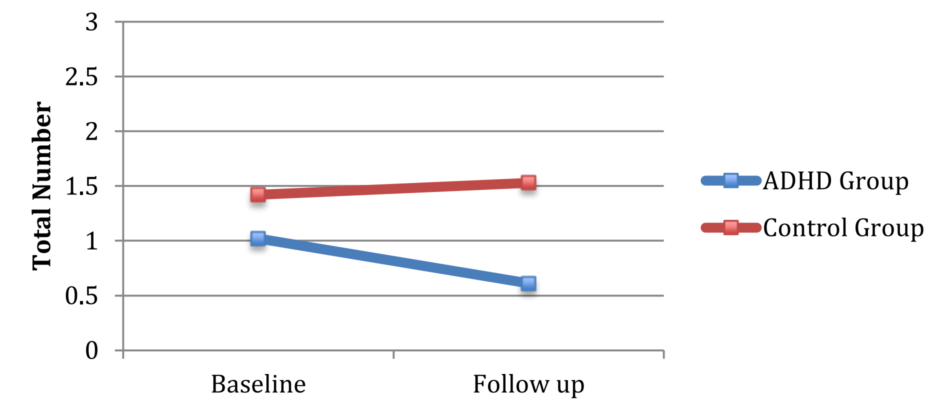

A mixed ANCOVA with participant group as a between groups factor and time point as a repeated measure revealed no effect of time point ($F[1,58]=1.12$, $p=.294$) or participant group ($F[1,58]=2.28$, $p=.137$) and there was no interaction ($F[1,58]=1.45$, $p=.235$). Planned contrasts revealed there were no significant differences between children with or without ADHD at baseline ($F[1,59]=0.17$, $p=.686$, $\eta^2=.002$) but there was a marginal effect of group at follow up ($F[1,59]=4.19$, $p=.045$, $\eta^2=.071$) such that the mean estimated crossing times offered by the control group were slightly higher than those offered by children with ADHD at time 2 as shown in Figure 15.8 below.

Figure 15.8: Estimated Crossing Time as a Function of Participant Group & Time point

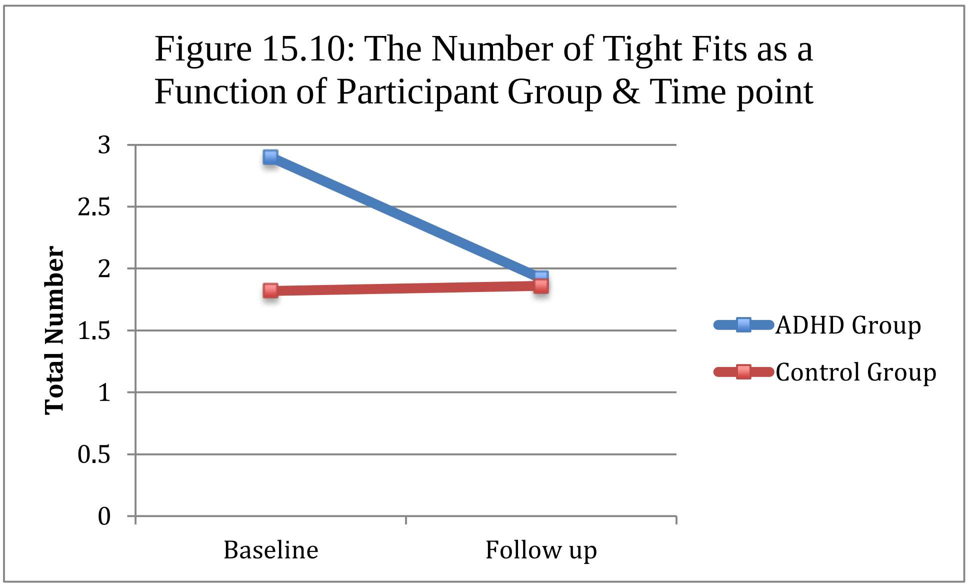



A mixed ANCOVA was conducted to examine differences in the number of missed opportunities with participant group as a between groups factor and time point as a repeated measure (with BPVS percentile rankings as a covariate) revealed no effect of time point ($F[1,58]=0.10$, $p=.755$, $\eta^2=.002$) but there was a significant main effect for participant group ($F[1,58]=16.24$, $p<.001$, $\eta^2=.231$). Children with ADHD missed fewer opportunities than did children in the control group. There was no interaction ($F[1,58]=2.44$, $p=.124$, $\eta^2=.043$). Planned contrasts revealed an effect of group at both baseline ($F[1,59]=30.38$, $p<.001$, $\eta^2=.35$) and follow up ($F[1,59]=14.96$, $p<.001$, $\eta^2=.22$) as shown in Figure 15.9 below.

Figure 15.9: The Number of Missed Opportunities as a Function of Participant Group & Time point




A mixed ANCOVA with participant group as a between subjects factor and time point as a repeated measure revealed no main effect of time point (F[1,58]=1.24, $p$=.271, $\eta^2$=.022) but there was a main effect of participant group (F[1,58]=7.75, $p$=.007, $\eta^2$=.126). Those with ADHD made more tight fits than controls. There was also an interaction between participant group and time point (F[1,58]=8.38, $p$=.005, $\eta^2$=.134) whereby the number of tight fits reduced between time one and time two for those in the ADHD group more markedly than for those in the control group (who continued to make approximately the same). Planned contrasts revealed although there were significant differences between participant groups at baseline (F[1,59]=16.07, $p$<.001, $\eta^2$=.22) there were no significant differences at follow up (F[1,59]=0.02, $p$=*.889*, $\eta^2$=.004).



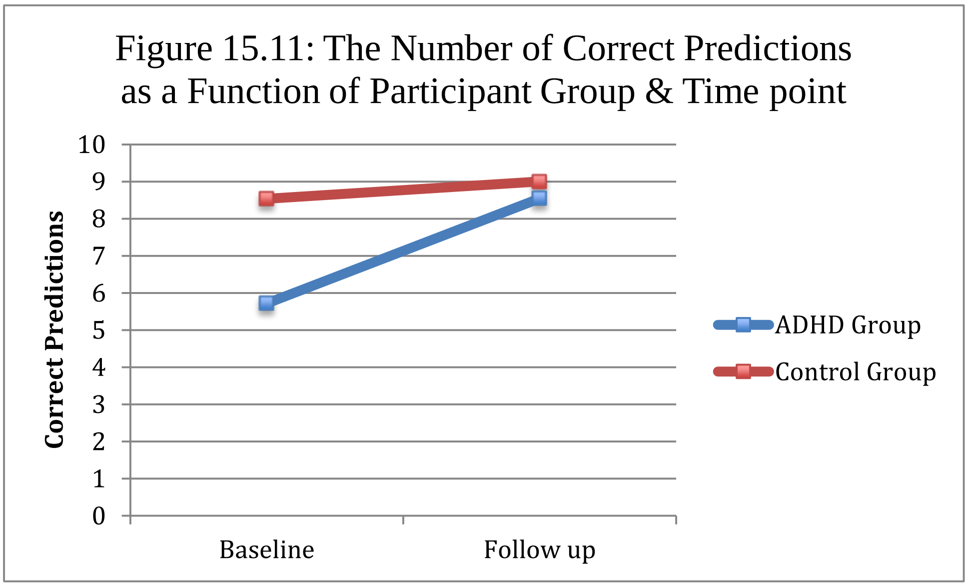

### 15.3.6 Predicting Road User Intentions

The mean (and standard deviation) number of correct predictions was calculated for baseline and follow up as a function of participant group as presented in Table 15.6 below.

Table 15.6: Mean (& S.D.) Number of Correct Predictions on the Predicting Road User Intentions Task as a function of Participant Group and Time point

| | ADHD Group | Control Group |
|---|---|---|
| Baseline | 5.72<br>(2.17) | 8.54<br>(2.19) |
| Follow up | 8.55<br>(1.92) | 9.00<br>(1.59) |

Differences in the number of correct predictions on the predicting road user intentions task made by children with and without ADHD at base line and follow-up were examined using a two way mixed ANCOVA with participant group as a between groups factor and time point as a repeated measure. BPVS percentile rankings were included as a covariate. This revealed a main effect of time point ($F[1,58]=7.91$, $p=.007$, $\eta^2=.128$) and a main effect of participant group ($F[1,58]=17.01$, $p<.001$, $\eta^2=.240$). There was also an interaction between participant group and time point ($F[1, 58]=10.86$, $p=.002$, $\eta^2=.167$). Those with ADHD improved much more significantly than did those in the control group. Planned contrasts revealed there was a significant effect of participant group at baseline ($F[1,59]=23.50$, $p<.001$, $\eta^2=.29$) but there were no significant differences between children with ADHD and controls at follow up ($F[1,59]=0.95$, $p=.334$, $\eta^2=.02$). Children with ADHD improved significantly between baseline and follow up where the performance of controls did not. This trend is shown in Figure 15.11 below.




## 15.4 Discussion

### 15.4.1 Follow up Findings

The findings of the current study broadly support the hypotheses. The performance of children with ADHD improved significantly across a range of measures of both neuropsychological function and pedestrian skill level at follow up compared to that at baseline. Findings demonstrate children with ADHD improved significantly, and to a much greater extent than control children, in respect of performance on both the SST assessing inhibitory control and DMtS task assessing short term visual memory at follow up. Such was the improvement of children with ADHD at follow up that there were no longer significant differences in the performance of children with ADHD compared with that of controls. These findings align very well with those reported previously which have reported chorionic administration of stimulant medication in children with ADHD improves inhibitory control (Coghill et al., 2007; Gilbert et al., 2006, Tamminga et al., 2016) and short term visual (but not working) memory (Coghill et al., 2014; Rhodes et al., 2004, 2006; Tamminga et al., 2016). At follow up, children in the ADHD group had improved so dramatically in their performance on the SST and DMtS that there was a significant interaction effect between participant group and time point demonstrating improvement was so significant for the ADHD group that differences in performance compared with the control group had diminished at follow up.

The findings of the current study also support the hypothesis that medication would improve pedestrian judgements in children with ADHD. These findings too demonstrate a positive impact of medication on performance on tasks assessing pedestrian competence. At 14 month follow up, by which time all of the children in the ADHD group had been taking dose optimal stimulant medication (prescription unchanged) for a mean time of 7.7 months, there were no longer significant differences in pedestrian skill level between the ADHD and control groups in respect of the ability to find a safe route across the road or the ability to predict the intentions of other road users. For both of these crucial skills, children with ADHD made significantly greater advances in skill level than did controls over the same period such that the differences between groups observed in the baseline data were no longer present at follow up. Following titration onto medication the performance of children with ADHD on the safe place finding and road user intentions tasks is effectively the same as that of controls. The ADHD group who were performing at a level significantly below that of the control group at baseline made much greater improvements than did controls such that their performance was indistinguishable from controls at follow up.

In addition, medication also appears to improve performance on some (but not all) aspects of the visual gap timing task. The size of gaps between cars in a flow of traffic children with ADHD were willing to cross through had been normalised by medication as had the number of tight fits. For both of these performance measures, children with ADHD were effectively indistinguishable from the control group at follow up. Children with ADHD also had longer starting delays at follow up than baseline and, although the change in effective gap size was only approaching significance, the combination of accepting larger gaps and reduced starting delays led to safer crossings as evidenced by the fact they made far fewer tight fits such that their performance in this regard was the same as that of controls. Children with ADHD however continued to underestimate the time needed to complete a crossing compared with control children. Thus medication alone does not improve all performance measures on the visual gap timing task which suggests children with ADHD may benefit from intervention in the form of specialist training to address aspects of the gap timing task which medication appears not to improve.

Overall, the findings of the current study demonstrate broad improvement in short term visual memory and inhibitory control as well as concurrent improvement in performance on tasks assessing safe place finding ability as well as the ability to predict road user intentions amongst children with ADHD following medication. In addition, medication appears to have also improved performance on some aspects of the visual gap timing task. In some cases, the difference between groups had disappeared altogether at follow up and in most of the others, it had been greatly reduced. The significant improvements observed at time 2 in respect of delayed short term visual memory also provide further evidence that as well as improving higher order (executive) aspects of cognition, medication also appears to improve more basic cognitive processes impaired in children with ADHD such as the ability to hold items in memory over time and adds further evidence to a growing evidence base demonstrating that medication having an ameliorating effect on delayed short term visual memory (Coghill et al., 2007, 2014; Rhodes et al., 2004, 2006).

Whilst insufficient numbers of participants were retained at follow up to allow for the same regression analyses reported in study 2.4 to be repeated on the follow up data, findings of the current study demonstrate significant improvement in aspects of both cognitive function and pedestrian skill level amongst children with ADHD who had been treated with stimulant medication. Of course these data do not demonstrate a causal relationship but they can be compared with the findings of studies 1.4 and 2.4 (reported in chapters 7 & 14 of this thesis).

In the current study, medication improved short term visual memory and inhibitory control. Study 1.4 showed short term visual memory to be a strong predictor of performance on the safe place finding and predicting road user intentions tasks. Study 2.4 showed the same relationships for control children but not for those in the ADHD group, who at baseline had poorer short term visual memory than controls. The current study showed medication improved performance on the DMtS assessing short term visual memory as well as safe place finding ability and the ability to predict the intentions of other road users level amongst children with ADHD. It would appear likely that the positive impact medication has on short term visual memory allows children with ADHD to begin to use this ability to complete the safe place finding and predicting road user intentions tasks in a manner more similar to that of controls. For example, delayed short term memory likely helps pedestrians to hold items in memory such as environmental hazards whist planning a crossing route and to remember cues that are indicative of the future actions of drivers when predicting intentions for a longer time period.

In addition, the findings relating to performance on the visual gap timing task at follow up may also be partly explained by the findings of study 2.4. Baseline findings show effective gap size was predicted by short term visual memory in both the ADHD and control groups. Those who performed better on the DMtS task assessing short term visual memory had higher effective gap sizes. DMtS task performance also predicted the number of tight fits in the control group whereby those with better short term visual memory, made fewer tight fits. The current study showed medication improved short term visual memory and so it is unsurprising that children with ADHD also had larger effective gaps and made fewer tight fits at follow up. A larger scale study to explore this interpretation directly would appear justified.

### 15.4.2 Methodological considerations and Future research

Children's medication regime was not controlled for in this study. Sufficient numbers of children receiving different medications (and at different doses) were not recruited in the current study to allow for comparisons in this regard to be drawn. These factors should also be examined directly by future research.

The time of day medication is administered relative to testing and the engagement with the traffic environment would also appear a pertinent direction for future work in this field. The current study tested children at a mean time of 2.5 hours following their most recent dose of medication, when its effects were still likely to be potent (Phelham, Swanson, Furman & Schwindt, 1995; Winsberg, Press, Biale & Kupietz, 1974). However, children with ADHD do not receive medication in a pattern that ensures these effects will always be present when interacting with traffic. Future research may wish to examine the effects of medication on children's pedestrian decision making relative to the time of ingestion.

This is important because immediate release MPH for the treatment of ADHD is typically administered either 2 or 3 times per day (Stein, Blondis, Schnitzler, O'Brien, Fishkin, Blackwell, Szumowski & Roizen, 1996); once in the morning before school and secondly at lunchtime whilst at school. Often a third dose is then administered when the child arrives home from school, towards the end of the day. The commonality of this pattern of administration for children with ADHD is reflected in intervention studies which have used similar patterns of administration to study the effects of the drug (e.g. Pelham, Gnagy, Chronis, Burrows-MacLean, Fabiano, Onyango, Meichenbaum, Williams, Aronoff & Steiner, 1999). Problems with medication being administered in this pattern in relation to pedestrian skill level become apparent when we consider the child road casualty statistics. On weekdays in Scotland the peak time for child traffic casualties is between 3 and 5 pm, yet there appear to be no clear peaks in child traffic casualties at weekends (Transport Scotland, 2010a). This suggests the majority of child casualties take place as children are making their way home from school, a time when for those with ADHD, the effects of medication may have at least partly worn off (Stavinros et al., 2011). In short when children with ADHD are walking home from school, this is likely at a time when levels of medication are at their lowest and consequently its effects weakest whilst exposure to traffic volume is approaching its highest. In some cases, the child is making the journey home from school to receive the very medication that they need to be able to do so safely. The implications of this would certainly appear worthy of further investigation and future research may wish to investigate this via an observational study conducted by the roadside. In addition, despite its ameliorating effects on pedestrian skill level, medication alone is unlikely to be enough to ensure children with ADHD behave consistently and always maintain safety by the road given the pattern by which medication is typically administered. A study examining differences in pedestrian behaviour of children with ADHD that takes account of how differences in treatment may yield a greater understanding of how best to treat ADHD relative to pedestrian skill level. It would also be pertinent for future research to consider the relative merits of using medication compared with other (behavioural) interventions such as pedestrian skills training.

### 15.4.3 Summary and Conclusion

In summary, the current study has revealed for the first time that stimulant medication appears to have a positive impact on child pedestrian skill level amongst children with ADHD. It was shown that after a mean period of 14 months, children with ADHD treated with dose optimal stimulant medication had improved significantly, to a level that was indistinguishable from controls. This was true across a range of outcome measures on what research has previously identified as key pedestrian skills (Thomson et al., 1996; Tolmie et al., 2002).

Following medication, children with ADHD were significantly more able to find a safe place to cross the road and plan a safe crossing route as shown by performance on the safe place finding task, which at re-test had been normalised. Performance on the predicting road user intentions task was also indistinguishable from that of controls at follow up. In addition, medication appears to have improved some (but not all) aspects of the visual gap timing ability of children with ADHD. Medication appears to normalise the size of gaps children with ADHD are willing to cross through and the number of tight fits made when crossing but had no impact on effective gap and estimated crossing times.

These findings provide strong evidence that medication has an ameliorating effect on pedestrian skill level of children with ADHD, across a range of skills and measures of performance. Future research should aim to build on these findings by investigating the effects of medication in greater detail in respect of dose and time of ingestion relative to the time at which children interact with traffic. The merits of intervention aiming to improve performance on aspects of the visual gap timing task not improved by medication would also seem appropriate. A randomised control trial may provide insights into the relative merits of behavioural, psychopharmacological and combined approaches to intervention for this vulnerable group.

# Chapter 16

## General Discussion of Part B

### 16.1 Introduction

Part B of this thesis adds to the small but growing body of research which highlights children with ADHD are a particularly vulnerable group of pedestrians. The studies reported in part B have shown children with ADHD are impaired on a broader range of pedestrian skills than has been previously demonstrated. The studies reported in chapters 11 and 13 showed this impairment extends beyond visual gap timing ability which is the only skill to have been previously studied in the ADHD population (Clancy et al., 2006; Stavrinos et al., 2011) and impairment extends to the ability to plan a safe route across the road and the ability to predict the intentions of other road users. Chapter 14 examined the relationships between neuropsychological function and skill level in respect of the three pedestrian skills under examination in this thesis. This study revealed the relationships between aspects of cognitive functioning and pedestrian skill level are different for children with ADHD compared with controls. The final study reported in chapter 15 then revealed that dose optimal stimulant medication improves aspects of neuropsychological function and pedestrian skill level in children with ADHD.

Chapter 11 showed children with ADHD were significantly less able to identify safe crossing locations and routes across the road than were matched control children. They also appear to have much poorer conceptual understanding of the task of doing so. With age, the proportion of safe routes selected by typically developing children increases dramatically in a manner similar to that previously reported (Ampofo-

Boateng & Thomson, 1993; Thomson et al., 1992), but this improvement was not observed for children with ADHD who in contrast continue to select very few safe routes regardless of age. Children with ADHD also had correspondingly poorer scores of conceptual understanding of the task of finding a safe crossing location. This suggests those with ADHD do not understand the aim of the task in the same manner as typically developing children. Further, whilst control children appear to foster an appreciation of the difficulty of the safe place finding task as they grow up, and rate it as being more difficult as a result, children with ADHD rate the task as being easier as they age, despite their much less safe performance. Children with ADHD appear not to realise the intricacies of planning a safe route across the road as they develop and fail to recognise the difficulties they experience when attempting to do so.

Chapter 12 revealed a similar pattern of results in respect of visual gap timing ability. Those with ADHD were willing to cross through smaller gaps between cars in a flow of traffic than were typically developing children. Children with ADHD had comparatively longer starting delays which resulted in shorter effective gaps and a greater number of tight fits as a result. These findings broadly resemble those of the two previous studies examining pedestrian skill level in children with ADHD, (Clancy et al., 2006, Stavrinos et al., 2011) but the task used in this thesis to assess visual gap timing ability has demonstrated impairment in this skill amongst children with ADHD in a much more detailed way such that the nature of this impairment is now more clear.

Children with ADHD also underestimate the difficulty of the visual gap timing task, relative to both matched control children and their own much less safe performance, in much the same way they do for the safe place finding task. Whilst control children appear to gain an appreciation of the difficulty of the task with age, this appears not to be the case for those with ADHD who continue to rate the task as being easy despite their relatively poor performance. This suggests children with ADHD experience a broader difficulty in monitoring their own behavioural performance by the roadside, which appears to extend across skills.

Chapter 13 then showed that children with ADHD are also much less able to make accurate predictions about the intentions and future actions of other road users. In study 2.3, children in the ADHD group made significantly fewer correct predictions about the intentions of other road users, and unlike control children, there was no age related improvement. Similar findings were revealed in respect of the ability of children with ADHD to identify environmental cues when children were asked to justify their predictions.

Collectively, these findings demonstrate significant impairment across a number of pedestrian skills amongst children with ADHD, in terms of both their behavioural response and conceptual understanding of the task at hand. These findings are the first to show children with ADHD are impaired in terms of a range of key pedestrian skills and that this impairment extends beyond the one skill in which children with ADHD have been previously shown to experience difficulties. The findings relating to perceived difficulty suggest not only are children with ADHD much less skilled than controls but also that they appear much less aware of the difficulty of the safe place finding and visual gap timing tasks and have a lack of insight into their own difficulties.

These findings carry important implications for clinicians, educators and public health professionals, as well as the parents of children with ADHD who should be made aware of the broad difficulties children with ADHD experience as pedestrians. Yet the novelty of this study and the small body of literature addressing pedestrian safety of children with ADHD that has been previously reported, means it is unlikely these groups have knowledge of these differences or at least the empirical evidence base demonstrating the extent of them. It is also important to note that there was *some* age related improvement in pedestrian skill level for children with ADHD. This improvement however was much less marked amongst children with ADHD compared with controls. Parents of children with ADHD may therefore be unaware of the extent of the problem, because they may confuse improvement with competence, which of course the findings of the current study have shown, is not the case. The significant differences in pedestrian skill level between children with ADHD and controls suggests those with ADHD will require much greater levels of supervision and guidance when interacting with traffic compared to peers of the same age. Clinicians and educators should disseminate these findings to professionals working with children with ADHD who at present will likely be unaware of the extent of the difficulties their children face by the roadside.

## 16.2 Neuropsychological Function and Pedestrian Skill Level of Children with ADHD

Chapter 14 showed children with ADHD to be impaired in terms of performance on tasks assessing inhibitory control, working memory and short term visual memory compared with case matched typically developing control children. These findings align well with those of past studies which have reported similar impairment in these aspects of neuropsychological function in children with ADHD.

Study 2.4 also showed predictive relationships between aspects of neuropsychological function and pedestrian skill level for typically developing children but these were different (and primarily absent) for children with ADHD. No relationships between performance on tasks assessing neuropsychological function and performance on the safe place finding and predicting road user intentions tasks were revealed for the ADHD group. This suggests difficulties with short term visual memory and spatial working memory (which were found to be predictive of pedestrian skill level amongst controls) prevent children with ADHD from applying these aspects of cognition by the roadside in the same manner as control children.

Some measures of performance on the visual gap timing task were predicted by short term visual memory for children with ADHD in the same way as was revealed for controls. Performance on the DMtS predicted starting delay and effective gap size for both groups. Those with better short term visual memory had shorter starting delays and longer effective gap sizes. However, problems with spatial working memory appear to result in children with ADHD accepting smaller gaps than controls and poorer inhibitory control seems to lead children with ADHD to estimate comparatively less time is needed to complete a crossing.

Together the findings reported in chapter 14 broadly support the findings of Stavrinos et al. (2011), which also reported a link between difficulties with aspects of neuropsychological function and pedestrian skill level.  They also extend the literature by revealing *which* aspects of functioning are linked with performance on the gap timing task as studied by Stavrinos and colleagues and by demonstrating difficulties with neuropsychological function appear to lead to a broader range of impairments, across multiple pedestrian skills.

**16.3 Impact of medication on Cognitive function and Pedestrian Skill Level**

The final study in this thesis, reported in chapter 15 then showed dose optimal stimulant medication appears to improve inhibitory control and delayed short term visual memory and pedestrian skill level amongst children with ADHD.  This was the first study to show medication appears to have a positive impact on the pedestrian skill level of children with ADHD.

Chapter 15 revealed dose optimal stimulant medication has an ameliorating impact on short term visual memory but no significant effect on working memory.  This finding fits very well with previous studies investigating the impact of medication on cognition in the ADHD population.  Rhodes et al. (2006) for example reported very similar findings using the same measures of neuropsychological function.  In this study, as was revealed here, medication normalised short term visual memory assessed using the DMtS from the CANTAB battery but had no impact on spatial working memory assessed using the CANTAB spatial working memory task. In addition, the current study showed medication had a positive impact on inhibitory control. This finding also fits well with the literature (e.g. Coghill et al., 2007).

The positive effects of medication on short term visual memory and inhibitory control were accompanied by correspondingly positive effects on pedestrian skill level. Medication appears to have normalised skill level of children with ADHD in respect of the safe place finding and predicting road user intentions tasks. At follow up, children with ADHD were able to select more safe routes and make more correct predictions than at baseline. They made much greater gains in the same period as controls and at follow up, the groups performed similarly. These findings will be of interest to clinicians when making decisions about the treatment of children with ADHD who should inform parents about the effects of medication on pedestrian skill level.

### 16.4 Limitations and Future Research

The study reported in chapter 15 did not control for the effects of medication dose or the time of day children took medication relative to testing. These are important factors which may impact upon pedestrian skill level of children with ADHD. As previously discussed, the typical pattern by which ADHD is treated is such that many children with ADHD walk home from school at a time when the effects of medication are at their lowest, when traffic volumes are high and thus when children are most vulnerable.  Future research should aim to investigate these factors explicitly, perhaps through an observational study taking account of medication regime.

It would also appear sensible to examine the relative merits of behavioural (versus pharmacological) intervention for children with ADHD.  Importantly, not all children with ADHD are treated with medication (see McCarthy, Wilton, Murray, Hodgkins, Asherson & Wong, 2012 for a discussion).  Future research should therefore aim to investigate intervention for those children with ADHD who are not treated with medication and examine the relative merits of a training approaches compared with pharmacological intervention for those who are.

On the one hand, it might be reasonably suggested that children with ADHD would benefit from practical pedestrian skill training such as that previously shown beneficial to the pedestrian skill development of typically developing children. Studies have shown that pedestrian skill level is susceptible to improvement through training delivered both by the roadside (Thomson et al., 1996) and via computer simulation (Thomson et al., 2005).  On the other, it is unclear whether problems with cognitive function might impact on the readiness of children with ADHD to benefit from such training, unless they are treated with medication.

The findings reported in this thesis also suggest that prospective interventions should take account of the difference in relation to the perceived difficulty ratings offered by children with ADHD compared with controls.  Peer tutoring approaches, which have been previously employed in relation to pedestrian skill training might be particularly appropriate.  Not only has this approach been shown effective in the training of pedestrian skill level previously (Tolmie et al., 2005), but such an approach would also align well with the inclusive education movement (Friend & Bursuck, 2002) as a pedagogically inclusive approach to road safety education for children with ADHD.

It would also appear sensible to examine the effectiveness of a multifactorial intervention which examines the merits of cognitive training, pedestrian skill training and approaches which combine the two.  The links between cognitive function and pedestrian skill level reported in this thesis suggest this is worthy of investigation.

Cognitive training has become a popular topic in recent years and there is much debate in the literature about its effectiveness.  Some studies report significant improvements following working memory and inhibition training amongst typical samples of children (Thorell, Lindqvist, Nutley, Bohlin & Klingberg, 2009).  Other studies report no effects (Rueda, Rothbart, McCandliss, Saccomanno & Posner, 2005).  A number of studies have reported that working memory training is effective in improving aspects of working memory in the ADHD population (Chacko et al., 2014; Gray et al., 2012; Klingberg et al., 2005; Roording-Ragetlie, Klip, Buitelaar, Slaats-Willemse, 2013) with some suggesting gains persist at 6 month follow up (Holmes et at., 2010).  Others however have suggested caution because here too transfer effects appear limited such that even if post-training gains are observed, they do not transfer to other domains (Thorell et al., 2009).  Some however have reported cognitive training has led to gains in achievement and productivity in mathematics learning (Cameron & Robinson, 1980; Kirby, 1984; Varni & Henker, 1979) and spelling (Alloway, Bibile & Lau, 2013) which suggests transfer effects of cognitive training may be domain specific.  No studies to the writer's knowledge have investigated transfer effects of cognitive training in relation to pedestrian skill level.

It would appear a randomised controlled trial is needed to determine the optimal approach to intervention for children with ADHD.  This should examine the effects of medication relative to the effects of training; both pedestrian and cognitive (as well as a combined approach to examine the effects of both).

It is also possible that the improvement in the pedestrian behaviour of the ADHD group at follow up is a result of medication having a positive effect on ADHD symptoms as well as on cognition.  This might be considered important because it has been generally assumed that cognitive impairment in ADHD underpins symptoms, it has been argued they merely co-occur are not causally related to one another.  The current study did not assess the mechanism by which medication improves pedestrian behaviour and so future studies may wish to consider this.

### 16.5 Conclusion

Part B of this thesis has shown differences in skill level when comparing the performances of children with and without ADHD on tasks assessing aspects of both neuropsychological function and pedestrian skill level.  Children with ADHD are much less able to find safe routes across the road, time gaps between cars in a flow of traffic and are less able to predict the intentions of other road users compared with case matched typically developing control children.

This thesis has also shown children with ADHD also have difficulties with aspects of cognitive function and appear unable to use these functions (including most notably delayed short term visual memory, working memory and to a lesser extent, inhibitory control) in the same manner typically developing children do when interacting with traffic. Stimulant medication appears to have a positive effect on short term visual memory and inhibitory control for children with ADHD. It also appears to have an ameliorating effect of pedestrian skill level of this group, which it would appear likely is a result of the impact it has on the neuropsychological functions which underpin children's ability to perform these skills by the roadside.

# Chapter 17

## Conclusion

Child pedestrian injuries remain one of the leading causes of death and serious injury in the developed world. This thesis adds to a growing literature which implicates children's cognitive development (and cognitive impairment in the case of children with ADHD) as being important factors that must be considered in order to address this public health problem.

Recent studies have reported cognitive abilities appear to underpin children's pedestrian skill level (e.g. Barton et al., 2010; Barton & Morrongiello, 2011) but have reported composite measures of cognition which made it unclear which functions were important. The experiments which comprise study one recruited typically developing children aged 5 to 12 years old and showed clear developmental improvement through middle childhood in respect of pedestrian skill level and aspects of cognitive function including inhibitory control, spatial working memory, delayed short term visual memory and risk taking. Gains in pedestrian skill level were accompanied by similar gains in respect of underlying conceptual understanding. Perceived difficulty of these skills was shown to increase with age amongst children aged 5 to 12 years old such that older children considered the safe place finding and visual gap timing tasks to be more difficult as they grow up whereas younger children rate the task as being easy despite their much less safe performance. It also shown that the cognitive functions under study predicted the performance of three key pedestrian skills.

These findings pave the way for the development and trial of prospective interventions which incorporate tasks that promote and require children to use short term visual memory, working memory and inhibitory control in the context of the traffic environment. They also suggest intervention targeting younger children ought to encourage children to reflect on their own performance and address the tendency of younger children to perceive the task of interacting with traffic as being easy, regardless of their limited ability to do so safely.

Part B adds to the growing evidence base that demonstrates as pedestrians, children with ADHD behave in a much less safe way than do typical children. Study 2 builds on two studies reported by Clancy et al. (2006) and Stavrinos et al. (2011) both of which reported children with ADHD were much more vulnerable as pedestrians than control children in respect of visual gap timing ability and in the case of the latter, which suggested this was because of problems with cognitive functioning. However, the composite measures used in this study meant it was impossible to identify the aspects of cognition that contributed to the performance of this skill. The experiments that comprise study 2 of this thesis showed children with ADHD are impaired on a much broader range of pedestrian skills than has been previously shown and that difficulties with neuropsychological function appear to at least partly explain this impairment. Specifically, children with ADHD appear unable to apply working memory and short term visual memory to help them by the roadside in the way typically developing children appear to be able to such that the relationships between cognitive function and pedestrian skill level revealed amongst controls were for the most part absent amongst those with ADHD. This results in a significant impairment in the safety of pedestrian behaviour in this group across three key pedestrian skills. This thesis has therefore shown children with ADHD are even more vulnerable than had been previously thought and that cognitive impairment common to this group appears to impact negatively on pedestrian skill level.

Study 3 then showed medication appears to normalise some aspects of neuropsychological function and pedestrian skill level amongst children with ADHD. 60 of the 122 children who took part in study 2 we retested 14 months later. By this time all of the children in the ADHD group had been titrated onto stimulant medication and were tested at follow up whilst taking optimal dose medication (prescriptions unchanged for a mean time of 7 months before testing). Medication normalised inhibitory control and delayed short term visual memory, but had no impact on working memory. Correspondingly, skill level on two of the three pedestrian skills had also been normalised. These skills on which children with ADHD improved were shown to be strongly linked with short term visual memory in chapter 14. Only some aspects of performance on a third pedestrian skill, that of visual gap timing were improved by medication. Whilst it would be tempting to conclude the mechanism by which medication improves pedestrian skill level is via its effects on cognitive function, further research is needed to investigate this.

These findings also highlight the need for future research to examine the potential of behavioural intervention for this vulnerable group and to evaluate the relative merits of pharmacological and behavioural interventions as well as an approach that combines the two to ensure the needs of this vulnerable group of children are fully and most appropriately met. Whilst much more research is required in this field, this thesis contributes to our understanding of the cognitive underpinnings of children's readiness to interact with the traffic environment. Practitioners should take account of the relationship between cognition and safety by the roadside and those working with the families of children with ADHD should highlight our growing understanding of their vulnerability as pedestrians. Researchers should strive to further disentangle the complex relationship between cognition and child pedestrian safety and ultimately should attempt to implement our understanding of these relationships through intervention in order to improve outcomes for children.

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# Appendices

## Appendix 1: Diagnostic Criteria for Attention Deficit Hyperactivity Disorder (ADHD) from DSM-V (APA, 2013).

A. Either (1) or (2):
(1) Inattention: six (or more) of the following symptoms of inattention have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:
(a) often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities
(b) often has difficulty sustaining attention in tasks or play activities
(c) often does not seem to listen when spoken to directly
(d) often does not follow through on instructions and fails to finish school work, chores, or duties in the workplace (not due to oppositional behaviour or failure to understand instructions)
(e) often has difficulty organizing tasks and activities
(f) often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)
(g) often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)
(h) is often easily distracted by extraneous stimuli
(i) is often forgetful in daily activities
(2) Hyperactivity-impulsivity: six (or more) of the following symptoms of hyperactivity-impulsivity have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:
Hyperactivity
(a) often fidgets with hands or feet or squirms in seat
(b) often leaves seat in classroom or in other situations in which remaining seated is expected
(c) often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)
(d) often has difficulty playing or engaging in leisure activities quietly
(e) is often "on the go" or often acts as if "driven by a motor"
(f) often talks excessively
Impulsivity
(g) often blurts out answers before questions have been completed
(h) often has difficulty awaiting turn
(i) often interrupts or intrudes on others (e.g., butts into conversations or games)
B. Some hyperactive-impulsive or inattentive symptoms that caused impairment were present before age 12 years.
C. Some impairment from the symptoms is present in two or more settings (e.g., at school [or work] and at home).
D. There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning.
E. The symptoms do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and are not better accounted for by another mental disorder (e.g., Mood Disorder, Anxiety Disorder, Dissociative Disorders, or a Personality Disorder).

## Appendix 2: Study 1 Information Sheet

# Participant Information Sheet (Parents/Guardians)

***School of Psychological Sciences & Health.***
***Examining the roles of Executive Functioning, Attention and Conceptual Understanding as Predictors of Child Pedestrian Behaviour.***

**Introduction**
My name is Martin Toye, I am a PhD researcher in the School of Psychological Sciences & Health at The University of Strathclyde. I have been a graduate member of the British Psychological Society since I gained my undergraduate degree in psychology from this department in 2011 and have since qualified as a primary school teacher registered with the General Teaching Council for Scotland. I am now researching executive (cognitive) functioning in children and its relationship to decision making and behaviour in a road safety context.

**What is the purpose of this investigation?**
This study will consider how specific psychological factors relate to road safety decision making in children. I am interested in a set of psychological skills known as executive functions and how these are used by children when making decisions about road safety. I will also look at how attention and conceptual understanding influences the decision making process and how these factors are influenced by age, gender and where children live geographically. Recent research suggests problems with some of these might explain the disproportionate involvement of children in pedestrian road accidents but a more detailed investigation of the relationship between these factors and child pedestrian behaviour is needed to inform future educational interventions aimed at improving road safety for children. I also hope to carry out follow-up work and repeat the same tasks with children in approximately one year to see how these factors develop as children grow up. I will contact you in one year from now to provide further information about this and to seek consent.

**Does your child have to take part?**
Participation in this study is entirely voluntary. Refusal to participate or the withdrawal of consent to participate at any stage before participation takes place will not affect any aspect of the way you or your child, are treated. All participants have a right to withdraw without detriment, at any stage before taking part in the project, without impact upon your rights or privacy. However, once your child has participated, it will not be possible to withdraw their data as this will remain pseudo-anonymous and thus be impossible to identify for the purposes of withdrawal.

**What will your child do in the project?**
You will be asked to sign and return the attached consent form to show you are happy for your child to take part now and that you consent to being contacted by the researcher again in one year to request permission for your child to be involved in a follow up project which you will be free to decide about at the time. Children themselves will complete a series of standardised (and well-validated) computer-based tasks which will require them to respond to different shapes and traffic scenarios on a computer screen using a computer mouse/keyboard, provided they themselves are happy to take part on the day. Tasks will be carried out in your child's school and children from each class will be asked to complete exactly the same tasks.

**Why has your child been invited to take part?**
Your child has been asked to take part to provide a sample of typical responses of children of their age. Your child's teacher will be asked to complete a brief questionnaire (Strength's and Difficulties Questionnaire, Goodman, 1997) about your child's behaviour at school in order to confirm it is indeed typical for a child their age. Children who do not score typically will be treated in exactly the same way

as all other children and offered the same opportunity to take part in the experiment alongside their peers so as to benefit from its educational value. All data about children who score outside the typical range on this questionnaire will be destroyed and not included in the analysis of this study. Because a score outside the typical range does not in itself carry any adverse consequences for children, and is of little meaning beyond the purpose it is being used for in this research project (to ensure those who take part behave typically for their age), only the researcher will be aware of which children's data will be omitted from analysis and scores for this questionnaire will not be disclosed to any other party, including parents and teachers. The responses from children who do participate will be representative of the typical responses of children at their age and stage of schooling. Thus responses from individual children are not of specific interest, but rather the combined responses of all children who take part (to provide a broad picture of children of different ages) which allows for pseudo-anonymity of data. This means you child's task responses will only be linked to their personal information (like age and gender) by a unique non-identifiable code. This data will be studied to attempt to better understand the relationship between psychological development and decision making. This in turn will help inform ways of improving future safety education and training for children to help them to make safer decisions and behave in more adult-like way.

**What are the potential risks to your child in taking part?**
There are absolutely no risks involved for those who take part.

**What happens to the information in the project?**
All information collected is confidential and pseudo-anonymity of data will be maintained at all times, no personal information will be published or disclosed to any party. Completed paperwork will be stored in a locked filing cabinet inside a secure office within the School of Psychological Sciences and Health. Furthermore, consent forms will not be stored with participant data, thus responses will be stored pseudo-anonymously. Data in electronic form will be pseudo-anonymous and will be saved on a password protected laptop which will also be locked away securely within the School of Psychological Sciences and Health. Any information participants provide will be kept confidential, used only for the purposes of completing this study, and will not be used in any way that can identify individuals.
The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.
Thank you for reading this information – please ask any questions if you are unsure about what is written here.

**What happens next?**
If you are happy to be involved in the project, you will be asked to sign the enclosed consent form to confirm this and then complete the participant information sheet, returning both to school with your child. If you do not want to be involved in the project then thank you for taking the time to read this information sheet.

Participants who would like to receive a copy of the final report to be produced from this study may request that this be provided by the researcher after the investigation is complete.

**Researcher Contact Details:**
*Mr. Martin K. Toye*
*School of Psychological Sciences & Health*
*40 George Street*
*Glasgow*
*G1 1QE*
*martin.toye@strath.ac.uk*
*tel:0141 548 4250*

**Chief Investigator Contact Details:**
*Professor James A Thomson*
*School of Psychological Sciences & Health*
*40 George Street*
*Glasgow*
*G1 1QE*
*j.a.thomson@strath.ac.uk*
*tel:0141 548 2572*

This investigation was granted ethical approval by the University of Strathclyde, School of Psychological Sciences & Health ethics committee. If you have any concerns, during or after the investigation, or wish to contact person independent from the project to whom any questions may be directed or further information may be sought from, please contact:

**School Ethics Contact Details:**
*Dr Susan Rasmussen (School Ethics Chair)*, *School of Psychological Sciences & Health, University of Strathclyde, Graham Hills Building, 40 George Street, Glasgow, G1 1QE, email: s.a.rasmussen@strath.ac.uk, tel: 0141 548 2575*

## Appendix 3: Study 1 Consent Form

# Consent Form *(Please return to School with your child sealed in the enclosed envelope)*

***School of Psychological Sciences & Health.***
***Examining the roles of Executive Functioning, Attention and Conceptual Understanding as Predictors of Child Pedestrian Behaviour.***

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.

- I understand that my participation is voluntary and that I am free to withdraw my child from the project at any time prior to their participation without having to give a reason and without consequence.

- I understand that although I can withdraw my child from the study at any time before they participate, it will not be possible to withdraw my child's data after this time as all information gathered will be pseudo-anonymous.

- I understand that any information recorded in the investigation will remain confidential and no information that identifies me or my child will be made publicly available.

- I consent to my child being a participant in the project.

Name of
Child:_________________________________________________________________________
(please print)

| | |
|---|---|
| Print Name(Parent/Guardian): | I hereby agree to my child taking part in the above project. |
| Signature of Parent/Guardian: | Date |

# Appendix 4: NHS Ethical Approval

EoSRES

NHS
SCOTLAND
Research Ethics Service

**East of Scotland Research Ethics Service (EoSRES) REC 1**
Tayside Medical Sciences Centre (TASC)
Residency Block C, Level 3
Ninewells Hospital & Medical School
George Pirie Way
Dundee DD19SY

Mr Martin K Toye
PhD Researcher (Psychology)
University of Strathclyde
40 George Street
Glasgow G1 1QE

| | |
|---|---|
| Date: | 05 March 2013 |
| Your Ref: | |
| Our Ref: | LR/13/ES/0012 |
| Enquiries to: | Mrs Lorraine Reilly |
| Direct Line: | 01382 383878 |
| Email: | eosres.tayside@nhs.net |

Dear Mr Toye

| | |
|---|---|
| **Study Title:** | **Predicting Pedestrian Behaviour in Children with Attention Deficit/Hyperactivity Disorder (ADHD)** |
| **REC reference:** | **13/ES/0012** |
| **IRAS project ID:** | **112917** |

Thank you for your letter of 27 February 2013, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information was considered in correspondence by a sub-committee of the REC. A list of the sub-committee members is attached.

We plan to publish your research summary wording for the above study on the NRES website, together with your contact details, unless you expressly withhold permission to do so. Publication will be no earlier than three months from the date of this favourable opinion letter. Should you wish to provide a substitute contact point, require further information, or wish to withhold permission to publish, please contact the Co-ordinator Mrs Lorraine Reilly, lorraine.reilly@nhs.net.

**Confirmation of ethical opinion**

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

**Ethical review of research sites**

NHS sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

**Conditions of the favourable opinion**

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to the start of

## Appendix 5: NHS R&D Approval (Health Board 1)

NHS
Tayside

08 March 2013

Mr Martin Toye
PhD Researcher (Psychology)
University of Strathclyde
40 George Street
Glasgow
G1 1QE

Dear Mr Toye,

**R & D MANAGEMENT APPROVAL - TAYSIDE**

**Title: Predicting Pedestrian Behaviour in Children with Attention Deficit/Hyperactivity Disorder (ADHD): the roles of Executive Functioning and Conceptual Understanding.**

**Chief Investigator:** Mr Martin Toye

**Principal Investigator: Dr David Coghill**

**Tayside Ref:** 2013PW01 **NRS Ref:** N/A

**REC Ref:** 13/ES/0012

**EudraCT Ref:** N/A **CTA Ref:** N/A

**Sponsor(s): University of Strathclyde**

**Funder(s): Unfunded Study**

Many thanks for your application to carry out the above project here in NHS Tayside. I am pleased to confirm that the project documentation (as outlined below) has been reviewed, registered and Management Approval has been granted for the study to proceed locally in Tayside.

Approval is granted on the following conditions:-

- ALL Research must be carried out in compliance with the Research Governance Framework for Health & Community Care, Health & Safety Regulations, data protection principles, statutory legislation and in accordance with Good Clinical Practice (GCP).
- All amendments to be notified to TASC R & D Office.
- All local researchers must hold either a Substantive Contract, Honorary Research Contract, Honorary Clinical Contract or Letter of Access with NHS Tayside where required (http://www.nihr.ac.uk/systems/Pages/systems_research_passports.aspx).
- TASC R & D Office to be informed of change in Principal Investigator, Chief Investigator or any additional research personnel locally.

Version 3 15/03/2012

## Appendix 6: NHS R&D Approval (Health Board 2)


**Operational Division**
Victoria Hospital

Hayfield Road
Kirkcaldy
Fife KY2 5AH
Telephone 01592 643355
www.show.scot.nhs.uk/faht

NHS
Fife


Mr Martin Toye
PhD Researcher (Psychology)
University of Strathclyde
40 George Street
GLASGOW
G1 1QE

Date: 3 June 2013
Our ref: 13-026 13/ES/0012
NRS13/MH102
Enquiries to: Aileen Yell
Direct Dial: 01383 623623 Ext 20940
Fax No:
E-mail: aileenyell@nhs.net

Dear Mr Toye

**Project Title: Predicting pedestrian behaviour in children with ADHD**

Thank you for your application to carry out the above project. Your project documentation (detailed below) has been reviewed for resource and financial implications for NHS Fife and I am happy to inform you that NHS permission for the above research has been granted on the basis described in the application form, protocol and supporting documentation. The documents reviewed were:

| Document | Version | Date |
| --- | --- | --- |
| Participant Data Sheet (Part A) | 1 | 18 January 2013 |
| Participant Data Sheet (Part B) | 1 | 18 January 2013 |
| CV – Martin Toye | | 21 January 2013 |
| IRAS R&D Form | 3.4 | 23 January 2013 |
| Evidence of insurance/indemnity | | 23 January 2013 |
| Provisional REC opinion letter | | 22 February 2013 |
| Assent Form for Children (Part A) | 2 | 25 February 2013 |
| Assent Form for Children (Part B) | 2 | 25 February 2013 |
| Final favourable REC opinion letter | | 5 March 2013 |
| Protocol | 2 | 22 April 2013 |
| Parent/Guardian Consent Form (Part A) | 3 | 22 April 2013 |
| Parent/Guardian Consent Form (Part B) | 3 | 22 April 2013 |
| Participant BPVS Recording Sheet | 1 | 22 April 2013 |
| REC letter confirming evidence of compliance with approval conditions | | 1 May 2013 |
| IRAS SSI Form | 3.4 | 8 May 2013 |
| NRS-PCC Certificate of Compliance | | 15 May 2013 |
| Site Specific Assessment Review | | 23 May 2013 |
| Information Sheet for Children (Part A) | 4 | 29 May 2013 |
| Information Sheet for Children (Part B) | 4 | 29 May 2013 |
| Parent/Guardian Information Sheet (Part A) | 4 | 29 May 2013 |
| Parent/Guardian Information Sheet (Part B) | 4 | 29 May 2013 |

Ver 1 – 01.11.09

## Appendix 7: Study 2 Guardian Information

**School of Psychological Sciences & Health**
**University of Strathclyde**

# Parent/Guardian Information Sheet (Part A)

Predicting Pedestrian Behaviour of Children with ADHD

My name is Martin Toye and I am a PhD Researcher at the University of Strathclyde. I am required to undertake a project as part of my course and invite you to take part in the following study. However, before you decide to do so, I need to be sure that you understand firstly why I am doing it, and secondly what it would involve if you agreed. I am therefore providing you with the following information. Please read it carefully and be sure to ask any questions you might have and, if you want, discuss it with others including your friends and family. I will do my best to explain the project to you and provide you with any further information which you may ask for now or later. The purpose of the study is to investigate the relationship between cognitive (psychological) functioning and computer-simulated road safety behaviour in children with ADHD.

<u>What is Attention Deficit Hyperactivity Disorder?</u>

Attention deficit hyperactivity disorder (ADHD) is a medical condition where children and young people experience difficulties with concentration, keeping still, remaining focused on tasks and thinking before acting. Children with ADHD often experience difficulties at school and are more likely to be involved in accidents (most commonly traffic accidents) compared to children who do not have ADHD.

<u>What is the purpose of this study?</u>

It is important that we try to find ways of helping children with ADHD become safer. We hope to do this by making educational resources and training more effective for children with ADHD. In order to do this, we must first study how the ways in which children with ADHD think about safety and danger are different to typically developing children and investigate the relationship between their psychological abilities and roadside behaviour.

<u>Medicines used to treat ADHD</u>

Although not all children and young people with ADHD require medication, some do. This is usually if their symptoms are more severe and/or if other treatment approaches like behavioural therapy hasn't helped them. The medicine most often prescribed by doctors is called Methylphenidate. It comes in several forms (e.g. Concerta XL, Equasym, Equasym XL, Medikinet, Medikinet XL). While methylphenidate has been prescribed for quite some time to reduce the symptoms of ADHD, very little information exists about the effect this medicine has on improving the roadside behaviour of children who take this, and in turn there is no way of knowing the impact medicines might have on how we should design and structure future road-safety educational resources for these children.

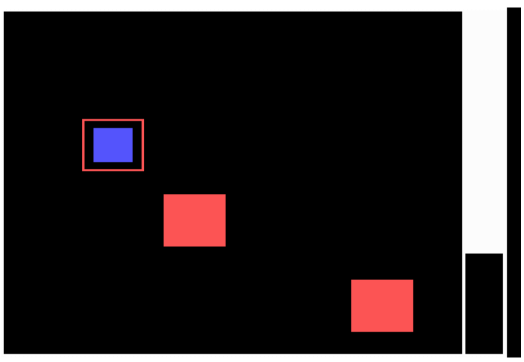
<u>Who is being invited to participate?</u>
Any child or young person aged between 5 and 12 years who has ADHD is being invited to take part. We hope this will provide some clues as to what influences road safety decision making in children with ADHD and reveal the effects of executive (psychological) functioning, what effects are due to medicines, and what differences may be due to individual factors like age, gender, and the places where children live.

<u>What does the study involve?</u>
The study is in two parts which will take place 12 months apart during other scheduled appointments. You and your child can choose whether your child takes part in both parts of the study or only Part A. The activities and process in Part B will be <u>exactly</u> the same as those in Part A because part B is to see how children's responses change as they grow up. Information about Part B will be given in a separate information sheet nearer the time, when you can decide if you want to be involved a second time.

**PART A**
Part A will take place during a scheduled appointment with NHS Tayside. During many appointments for children, it is normal that the doctors and nurses spend some time talking with parents/guardians, during which time children are free to play (as you will know doubt be aware). We hope to use this time to work through some computer-based activities with your child who will complete game-like activities on a standard laptop computer and touch-screen tablet device. We will also record your child's score on the British Picture Vocabulary Scale (BPVS) which is a short (4-8minute) picture vocabulary test that simply requires children to select (by pointing) to the everyday object the researcher reads out to them from a choice of four pictures. Your child may have had this carried out recently by their psychiatrist, if this is the case; their psychiatrist will communicate their score to us. If they have, not this will be administered by the researcher before the other tasks. This will allow us to accurately compare the performance of children with ADHD to children of the same ability without ADHD, which in turn will help us better design road safety interventions for those with ADHD.

The activities on the touch-screen tablet device are simple problem solving tasks which require children to respond to different colours and shapes. These have different levels of complexity and assess their executive (psychological) functioning. The laptop activities involve children moving a virtual character through a series of simulated traffic environments safely. This assesses the safety of their decision-making and road safety behaviour.

Here are some examples of the computer activities children will respond to. They will also be asked simple questions such as "What do you think the car is going to do next?" to ensure they understand the activities.



Both of these activities have been used previously in other studies (in which children have said they have enjoyed them). Furthermore, the road safety activities have been shown to be educationally effective when previously used in mainstream schools. We have tried to keep these as short as possible.

**PART B.**

Part B will be exactly the same as part A, only this will take place one year (12 months) later. This will allow us to investigate how safety and decision making in children with ADHD changes as children get older and (if you child has started taking medicine since they took part in Part A) the impact medicine has had on how they respond to the activities. Another information sheet and consent form will be given to you nearer the time which will provide more information and allow you to decide if you want to be involved the next time.

What will happen to the information collected in the study?

All information collected is confidential and pseudo-anonymity of the data will be maintained at all times, no personal information will be published or disclosed to anyone. Completed paperwork will be stored in secure offices within the School of Psychological Sciences and Health at the University of Strathclyde. Consent forms will not be stored with information, thus responses will be stored pseudo-anonymously. Data in electronic form will also be pseudo-anonymous and will be saved on a password protected laptop which will also be locked securely within the School of Psychological Sciences and Health. Any information participants provide will be kept confidential, used only for the purposes of completing this study, and will not be used in any way that can identify individuals. The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Should your child withdraw from the study at any point, no further data would be collected or any other research procedures carried out on or in relation to your child after the withdrawal date. All identifiable data collected to that date would be retained and used in the study.

Who has reviewed the study?

The East of Scotland Research Ethics Committee REC 1, which has the responsibility for reviewing proposals for research with humans has examined the proposal and has raised no objections from the point of view of medical ethics. The University of Strathclyde ethics committee has conducted a similar review and has also approved the research. It is a requirement that your child's records in this research, together with any relevant records, be made available for scrutiny by monitors from the University of Strathclyde, whose role is to check that research is being properly conducted and that the interests of those taking part are adequately protected.

What are my rights?

If you believe that you or your child have been harmed in any way by taking part in this study, you have the right to pursue a complaint and seek any resulting compensation through the University of Strathclyde who is acting as the research sponsor. Details about this are available from the research team. Also, as a patient of the NHS, you have the right to pursue a complaint through the usual NHS process. To do so, you can submit a written complaint to the following address.

Patient Liaison Manager,
Complaints Office,
Level 7, Ninewells Hospital
Dundee DD1 9SY
Free Phone 0800 027 5507
Email: nhstaysidecomplaints@thb.scot.nhs.uk

The NHS has no legal liability for non-negligent harm. However, if you are harmed and this is due to someone's negligence, you may have grounds for a legal action against the University of Strathclyde but you may have to pay your legal costs.

What are the potential risks to my child in taking part?
There are no risks to your child to taking part in this research. If a medical condition not previously known is discovered during your child's visit (the day of participation) by members of their NHS Tayside clinical care team, your child will be treated in the usual way by their doctors and this may or may not mean that your child will have to withdraw from the study.

Findings
Using the information gathered in this research project, we hope to find the answers to our questions about how psychological functioning influences road safety behaviours in children with ADHD. If our findings prove to be significant we hope to publish them and share our results with others in the field of ADHD by making conference presentations which in turn could lead to more research or the development of new interventions to help these children become safer. Your child's personal information will never appear in any of these publications and at all times will remain pseudo-anonymous.

Informed consent
If you consent to your child's participation in any of this research, you will be given a consent form to read and sign. Your child will also be asked to complete an assent form on the day of their participation to show they are happy to take part. Both must be completed for children to participate. If either you or your child wish to withdraw participation in the study then both of you are free to do so at any time. This will in no way affect your child's current or future healthcare or how either of you are treated by the research team or members of the clinical care team.

If you have any further questions then please do not hesitate to contact us using the contact details over the page.

**Martin K Toye**
School of Psychological Sciences and Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow, G1 1QE
Email: martin.toye@strath.ac.uk
Tel: 0141 548 4250

**Dr David R Coghill (Psychiatrist)**
Centre for Child Health
19 Dudhope Terrace
Dundee
Tel: 01382 204004

**Prof. James Thomson (Professor)**
School of Psychological Sciences & Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow G1 1QE
Email: j.a.thomson@strath.ac.uk
Tel: 0141 548 2572

**Dr Sinéad Rhodes (Senior Lecturer)**
School of Psychological Sciences & Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow G1 1QE
Email: sinead.rhodes@strath.ac.uk
Tel: 0141 548 2489

If you have any concerns, during or after the investigation, or wish to contact person independent from the project to whom any questions may be directed or further information may be sought from, please contact:

**University Ethics Committee Secretariat**
University of Strathclyde
Graham Hills Building
50 George Street
Glasgow G1 1QE
Email: ethics@strath.ac.uk
Tel: 0141 548 3707

Thank you for taking the time to read this information sheet and for considering taking part in this study.

**Appendix 8: Study 2 Child Information Sheet**

School of Psychological Sciences & Health
University of Strathclyde

# Information Sheet for Children (Part A)

## Predicting Pedestrian Behaviour of Children with ADHD

My name is Martin and I am running a project to learn about how Attention Deficit Hyperactivity Disorder (ADHD) affects how children think about road safety. This is important as crossing roads can be difficult and dangerous when you have ADHD. I am inviting you to take part.

Before you decide whether or not you want to, I need to make sure you know what you would be doing if you decide you do want to take part.

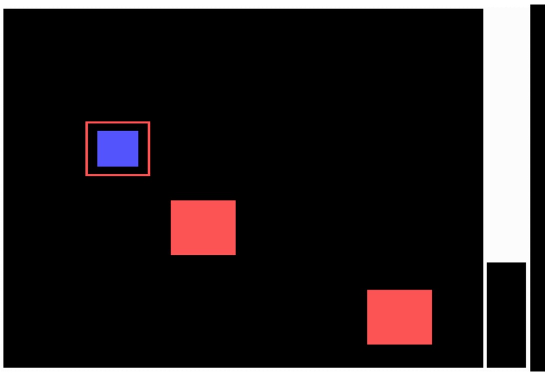
We are giving you this sheet to help you understand these things. Please read it carefully and ask any questions you might have. We will do our best to explain and give you any more information you might want to know or later. You do not have to decide straight away.


**Who is being asked to take part and why?**
Anyone who is at primary school who has recently been told they have ADHD by their doctor is being invited to take part. This will help us understand if children with ADHD think differently about road safety to children without ADHD.

**Do I have to take part?**
No, it is completely up to you. You should read this information sheet and ask your family, me or your doctor if you have any questions. If you decide not to take part, that's fine. Nobody will be cross with you. If you change your mind you can stop taking part at any time without giving a reason.

**What will happen to me if I take part?**
We will ask you to write your name on an assent form to show you are happy to take part.

Then, while your family is talking with the doctors and nurses I will ask you to work through some computer activities with me. Some will show you different shapes and colours and others will ask you to move a character across different roads. There are some photos below to show you what these activities will look like. I will also ask you some simple questions like "What do you think the car is going to do next?" There are no right or wrong answers to these – I just want you to tell me what you think.  I might also ask you to complete a short activity in which I ask you to pick out the picture of different words I say.




**What are the possible benefits of taking part?**
The information we get from the study will also help us learn more about ADHD and some children who have done these activities before have learned to make safer decisions when crossing roads.

**What will happen to the information collected in the study?**
All of your answers on the computer programs will be kept safe on computers with passwords.  Your answers won't have your name on them.  All other information will be kept in locked offices.  If you want to stop taking part we will use the information collected up to that time but won't collect any more information about you once you tell us you want to stop taking part.

**Who has reviewed the study?**
The East of Scotland Research Ethics Service checks that research is going to be properly carried out and they have agreed that this study is safe to take part in.

**What are my rights?**
If you think you have been harmed in any way by taking part, you can complain. The research team can tell you and your parents more about how to do this.

**Is there anything else to be worried about if I take part?**
We do not think there is anything to worry about by taking part in this study, you can stop at any time and this will be done while whoever has taken you to the hospital is talking with the doctors and nurses, so you won't have to make any extra trips into the hospital.

**Results**
We hope to find the answers to our questions about how to make children with ADHD safer when out and about near roads.  At the end, after we have seen lots of children, if we think we might have a new way to do this, we hope to share this with other people who work with children who have ADHD but no personal information about you will ever be shared with anyone.

**Do you want more information?**
If you would like any further information or have any questions please ask your family or contact:

**Martin K Toye**
School of Psychological Sciences and Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow, G1 1QE
Tel: 01415484250

**Dr David R Coghill (Psychiatrist)**
Centre for Child Health
19 Dudhope Terrace
Dundee
Tel: 01382 204004

Or if you would like to someone not involved, you can contact:

**University Ethics Committee**
University of Strathclyde
Graham Hills Building
50 George Street
Glasgow G1 1QE
Email: ethics@strath.ac.uk

Thank you for reading this information sheet and for thinking about taking part in this study.

## Appendix 9: Study 2 Guardian Consent

Consent Form (A) Guardians

University of Strathclyde Glasgow NHS Tayside University of Dundee

School of Psychological Sciences & Health
University of Strathclyde

Participant ID:______

# Parent/Guardian Consent Form (Part A)

## Predicting Pedestrian Behaviour of Children with ADHD

Please read each statement carefully and write your initials in the box to the right only if you agree with the corresponding statement.

Please Initial

- I confirm that I have read and understood the information sheet (version 3, dated 22/4/2013) for the above project and the researcher has answered any queries to my satisfaction. ☐
- I understand that my participation is voluntary and that I am free to withdraw my child from the project at any time prior to their participation without having to give a reason and without consequence. ☐
- I understand that although I can withdraw my child from the study at any time before they participate, it will not be possible to withdraw my child's data after this time as all information gathered will be pseudo-anonymous. ☐
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me or my child will be made publicly available. ☐
- I consent to my child being a participant in the project. ☐

*If you do not agree with all of the above statements, or you don't want to take part, please do not complete the below information. If each of the above is initialed (signifying agreement with each) and you do want to take part, please now complete the below information as consent.*

Name of Child:
(please print) ..........................................................................................................................................

| Print Name(Parent/Guardian): | *I hereby agree to my child taking part in the above project.* |
|---|---|
| Signature of Parent/Guardian: | Date: |

| Witnessed by (Print Name): | Witness Signature: | Date: |
|---|---|---|
| | | |

- I agree/disagree for me and my child to be sent information about future research (*please delete as appropriate*). ☐
  *(if yes please complete the below information which will be held for 5 years, if no, please leave blank)*

---

**Contact Details for Future Research**

| Print Name(Parent/Guardian): | Address (including postcode): |
|---|---|
| Print Name(Child):<br><br>DOB: | Tel:<br><br>Mobile: |

Version 4 22/8/2013

## Appendix 10: Study 2 Child Assent Form

Assent Form (A) Children

University of Strathclyde Glasgow | NHS Tayside | University of Dundee

School of Psychological Sciences & Health
University of Strathclyde

Participant ID:______

### Assent Form for Children (Part A)

Predicting Pedestrian Behaviour of Children with ADHD

(To be completed by children and their parent/guardian)

Child (or guardian on their behalf if unable), please circle yes for all you agree with:

| | |
|---|---|
| Have you read (or had read to you) information about this project? | Yes/No |
| Has somebody else explained this project to you? | Yes/No |
| Do you understand what this project is about? | Yes/No |
| Have you asked all the questions you want? | Yes/No |
| Have you had all your questions answered in a way you understand? | Yes/No |
| Do you understand it is ok to stop taking part at any time? | Yes/No |
| Are you happy to take part? | Yes/No |

If any are 'no' answers or you don't want to take part, please do not sign your name below, but If each of the above is marked yes and you do want to take part, please write your name and today's date

Your name ........................................................................Date.......................................................................

Your parent or guardian must also write their name here if they are happy for you to take part in the project

Print Name ......................................................................

Signed ...................................................................... Date ......................................................................

The researcher who explained this project to you needs to sign here too:

Print name......................................................................

Signed ...................................................................... Date ......................................................................

Version 2 25/2/2013

## Appendix 11: Study 2 Control Information Sheet

# Parent/Guardian Information Sheet

**School of Psychological Sciences & Health**
**Executive Functions and Child Pedestrian Behaviour: A Follow up Study**

**Introduction**
My name is Martin Toye, I am a PhD researcher in the School of Psychological Sciences & Health at The University of Strathclyde. I have been a graduate member of the British Psychological Society since I gained my undergraduate degree in psychology and have since qualified as a primary school teacher registered with the General Teaching Council for Scotland. I am now researching executive (cognitive) functioning in children and its relationship to decision making and child safety in a road safety context.

**What is the purpose of this investigation?**
This study is a follow-up to a study you may have consented to your child participating in last year. If your child took part in this previous study, we would like to invite them to take part in this follow-up research project. The title of this study was "Examining the roles of Executive Functioning, Attention and Conceptual Understanding as Predictors of Child Pedestrian Behaviour". If your child did not take part in this study, please ignore this information sheet and disregard the attached documents for this follow up study. This follow up study aims to investigate how specific psychological factors develop over the period of a year and how their relationship to road safety decision making in children develops. I am interested in a set of psychological skills known as executive functions (which include aspects of memory and behavioural control) and how these are used by children when making decisions about road safety. Recent research suggests problems with some of these might explain the disproportionate involvement of children in pedestrian road accidents but a more detailed investigation of the relationship between these factors and child pedestrian behaviour is needed to inform future educational interventions aimed at improving road safety for children.

**Does your child have to take part?**
Participation in this study is entirely voluntary. Refusal to participate or the withdrawal of consent to participate at any stage before participation takes place will not affect any aspect of the way you or your child, are treated. All participants have a right to withdraw without detriment at any time, without impacting upon your rights or privacy.

**What will your child do in the project?**
You will be asked to sign and return the attached consent form to show you are happy for your child to take part. Children themselves will complete the same computer-based tasks they did last year, which will require them to respond to different shapes and traffic scenarios on a computer screen using a computer mouse/keyboard, provided they themselves consent to take part on the day. Children will also complete a brief vocabulary exercise (using the British Picture Vocabulary Scale) which provides a general measure of their language ability. This will help the research team establish how language ability might influence task performance. All tasks will be carried out in your child's school and all children taking part will be asked to complete the same tasks which take around one hour to complete. Children will be asked if they would like to take part and only those who wish to do so on the day will be invited to complete these activities.

**Why has your child been invited to take part?**
Your child has been asked to take part because they have previously participated in a similar study. By taking part again, they will become part of a large sample of responses of children of their age and their scores can be compared to those from last year. Your child's teacher will also be asked to complete a brief questionnaire (Strengths and Difficulties Questionnaire, Goodman, 1997) about your child's behaviour at school in order to confirm it is typical for a child their age. Children who do not score typically will be treated in exactly the same way as all other children and offered the same

opportunity to take part in the experiment alongside their peers so as to benefit from its educational value. All data about children who score outside the typical range on this questionnaire will be destroyed and not included in the analysis of this study. Because a score outside the typical range does not in itself carry any adverse consequences and is of little meaning beyond the purpose it is being used for in this research project (to ensure those who take part behave typically for their age), only the researcher will be aware of which children's data will be omitted from analysis and scores for this questionnaire will not be disclosed to any other party, including parents and teachers. The responses from children who do participate will be representative of the typical responses of children at their age and stage of schooling. Thus responses from individual children are not of specific interest, but rather the combined responses of all children who take part (to provide a broad picture of children of different ages) which allows for pseudo-anonymity of data. This means you child's task responses will only be linked to their personal information (like name, age and gender) by a unique non-identifiable code. This data will be studied to attempt to better understand the relationship between psychological development and decision making. This in turn will help inform ways of improving future safety education and training for children to help them to make safer decisions and behave in more adult-like way.

**What are the potential risks to your child in taking part?**
There are no anticipated risks for those who take part. Your child has completed these tasks previously.

**What happens to the information in the project?**
All information collected will be treated as confidential and pseudo-anonymity of data will be ensured when the data is stored. No personal information will be published or disclosed to any party. Completed paperwork will be stored in a locked filing cabinet inside a secure office within the School of Psychological Sciences and Health. Furthermore, consent forms will not be stored with participant data, thus responses will be stored pseudo-anonymously. Data in electronic form will be pseudo-anonymous and will be saved on a password protected laptop which will also be locked away securely within the School of Psychological Sciences and Health. Any information participants provide will be kept confidential, used only for the purposes of completing this study, and will not be used in any way that can identify individuals.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998. Please ask any questions about anything written here you are unsure about.

**What happens next?**
If you are happy to be involved in the project, you will be asked to sign the enclosed consent form to confirm this and then complete the participant information sheet, returning both to school with your child. If you do not want to be involved in the project then thank you for taking the time to read this information sheet.

Participants who would like to view a copy of the final report to be produced from this study may do so by contacting their child's school which will be provided by the researcher after the investigation is complete.

**Researcher Contact Details:**
*Martin K. Toye*
*School of Psychological Sciences & Health*
*40 George Street*
*Glasgow*
*G1 1QE*
*martin.toye@strath.ac.uk*
*tel:0141 548 4250*

**Chief Investigator Contact Details:**
*Professor James A Thomson*
*School of Psychological Sciences & Health*
*40 George Street*
*Glasgow*
*G1 1QE*
*j.a.thomson@strath.ac.uk*
*tel:0141 548 2572*

This investigation was granted ethical approval by the University of Strathclyde, School of Psychological Sciences & Health ethics committee. If you have any concerns, during or after the investigation, or wish to contact person independent from the project to whom any questions may be directed or further information may be sought from, please contact:

**School Ethics Contact Details:**
*Dr Susan Rasmussen (School Ethics Chair)*, *School of Psychological Sciences & Health, University of Strathclyde Graham Hills Building, 40 George Street, Glasgow, G1 1QE, e: s.a.rasmussen@strath.ac.uk, tel: 0141 548 2575*

## Appendix 12: Study 2 Control Consent Form

# Consent Form *Please return this form to school with your child.*

**School of Psychological Sciences & Health**
**Executive Functions and Child Pedestrian Behaviour: A Follow up Study**

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.
- I understand that my participation is voluntary and that I am free to withdraw my child from the project at any time prior to their participation without having to give a reason and without consequence.
- I understand that although I can withdraw my child from the study at any time before they participate, it will not be possible to withdraw my child's data after this time as all information gathered will be pseudo-anonymous.
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me or my child will be made publicly available.
- I consent to my child being a participant in the project.

Name of
Child:_______________________________________________________________________
(please print)

| | |
|---|---|
| Print Name(Parent/Guardian): | I hereby agree to my child taking part in the above project. |
| Signature of Parent/Guardian: | Date |

**Appendix 13: Study 3 Guardian Information Sheet**

School of Psychological Sciences & Health
University of Strathclyde

# Parent/Guardian Information Sheet (Part B)

## Predicting Pedestrian Behaviour of Children with ADHD: Follow-up

My name is Martin Toye and I am a PhD Researcher at the University of Strathclyde. I am required to undertake a project as part of my course and invite you to take part in the following study. However, before you decide to do so, I need to be sure that you understand firstly why I am doing it, and secondly what it would involve if you agreed. I am therefore providing you with the following information. Please read it carefully and be sure to ask any questions you might have and, if you want, discuss it with others including your friends and family. I will do my best to explain the project to you and provide you with any further information which you may ask for now or later. The purpose of the study is to investigate the relationship between cognitive (psychological) functioning and computer-simulated road safety behaviour in children with ADHD.

<u>What is Attention Deficit Hyperactivity Disorder?</u>
Attention deficit hyperactivity disorder (ADHD) is a medical condition where children and young people experience difficulties with concentration, keeping still, remaining focused on tasks and thinking before acting. Children with ADHD often experience difficulties at school and are more likely to be involved in accidents (most commonly traffic accidents) compared to children who do not have ADHD.

<u>What is the purpose of this study?</u>
It is important that we try to find ways of helping children with ADHD become safer. We hope to do this by making educational resources and training more effective for children with ADHD. In order to do this, we must first study how the ways in which children with ADHD think about safety and danger are different to typically developing children and investigate the relationship between their psychological abilities and roadside behaviour. This time, we want to find out how these things have changed since your child last took part.

<u>Medicines used to treat ADHD</u>

Although not all children and young people with ADHD require medication, some do. This is usually if their symptoms are more severe and/or if other treatment approaches like behavioural therapy hasn't helped them. The medicine most often prescribed by doctors is called Methylphenidate. It comes in several forms (e.g. Concerta XL, Equasym, Equasym XL, Medikinet, Medikinet XL). While methylphenidate has been prescribed for quite some time to reduce the symptoms of ADHD, very little information exists about the effect this medicine has on improving the roadside behaviour of children who take this, and in turn there is no way of knowing the impact medicines might have on how we should design and structure future road-safety educational resources for these children.

Who is being invited to participate?

All children who took part in Part A of this study are being invited back to take part in this follow-up part of the study. This will give us information about how the safety and decision making abilities of children with ADHD change over time and what effects any medicines your child might have started taking have had on their executive (psychological) functioning and the safety of their road-safety decision making.

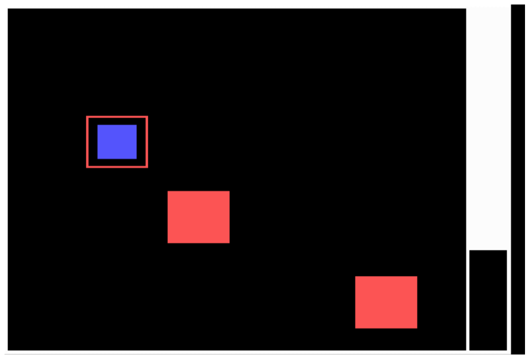
What does the study involve?

This part of the study involves your child taking part in exactly the same activities as they did in Part A because we are interested in how responses might have changed.

Like Part A, Part B will take place during another scheduled appointment with NHS Tayside while you are talking with the doctors/nurses. We will use time to work through the same computer-based activities with your child who will complete the same game-like activities on a laptop computer and touch-screen tablet device. We will also record your child's score on the British Picture Vocabulary Scale (BPVS) which is a short (4-8minute) picture vocabulary test that simply requires children to select (by pointing) to the everyday object the researcher reads out to them from a choice of four pictures. Your child may have had this carried out recently by their psychiatrist, if this is the case; their psychiatrist will communicate their score to us. If they have, not this will be administered by the researcher before the other tasks. This will allow us to accurately compare the performance of children with ADHD to children of the same ability without ADHD, which in turn will help us better design road safety interventions for those with ADHD.

The activities on the touch-screen tablet device will be the same simple problem solving tasks which require children to respond to different colours and shapes. These have different levels of complexity and assess their executive (psychological) functioning. The laptop activities will again, involve children moving a virtual character through a series of simulated traffic environments safely. This assesses the safety of their decision-making and road safety behaviour.

Here are some examples of the computer activities children will respond to.



They will also be asked simple questions such as "What do you think the car is going to do next?" to ensure they understand the activities.

Both of these activities have been used previously in other studies (in which children have said they have enjoyed them). Furthermore, the road safety activities have been shown to be educationally effective when previously used in mainstream schools. We have tried to keep these as short as possible.

<u>What will happen to the information collected in the study?</u>

All information collected is confidential and pseudo-anonymity of the data will be maintained at all times, no personal information will be published or disclosed to anyone. Completed paperwork will be stored in secure offices within the School of Psychological Sciences and Health at the University of Strathclyde. Consent forms will not be stored with information, thus responses will be stored pseudo-anonymously. Data in electronic form will also be pseudo-anonymous and will be saved on a password protected laptop which will also be locked securely within the School of Psychological Sciences and Health. Any information participants provide will be kept confidential, used only for the purposes of completing this study, and will not be used in any way that can identify individuals. The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Should your child withdraw from the study at any point, no further data would be collected or any other research procedures carried out on or in relation to your child after the withdrawal date. All identifiable data collected to that date would be retained and used in the study.

<u>Who has reviewed the study?</u>

The East of Scotland Research Ethics Committee REC 1, which has the responsibility for reviewing proposals for research with humans has examined the proposal and has raised no objections from the point of view of medical ethics. The University of Strathclyde ethics committee has conducted a similar review and has also approved the research. It is a requirement that your child's records in this research, together with any relevant records, be made available for scrutiny by monitors from the University of Strathclyde, whose role is to check that research is being properly conducted and that the interests of those taking part are adequately protected.

What are my rights?

If you believe that you or your child have been harmed in any way by taking part in this study, you have the right to pursue a complaint and seek any resulting compensation through the University of Strathclyde who is acting as the research sponsor. Details about this are available from the research team. Also, as a patient of the NHS, you have the right to pursue a complaint through the usual NHS process. To do so, you can submit a written complaint to the following address.

Patient Liaison Manager,
Complaints Office,
Level 7, Ninewells Hospital
Dundee DD1 9SY
Free Phone 0800 027 5507
Email: nhstaysidecomplaints@thb.scot.nhs.uk

The NHS has no legal liability for non-negligent harm. However, if you are harmed and this is due to someone's negligence, you may have grounds for a legal action against the University of Strathclyde but you may have to pay your legal costs.

What are the potential risks to my child in taking part?

There are no risks to your child to taking part in this research. If a medical condition not previously known is discovered during your child's visit (the day of participation) by members of their NHS Tayside clinical care team, your child will be treated in the usual way by their doctors and this may or may not mean that your child will have to withdraw from the study.

Findings

Using the information gathered in this research project, we hope to find the answers to our questions about how psychological functioning influences road safety behaviours in children with ADHD. If our findings prove to be significant we hope to publish them and share our results with others in the field of ADHD by making conference presentations which in turn could lead to more research or the development of new interventions to help these children become safer. Your child's personal information will never appear in any of these publications and at all times will remain pseudo-anonymous.

Informed consent

If you consent to your child's participation in any of this research, you will be given a consent form to read and sign. Your child will also be asked to complete an assent form on the day of their participation to show they are happy to take part. Both must be completed for children to participate. If either you or your child wish to withdraw participation in the study then both of you are free to do so at any time. This will in no way affect your child's current or future healthcare or how either of you are treated by the research team or members of the clinical care team.

If you have any further questions then please do not hesitate to contact us:

**Martin K Toye**
School of Psychological Sciences and Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow, G1 1QE
Email: martin.toye@strath.ac.uk
Tel: 0141 548 4250

**Prof. James Thomson (Professor)**
School of Psychological Sciences & Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow G1 1QE
Email: j.a.thomson@strath.ac.uk
Tel: 0141 548 2572

**Dr Sinéad Rhodes (Senior Lecturer)**
School of Psychological Sciences & Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow G1 1QE
Email: sinead.rhodes@strath.ac.uk
Tel: 0141 548 2489

**Dr David R Coghill (Psychiatrist)**
Centre for Child Health
19 Dudhope Terrace
Dundee
Tel: 01382 204004

If you have any concerns, during or after the investigation, or wish to contact person independent from the project to whom any questions may be directed or further information may be sought from, please contact:

**University Ethics Committee Secretariat**
University of Strathclyde
Graham Hills Building
50 George Street
Glasgow G1 1QE
Email: ethics@strath.ac.uk
Tel: 0141 548 3707

Thank you for taking the time to read this information sheet and for considering taking part in this study.

**Appendix 14: Study 3 Child Information Sheet**

School of Psychological Sciences & Health
University of Strathclyde

# Information Sheet for Children (Part B)

## Predicting Pedestrian Behaviour of Children with ADHD: Follow-up

My name is Martin and last year you took part in a study I was running about how Attention Deficit Hyperactivity Disorder (ADHD) affects how children think about road safety. I am now inviting you back to take part in another research project I am running.

Before you decide whether or not you want to, I need to make sure you know what you would be doing if you decide you do want to take part.

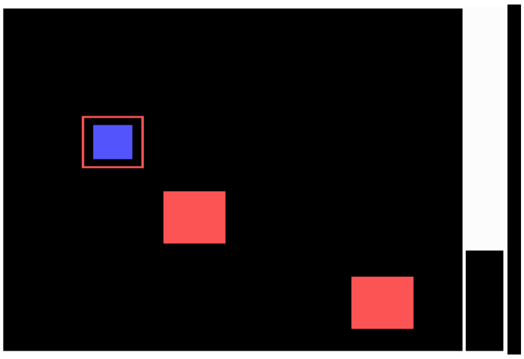
We are giving you this sheet to help you understand these things. Please read it carefully and ask any questions you might have. We will do our best to explain and give you any more information you might want to know or later. You do not have to decide straight away.


**Who is being asked to take part and why?**
Everyone who took part in the first part of this study a year ago is being invited back to take part in this next part. This will help us understand how the safety choices of children with ADHD change as they get older. If you have started taking medicine we can also see if this helps you make safer decisions about road safety.

**Do I have to take part?**
No, it is completely up to you. You should read this information sheet and ask your family, me or your doctor if you have any questions. If you decide not to take part, that's fine. Nobody will be cross with you. If you change your mind you can stop taking part at any time without giving a reason.

**What will happen to me if I take part?**
We will ask you to write your name on an assent form to show you are happy to take part.

Then, while your family is talking with the doctors and nurses I will ask you to work through some computer activities with me. Some will show you different shapes and colours and others will ask you to move a character across different roads. There are some photos below to show you what these activities will look like. I will also ask you some simple questions like "What do you think the car is going to do next?" There are no right or wrong answers to these – I just want you to tell me what you think. I might also ask you to complete a short activity in which I ask you to pick out the picture of different words I say.



**What are the possible benefits of taking part?**
The information we get from the study will also help us learn more about ADHD and some children who have done these activities before have learned to make safer decisions when crossing roads.

**What will happen to the information collected in the study?**

All of your answers on the computer programs will be kept safe on computers with passwords. Your answers won't have your name on them. All other information will be kept in locked offices. If you want to stop taking part we will use the information collected up to that time but won't collect any more information about you once you tell us you want to stop taking part.

**Who has reviewed the study?**

The East of Scotland Research Ethics Service checks that research is going to be properly carried out and they have agreed that this study is safe to take part in.

**What are my rights?**

If you think you have been harmed in any way by taking part, you can complain. The research team can tell you and your parents more about how to do this.

**Is there anything else to be worried about if I take part?**
We do not think there is anything to worry about by taking part in this study, you can stop at any time and this will be done while whoever has taken you to the hospital is talking with the doctors and nurses, so you won't have to make any extra trips into the hospital.

**Results**
We hope to find the answers to our questions about how to make children with ADHD safer when out and about near roads. At the end, after we have seen lots of children, if we think we might have a new way to do this, we hope to share this with other people who work with children who have ADHD but no personal information about you will ever be shared with anyone.

**Do you want more information?**
If you would like any further information or have any questions please ask your family or contact:

**Martin K Toye**
School of Psychological Sciences and Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow, G1 1QE
Tel: 01415484250

**Dr David R Coghill (Psychiatrist)**
Centre for Child Health
19 Dudhope Terrace
Dundee
Tel: 01382 204004

Or if you would like to someone not involved, you can contact:

**University Ethics Committee**
University of Strathclyde
Graham Hills Building
50 George Street
Glasgow G1 1QE

Thank you for reading this information sheet and for thinking about taking part in this study.

# Appendix 15: Study 3 Guardian Consent

Consent Form (B) Guardians

School of Psychological Sciences & Health
University of Strathclyde

Participant ID:______

## Parent/Guardian Consent Form (Part B)

Predicting Pedestrian Behaviour of Children with ADHD: Follow-up

Please read each statement carefully and write your initials in the box to the right only if you agree with the corresponding statement.

Please Initial

- I confirm that I have read and understood the information sheet (version 3, dated 22/4/2013) for the above project and the researcher has answered any queries to my satisfaction. ☐
- I understand that my participation is voluntary and that I am free to withdraw my child from the project at any time prior to their participation without having to give a reason and without consequence. ☐
- I understand that although I can withdraw my child from the study at any time before they participate, it will not be possible to withdraw my child's data after this time as all information gathered will be pseudo-anonymous. ☐
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me or my child will be made publicly available. ☐
- I consent to my child being a participant in the project. ☐

*If you do not agree with all of the above statements, or you don't want to take part, please do not complete the below information. If each of the above is initialed (signifying agreement with each) and you do want to take part, please now complete the below information as consent.*

Name of Child:
(please print) ……………………………………………………………………………………………

| Print Name(Parent/Guardian): | *I hereby agree to my child taking part in the above project.* |
|---|---|
| Signature of Parent/Guardian: | Date: |

| Witnessed by (Print Name): | Witness Signature: | Date: |
|---|---|---|
| | | |

- I agree/disagree for me and my child to be sent information about future research (*please delete as appropriate*). ☐
  *(if yes please complete the below information which will be held for 5 years, if no, please leave blank)*

---

**Contact Details for Future Research**

| Print Name(Parent/Guardian): | Address (including postcode): |
|---|---|
| Print Name(Child):<br><br>DOB: | Tel:<br><br>Mobile: |

Version 4 22/8/2013

# Appendix 16: Study 3 Child Assent Form

Assent Form (B) Children

School of Psychological Sciences & Health
University of Strathclyde

Participant ID:______

## Assent Form for Children (Part B)

Predicting Pedestrian Behaviour of Children with ADHD: Follow-up

(To be completed by children and their parent/guardian)

Child (or guardian on their behalf if unable), please circle yes for all you agree with:

| | |
|---|---|
| Have you read (or had read to you) information about this project? | Yes/No |
| Has somebody else explained this project to you? | Yes/No |
| Do you understand what this project is about? | Yes/No |
| Have you asked all the questions you want? | Yes/No |
| Have you had all your questions answered in a way you understand? | Yes/No |
| Do you understand it is ok to stop taking part at any time? | Yes/No |
| Are you happy to take part? | Yes/No |

If any are 'no' answers or you don't want to take part, please do not sign your name below, but If each of the above is marked yes and you do want to take part, please write your name and today's date

Your name ............................................................................Date............................................................................

Your parent or guardian must also write their name here if they are happy for you to take part in the project

Print Name ..........................................................................

Signed ............................................................................ Date ............................................................................

The researcher who explained this project to you needs to sign here too:

Print name..........................................................................

Signed ............................................................................ Date ............................................................................

Version 2 25/2/2013