Understanding the Roadside Behaviour of Children with DCD and/or ADHD: An Exploratory Sequential Design Study

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Abstract

Background

Navigating roads safely is a complex task, requiring a high level of perceptual-motor skills including selecting safe crossing sites, perceiving and responding to approaching vehicles, and selecting safe crossing gaps. This places pedestrians as a vulnerable group at the roadside. However, previous research has identified that children with neurodevelopmental disorders (NDDs), particularly Developmental Coordination Disorder (DCD) and Attention Deficit Hyperactivity Disorder (ADHD), are at an even higher risk of pedestrian injuries. To address the pressing issue of pedestrian safety for children with DCD and children with ADHD, this thesis aimed to investigate the unique challenges they encounter at the roadside.

Methods

Employing an exploratory sequential mixed methods design, the research initially explored, qualitatively, the perspectives of 14 parents of children with DCD and/or ADHD aged 7 – 17 years (Phase one; see Chapter four). This informed subsequent quantitative analysis focused on examining the specific behaviours of 35 children with DCD or ADHD and typically developing (TD) peers aged 11 – 16 years during simulated road crossing tasks including identification of safe crossing sites, looming detection, and temporal gap acceptance (Phase two; see Chapter six, Chapter seven, & Chapter eight). By combining these qualitative and quantitative approaches, this study provides a comprehensive understanding of the challenges faced by children with DCD and/or ADHD at the roadside.

Findings

Phase one generated three themes. The first theme related to the challenges experienced by children with DCD and/or ADHD at the roadside from a parent's perspective; parents favoured designated crossings, perceiving them as safer options for their children compared to uncontrolled locations due to increased risk concerns. The second theme focused on parental concerns and influence children's road safety, highlighting increased monitoring and a more protective approach to road crossing. The third theme introduced parental strategies for promoting road safety, balancing children's independence with their safety needs.

In relation to Phase two (Chapter six), the results from the first task of selecting crossing sites revealed that all groups including children with DCD, Children with ADHD, and TD children were able to accurately identify safe and unsafe crossing locations. Nonetheless, noticeable differences were observed in their visual attention strategy. Based on descriptive analysis, the results from the looming detection task tentatively showed that children with DCD and ADHD had less refined looming detection thresholds in comparison to their Typically Developing (TD) peers in some viewing conditions. Further the gap acceptance task revealed that children with DCD or ADHD had more near misses compared to the TD group. There was also variability in these tasks when comparing children with DCD and children with ADHD reflecting the distinct challenges that children with different neurodevelopmental disorders may have at the roadside.

Conclusion

This study has given the parents of children with DCD and/or ADHD a voice to convey the experiences they feel that their children face at the roadside. The issue of vulnerability of these children at the roadside was further investigated through the series of lab-based tasks, these findings have added to our knowledge and understanding about the road crossing difficulties that may be experienced by children with DCD or ADHD. The findings revealed that secondary school aged children with DCD or ADHD still have limitations in their ability to accurately judge approaching traffic, potentially due to perceptual-motor deficits, compared to their TD peers potentially leading to increased risk of accidents. This study has valuable insights and makes recommendations to improve pedestrian safety education and for the development of related interventions.

Glossary of Abbreviations

RTAs	Road Traffic Accidents
NDDs	Neurodevelopmental disorders
DCD	Developmental Coordination Disorder
ADHD	Attention Deficit Hyperactivity Disorder
TTC	Time-To-Contact
TD	Typically developing
APA	American Psychological Association
DCDQ'7	Developmental Coordination Disorder Questionnaire (Wilson et al., 2007)
SNAP-IV	Swanson, Nolan, and Pelham-IV
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
SCQ	Social Communication Questionnaire

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1 Chapter One: General Introduction

1.1 Community Mobility

The ability to move around one's community and from one location to another by any mode of transportation such as walking, cycling, wheeling, driving and public transport can be defined as community mobility (Scott and Tulloch, 2021; American Occupational Therapy Association, 2017). This notion is not merely about transporting from one place to another, it is a fundamental aspect of daily life (Dickerson, 2020). Community mobility is considered an integral occupational enabler, as it plays a vital role in supporting individuals' participation in meaningful occupations such as education, social participation, and leisure activities (American Occupational Therapy Association, 2017; Stav, 2014). Occupation can be defined as an active, purposeful, meaningful, culturally relevant activity that can be related to self-care, productivity, leisure, recreation, and rest (Evans, 1987; Hasselkus & Dickie, 2024). The role of community mobility in supporting the engagement and participation in meaningful occupations cannot be overstated because this will significantly contribute to the individuals' overall health, wellbeing and quality of life (Scott and Tulloch, 2021). Despite its vital role in facilitating daily activities, community mobility presents inherent risks and challenges for pedestrians navigating their environments.

Preventable Road Traffic Accidents (RTAs) are a global issue, with approximately 1.19 million annual fatalities reported worldwide (World Health Organization [WHO], 2023). By 2030, the United Nations General Assembly (UNGA) aims to reduce traffic related deaths and injuries globally by half (WHO, 2021). Vulnerable road users include pedestrians, cyclists, and motorcyclists, who account for more than half of all road traffic fatalities globally (WHO, 2023). Pedestrians are particularly vulnerable, accounting for approximately 22% of these deaths (WHO, 2018; Wilmut & Purcell, 2020). In 2022, approximately 7,522 pedestrians were killed in traffic crashes in the United States alone representing a significant increase compared to previous years (National Safety Council, 2024; National Highway Traffic Safety Administration, 2024). This overrepresentation of pedestrians in RTA statistics is mirrored in Europe, where 27% of preventable road traffic deaths were pedestrians, with higher rates reported in middle and low-income countries (WHO, 2018). These alarming figures have become an international challenge which needs to be addressed urgently due to its negative impact on the world economy and health services, not to mention the human cost (Wilmut & Purcell, 2021). It is, therefore, necessary to focus research activities on understanding what makes people vulnerable in order to foster safe community mobility. To do this, it is necessary to first understand the components of road crossing.

1.2 Road Crossing Components

Having discussed the importance of community mobility, it is evident that being able to safely execute a road crossing is a critical pedestrian skill when navigating from one place to another. Safely navigating road environments requires a thorough understanding of the factors involved in pedestrian road crossings. Luu et al. (2022) stated that a sequential understanding of pedestrian behaviours both before and during road crossing is essential. Therefore, the following sections will deconstruct road crossing into before and during crossing. This will be in the form of two essential domains: 'Where and When to Cross,' and 'What to do When Crossing'.

1.2.1 Where & When to Cross

A myriad of factors collectively influence the overall safety of road crossings (Olowosegun et al., 2022; Tabibi et al., 2021). Where to cross includes choosing the safest crossing site (Morrongiello et al., 2018; Meir et al., 2015; Schwebel, & McClure 2014). Selecting crossing sites can play an important role in pedestrian safety and represents an important factor that can enhance the safety of pedestrians when crossing roads (Tabibi, & Pfeffer, 2007). Previous research underscores the importance of informed decision-making when it comes to selecting crossing sites, with studies revealing notable variations in safety levels across different types of crossing sites (Olowosegun et al., 2022; Schwebel et al., 2014; Pantangi et al., 2021). These studies showed that signalised crossings (i.e. traffic lights), zebra crossings, and footbridges are relatively low risk when compared to junctions and mid-block crossing sites (Olowosegun et al., 2022, Schwebel et al., 2014, Pantangi et al., 2021). This is due to various factors including traffic conditions, spatial and temporal design, visibility, accessibility and engineering measures considered when designing different types of road crossing sites (Pantangi et al., 2021; Ashur and Alhassan, 2015; Guo et al., 2012; Basile et al., 2010).

In support of this notion, road crossing sites can be categorised based on controlled pedestrian crossings and uncontrolled pedestrian crossings. Controlled crossings are equipped with traffic regulation mechanisms to ensure pedestrian safety (Ezzati Amini et al., 2019). These encompass two main types: signalised crossings and human controlled crossings. Signalised crossings, such as pelican crossings and toucan crossings, utilise traffic signals and pedestrian signal lights to regulate traffic flow and guide pedestrians safely across the road (Aghabayk et al., 2021). In contrast, human-controlled crossings rely on a person, such as a crossing guard or a lollipop man/lady or school crossing patrol, to manage traffic and ensure the safe crossing of pedestrians (Hannah et al., 2018). The presence of a human controller allows for more flexibility and adaptability in responding to pedestrian needs and traffic conditions compared to automated signal systems (Hannah et al., 2018). However, pedestrians are expected to exercise caution and choose safe crossing points, avoiding crossing between parked cars, on blind corners, or below hills (Department for Transport, 2023). Moreover, uncontrolled crossings lack the infrastructure of traffic signals or human traffic control measures, relying instead on the vigilance and judgment of road users to navigate the environment safely (Aghabayk et al., 2021). Examples of uncontrolled crossings include zebra crossings, pedestrian overpasses, crossing islands and pedestrian underpasses, where the responsibility for safe road crossing is between either pedestrians and drivers or only pedestrians, necessitating heightened awareness and caution (Hannah et al., 2018). It is also important to emphasise that, in the UK at least, there are no explicit laws prohibiting jaywalking or crossing anywhere along a road, leaving the decision to pedestrians to assess the safety of each crossing situation and to act accordingly based on the Green Cross Code (Transport for London, 2010; Department for Transport, 2023). Overall, the strategic selection of crossing sites is instrumental in promoting pedestrian safety and mitigating road-related hazards. Understanding the distinct characteristics and safety implications associated with different types of crossing sites enables pedestrians to make safe road crossing decisions.

The decision of when to cross a road is a complex process influenced by various factors. At signalised crossings, the timing of the pedestrian signal and the presence of traffic lights provide clear cues for safe road crossing (Ezzati Amini et al., 2019). However, at non-signalised crossings, pedestrians must rely on their own judgment and perception to determine when to cross (Wann et al., 2011). Prior to initiating a crossing, pedestrians should engage in a thorough assessment of the road environment, meticulously considering various factors (Cœugnet et al., 2019). These include factors such as the number of times a pedestrian looks right and left, attention to traffic, start/delay time to execute a road crossing, number of missed crossing opportunities, waiting time, the ability to detect a vehicle as approaching and determining the Time-To-Contact (TTC) of approaching vehicles (Jiang et al., 2021; Schwebel et al., 2016; Zare et al., 2018; Purcell et al., 2011; Stavrinos et al., 2011; Andersson et al., 2023). As emphasised before, the configuration of crossing sites also plays a pivotal role in enhancing pedestrian safety (Olowosegun et al., 2022). Nevertheless, pedestrians encounter additional complexities in certain crossing scenarios, particularly when conducting mid-block crossings (Purcell et al., 2011). In such instances, pedestrians must navigate through a myriad of dynamic factors including traffic conditions and environmental factors while relying on their cognitive abilities, visual perception, and motor skills to make safe crossing decisions (Wann et al., 2011; Zhai et al., 2019; Theofilatos et al., 2021). Although environmental factors such as time of day and weather have an impact on pedestrian safety (Zhai et al., 2019; Shaaban and Muley, 2016), pedestrians may struggle mostly with assessing dynamic traffic conditions due to its complexity including vehicular speed, traffic volume, moving vehicles and identifying safe crossing gaps, all of which contribute to the intricate decision-making process surrounding pedestrian crossings (Theofilatos et al., 2021; Thakur and Biswas, 2019, Purcell et al., 2012; Purcell et la., 2011). Therefore, pedestrian safety is influenced by a complex interplay of factors, including environmental conditions, traffic characteristics, and individual abilities.

When it comes to individual abilities, accurately determining the rate of looming and TTC of approaching vehicles is crucial for safe road crossing (Wann et al., 2011). Rate of looming is the speed at which an object's image expands on the retina as it approaches an observer or how quickly an object appears to be growing in size (Purcell, 2011).

Looming detection refers to the ability to rapidly perceive objects as approaching based on changes in optical size of an object, in this context vehicles (Purcell et al., 2012). Looming detection involves the capacity to detect and interpret changes based on the ratio of optical size and rate of looming in order to anticipate the object's proximity and adjust one's behaviour accordingly, particularly in situations where a rapid response is necessary to avoid potential collisions (Purcell et al., 2012). This perceptual skill is essential for pedestrian safety, as it allows individuals to effectively gauge the TTC of approaching vehicles, rather than relying solely on speed and distance when crossing roads or navigating other dynamic environments, which can be prone to considerable bias (Purcell et al., 2017). Relying solely on speed and distance calculations can be misleading, for example a large, slow-moving vehicle at a distance might not be perceived as an immediate threat, while a smaller, faster-moving vehicle closer to the observer, even with a longer TTC, might be perceived as more threatening due to its rapid approach. Additionally, TTC provides a direct and reliable cue to impending danger, allowing individuals to make timely decisions and avoid potential collisions. Moreover, effective TTC enables pedestrians to identify suitable gaps in traffic flow during which they can safely initiate a crossing (Purcell et al., 2011). Suitable crossing gaps for pedestrians refer to the intervals or spaces between vehicles in a flow of traffic that provide pedestrians with a safe opportunity to cross the road based on their action capabilities (Purcell et al., 2011). These gaps are characterised by several factors, including sufficient distance between vehicles based on an understanding of locomotor ability, appropriate vehicle speed, and clear visibility for both pedestrians and drivers (Theofilatos et al., 2021). As such, suitable gaps should provide pedestrians with enough time to cross the road comfortably, without feeling rushed or pressured by approaching vehicles. Overall, by accurately perceiving approaching vehicles and identifying safe crossing opportunities, pedestrians can make informed decisions about when to cross the road, thereby reducing the risk of potential collisions.

1.2.2 What to do When Crossing

When executing a road crossing the ability to continually monitor the environment and adjust walking speed accordingly is essential (Jiang et al., 2021; Schwebel et al, 2016; Purcell et al., 2011; Clancy et al., 2006).

After determining when to cross as discussed in the previous section, it is imperative to understand the essential components required during the crossing itself. This section focuses on skills that can ensure safety during crossings including pedestrian-driver communication techniques, maintaining awareness, and reacting to unexpected situations encountered during the crossing process.

Once pedestrians have made the decision to cross, employing pedestrian-driver communication techniques become crucial to increase visibility and signalling a crossing intention to drivers, thereby reducing the risk of collisions (Myers et al., 2022). Examples include making eye contact with drivers, using hand gestures or signals to indicate intent, and positioning oneself prominently at the edge of the crossing site (Myers et al., 2022; Kong et al., 2021). These techniques help establish visual contact with drivers and enhance mutual awareness, reducing the likelihood of misunderstandings or conflicts during road crossings (Kong et al., 2021).

Maintaining situational awareness is also essential for pedestrians to anticipate and respond effectively to changing road conditions and potential hazards (Salmon et al., 2021). Pedestrians should remain vigilant and attentive throughout the crossing process, continuously scanning their surroundings for approaching vehicles or cyclists (Salmon et al., 2021). This includes regularly checking gaps in traffic flow, monitoring traffic signals, and staying alert to auditory cues such as honking horns or engine sounds (Ridel et al., 2018; Salmon et al., 2021). By staying aware of their environment, pedestrians can identify potential risks early and take appropriate action to mitigate them (Ridel et al., 2018).

Furthermore, reacting to unexpected situations is a significant skill for pedestrians to maintain their safety while crossing (Soni et al., 2013). Pedestrians encounter various unexpected situations while crossing roads, ranging from sudden changes in traffic flow to unforeseen obstacles or hazards (Wood et al., 2010). Reacting effectively to these situations requires pedestrians to remain vigilant, adaptable, and responsive throughout the crossing process (Soni et al., 2013). Key considerations include reaction time, adaptability in response to changing conditions, and quick decision-making under pressure (Soni et al., 2013; Purcell et al., 2011; Wood et al., 2010). Pedestrians must also adjust their walking speed appropriately to suit traffic conditions and optimise crossing efficiency (Fitzpatrick et al., 2013; Knoblauch et al., 1996). Thus, pedestrians can navigate road crossings safely and confidently by combining these skills and techniques, contributing to overall pedestrian safety and reducing the risk of accidents or collisions.

Overall, safe road crossing is a complex task that involves a combination of perceptual and motor skills. Pedestrians must carefully assess the road environment, including traffic conditions, and make informed decisions about where to cross, when to cross, and what to do during crossing. By understanding the key components of road crossing, including route selection, timing, execution and adjusting, improved pedestrian safety and reduced risk of accidents can be achieved.

1.3 Avoiding Collisions: Ensuring Pedestrian Safety

While advancements in vehicle technology offer potential collision prevention (Llorca et al., 2011), pedestrians need to ensure their own safety at the roadside. Understanding how to avoid collisions from an ecological approach is paramount for pedestrian safety because it empowers individuals to actively assess and manage risk in dynamic traffic environments leading to safe and informed decisions when crossing and at the roadside. The ecological approach to perception, as proposed by Gibson (1979), emphasises that perception is not a passive process of interpreting sensory data, but rather an active process of directly perceiving the affordances of the environment. Affordances refer to the possibilities for action that the environment offers to an organism/ a human (Gibson, 1979). For example, a chair affords sitting, a door affords passage, and a ramp affords ascent or descent. This perspective highlights that perception is not solely about detecting and processing sensory information, but about understanding how the environment can be used and interacted with. Furthermore, Gibson (1979) argued that perception is linked to action. We perceive the world not as a collection of isolated sensations, but as a source of opportunities for action (Gibson, 1979). In essence, the ecological approach emphasises that perception is an active, dynamic process that is shaped by the interaction between the organism and its environment (Gibson, 1979). It shifts the focus from internal representations and mental processes to the direct perception of the affordances available in the environment. This section explores avoiding collisions from an ecological approach.

1.3.1 Where to Cross to Avoid Collisions

From an ecological perspective, identifying safe crossing locations involves perceiving and responding to the affordances of the environment. Designated pedestrian crossing sites, such as controlled and uncontrolled crossings, are designed to provide clear affordances for safe pedestrian movement (Pantangi et al., 2021; Olowosegun et al., 2022). These sites, with features such as zebra crossings, traffic signals, and pedestrian islands, offer cues that guide pedestrian behaviour and reduce the risk of collisions (Hatfield et al., 2007). However, pedestrians, e.g. in the UK, often cross outside designated locations, such as in the middle of the street, relying on the interaction between their judgment and the dynamic elements of the road environment to ensure safety (Department for Transport, 2023; Ghafoor et al., 2023). This can lead to various risky crossing behaviours such as mid-block crossings and jaywalking. Despite this, pedestrians must actively perceive and interpret the action opportunities that crossing sites afford, considering factors such as traffic flow, vehicle speed, and the presence of gaps in traffic (Rnakavat and Tiwar, 2020; Tabibi and Pfeffer, 2007). This dynamic perception allows pedestrians to assess the situation and make informed decisions about when and where to cross safely. Adhering to traffic rules and regulations at designated crossing sites is crucial for maximising the safety afforded by these infrastructure elements (Hatfield et al., 2007; Gårder, 1989).

1.3.2 When to Cross to Avoid Collisions

In the absence of designated crossings, pedestrians face the challenge of assessing complex traffic conditions to determine safe crossing opportunities (Theofilatos et al., 2021). As mentioned earlier, the ability to detect approaching vehicles (looming detection) and TTC judgments are necessary in order to determine and execute safe road crossings

(Purcell et al., 2011; Purcell et al., 2017). To understand how these skills assist pedestrians in avoiding accidents, it is necessary to consider the dynamic nature of visual information. As proposed by Gibson (1979), perceiving and responding to approaching objects, such as vehicles, relies on the ability to perceive dynamic visual cues in the context of action capabilities. Pedestrians rely on flow patterns across the retina to gauge their own heading and speed, while the symmetrical expansion of an object's contour (looming) on our retina signals a potential collision course (Purcell, 2011). Lee's (1976) concept of tau, the ratio of optic size to rate of looming, provides a simple yet elegant solution for pedestrians to calculate TTC of approaching vehicles. Tau offers a direct estimate of TTC without requiring complex calculations of distance and speed. Tau will be discussed in more detail, further in the following section. Notably, neural circuits in the brain are particularly sensitive to looming stimuli (Regan & Hamstra, 1993). When the optic size of an object rapidly increases, these circuits trigger a cascade of responses within the dorsal stream network, a brain pathway associated with planning and executing actions (Sun and Frost, 1998). This neural response translates to a heightened state of alertness and the initiation of collision avoidance maneuvers, such as stopping or changing direction (Sun and Frost, 1998). Essentially, tau allows pedestrians to leverage a pre-existing neural mechanism for rapid collision avoidance judgments.

1.3.2.1 Developing Sensitivity to tau

Developmental research has shown that infants transition from relying solely on optical size to incorporating tau for depth perception (Kayed & Van der Meer, 2009). This shift coincides with neural development during the first year of life (van der Weel & van der Meer, 2009). Even young infants exhibit defensive responses to looming objects, suggesting a basic reflex response to object motion and potential threats (Ball & Tronick, 1971).

Kayed and van der Meer (2007) examined infants' responses to looming stimuli, finding that they initially rely on visual angle cues but later transition to using tau information. While infants may exhibit robust responses to looming stimuli at relatively high looming rates, children may struggle with slower looming/expansion rates due to faster moving stimuli such as vehicles, as encountered in real-world road crossing situations. This can pose challenges for children because if the object's image expands at a rate below the observer's looming detection threshold, they may not be able to detect the object as approaching, leading to incorrect decisions and potentially dangerous consequences (Purcell et al., 2017). Wann et al. (2011) highlighted the challenges faced by children aged 10 to 11 years in perceiving and responding to rapidly approaching vehicles, particularly at higher speeds. These findings suggest a need for further research to investigate the specific challenges faced by children in perceiving and responding to looming stimuli to understand children's ability to make safe road crossing judgement.

1.3.3 How to Cross to Avoid Collisions

Once pedestrians have initiated a crossing, they must employ strategies to avoid collisions with oncoming vehicles. Implementing techniques, such as enhancing visibility and improving driver-pedestrian communication, can play a crucial role in reducing the risk of collisions (Myers et al., 2022). Maintaining awareness of their surroundings, reacting to unexpected situations, and employing effective crossing techniques are also essential skills for navigating the road safely (Ridel et al., 2018; Salmon et al., 2021). Walking speed during a road crossing also influences the time available to complete the crossing and avoid collisions (Wang et al, 2022). Importantly, the ability to integrate one's body capabilities into environmental situations is crucial to adjust behaviours during crossing in order to avoid collisions. As mentioned before, this perception-action coupling allows pedestrians to directly perceive the affordances for safe crossing within the dynamic traffic environment and adjust their behaviour accordingly (Gibson, 1979). For instance, the perceived affordance of a sufficient gap in traffic may prompt a pedestrian to cross, while the perceived lack of such a gap may inhibit crossing.

Incorporating strategies and skills to avoid collisions within the context of where to cross, when to cross, and during crossing is vital for enhancing pedestrian safety. By understanding the factors influencing collision avoidance and employing appropriate strategies, pedestrians can navigate road environments safely and reduce the risk of accidents.

1.4 Road Crossing Difficulties in Children

While adults generally demonstrate a higher level of awareness, planning, and coordination when crossing roads, children face unique challenges due to their ongoing cognitive and motor development (Stafford et al., 2021; Tapiro et al., 2020).

Compared to adults, children exhibit limitations in attention and perceptual-motor domains that pose significant challenges for safe road crossing. Younger children aged 9 – 13 years are more susceptible to distraction by visual and auditory stimuli in their environment, such as visual stimuli in the periphery or sounds from nearby playgrounds (Soathong et al., 2022; Tapiro et al., 2020). This can lead to a critical lapse in focus on the flow of traffic, potentially causing them to miss vital cues like approaching vehicles or traffic signals (Tapiro et al., 2020). Furthermore, due to ongoing brain development, children may have difficulties in accurately perceiving and responding to dynamic visual information, such as approaching vehicles (Wann et al., 2011). This can hinder their ability to accurately judge approaching vehicles which can lead to an increased risk of impulsive road crossing decisions (Whitebread and Neilson, 2000). This delayed processing could also translate to slower reaction times (Meir & Oron-Gilad, 2020). Children in the 6–11-year age range often struggle with rapid information processing, which can hinder their ability to react promptly to sudden changes in traffic conditions, such as a car accelerating or a cyclist emerging from an intersection (Serrien & O’Regan, 2020; Meir & Oron-Gilad, 2020). Additionally, their developing motor skills, including balance, coordination, and agility, can further limit their ability to navigate complex road environments safely (Serrien and O’Regan, 2020; Wilmut & Purcell, 2020). These factors, combined with their tendency towards impulsivity, increase children's vulnerability to pedestrian accidents. Therefore, children are at a higher risk of being involved in pedestrian accidents compared to adults, as evidenced by numerous studies that have shown increased vulnerability of pedestrian injuries and fatalities among children (e.g., Schwebel et al., 2014; Wilmut & Purcell, 2020).

While TD children face challenges navigating roads when compared to adults, children with neurodevelopmental disorders (NDDs) encounter even greater difficulties (Wilmut & Purcell, 2021). This could be because NDDs are a diverse group of conditions that affect brain development and function (Parenti et al., 2020). These disorders, which include Developmental Coordination Disorder (DCD) and attention deficit hyperactive disorder (ADHD), are characterised by significant variability in terms of their genetic underpinnings and clinical manifestations (Parenti et al., 2020). Both ADHD and DCD, which often co-occur, can impair perceptual-motor skills necessary for safe road crossing (Schwebel et al., 2016; Wilmut & Purcell, 2021; James et al, 2021). Not surprisingly therefore, children with ADHD or DCD as pedestrian face additional challenges at the roadside when compared to TD children (DiScala et al., 1998; Pastor and Reuben, 2006; Wilmut & Purcell, 2020; Tabibi et al., 2021). Although there is no clear explanation for why there are additional challenges or risks among children with ADHD or DCD at the roadside, some studies suggest that it could be due to the characteristics of these disorders (Clancy et al., 2006). According to Clancy et al. (2006), the additional challenges in adolescents with ADHD can be mainly attributed to inattention. Other studies have found that the main underlying cause for the high pedestrian vulnerability among children with ADHD is executive dysfunction (Tabibi et al., 2021; Wilmut & Purcell, 2020; Toye, 2016; Stavrinos et al., 2011). Similarly, children with DCD may have impaired executive function but, the link between executive dysfunction and poor roadside behaviour is still unclear in children with DCD and children with co-occurring DCD and ADHD (Wilson et al., 2020; Sartori et al., 2020; Purcell et al., 2017). However, previous studies suggest that children with DCD and/or ADHD often have impaired perceptual-motor skills, which are important to execute safe road crossing (Jahani et al., 2016; Purcell et al., 2017; Dyck et al., 2022).

1.5 DCD and ADHD Diagnosis

Diagnosis of DCD and ADHD involves careful consideration of established criteria (American Psychiatric Association [APA], 2013). However, this was not always the case for the diagnosis of DCD or ADHD, diagnostic criteria have undergone various changes over the years to move away from vague descriptions to well-defined criteria (Smits-Engelsman et al., 2015). In the early 20th century, there were anecdotal observations regarding children with persistent motor difficulties or hyperactivity, impulsivity and attention difficulties without apparent medical causes (Kirby and Sugden, 2017). These anecdotal observations had limited systematic understanding of the disorders (Kirby and

Sugden, 2017). In the 1970s and 1980s, the term "clumsy child syndrome" gained popularity to describe children with poor motor coordination (Zoia et al., 2006; Gillberg and Kadesjö, 2003). No well-defined concept regarding DCD was provided at the time of the term "clumsy child syndrome" (Zoia et al., 2006). Similarly for ADHD, the term "Hyperkinetic Reaction of Childhood" became popular in the 1970s reflecting the belief that hyperactivity was a reaction instead of a disorder (Burks, 1960; Mattes, 1980). The third edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-III), published in 1980, introduced the term "Attention Deficit Disorder" (ADD) with or without hyperactivity (Lahey & Carlson, 1991). It included clear diagnostic criteria for the first time, distinguishing between subtypes. Since then, the terms for both disorders have evolved and well-established criteria were first provided in the Diagnostic and Statistical Manual of Mental Disorders (DSM), version IV (Fenton, 1996). More recently, the DSM-5 provides a widely recognised set of criteria for DCD and ADHD (APA, 2013).

1.5.1 The Diagnostic Criteria for DCD and for ADHD (DSM-5)

The diagnostic criteria for DCD and for ADHD, as outlined in the DSM-5 (APA, 2013), are presented in Table 1.1 and 1.2. Table 1.1 provides the criteria for DCD, while Table 1.2 outlines the diagnostic criteria for ADHD, including inattentive and hyperactive-impulsive presentations.

Table 1.1. Diagnostic Criteria for Developmental Coordination Disorder (APA, 2013)

List	Diagnostic Criteria
A	The acquisition and execution of coordinated motor skills is substantially below that expected given the individual’s chronological age and opportunity for skill learning and use. Difficulties are manifested as clumsiness (e.g., dropping or bumping into objects) as well as slowness and inaccuracy of performance of motor skills (e.g., catching an object, using scissors or cutlery, handwriting, riding a bike, or participating in sports).
B	The motor skills deficit in Criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (e.g., self-care and self-maintenance) and impacts academic/school productivity, prevocational and vocational activities, leisure, and play.
C	Onset of symptoms is in the early developmental period.

D	The motor skills deficits are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and are not attributable to a neurological condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder).

Table 1.2. Diagnostic Criteria for attention-deficit/hyperactivity (APA, 2013)

List	Diagnostic Criteria
A	A persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development, as characterised by (1) and/or (2):
1	**Inattention**: Six (or more) of the following symptoms have persisted for at least 6 months to a degree that is inconsistent with developmental level and that negatively impacts directly on social and academic/occupational activities: **Note**: The symptoms are not solely a manifestation of oppositional behaviour, defiance, hostility, or failure to understand tasks or instructions. For older adolescents and adults (age 17 and older), at least five symptoms are required. a. Often fails to give close attention to details or makes careless mistakes in schoolwork, at work, or during other activities (e.g., overlooks or misses details, work is inaccurate). b. Often has difficulty sustaining attention in tasks or play activities (e.g., has difficulty remaining focused during lectures, conversations, or lengthy reading). c. Often does not seem to listen when spoken to directly (e.g., mind seems elsewhere, even in the absence of any obvious distraction). d. Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (e.g., starts tasks but quickly loses focus and is easily sidetracked). e. Often has difficulty organizing tasks and activities (e.g., difficulty managing sequential tasks; difficulty keeping materials and belongings in order; messy, dis organized work; has poor time management; fails to meet deadlines). f. Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (e.g., schoolwork or homework; for older adolescents and adults, preparing reports, completing forms, reviewing lengthy papers).

	g. Often loses things necessary for tasks or activities (e.g., school materials, pencils, books, tools, wallets, keys, paperwork, eyeglasses, mobile telephones). h. Is often easily distracted by extraneous stimuli (for older adolescents and adults, may include unrelated thoughts). i. Is often forgetful in daily activities (e.g., doing chores, running errands; for older adolescents and adults, returning calls, paying bills, keeping appointments).
2	**Hyperactivity and impulsivity:** Six (or more) of the following symptoms have persisted for at least 6 months to a degree that is inconsistent with developmental level and that negatively impacts directly on social and academic/occupational activities: **Note**: The symptoms are not solely a manifestation of oppositional behaviour, defiance, hostility, or a failure to understand tasks or instructions. For older adolescents and adults (age 17 and older), at least five symptoms are required. a. Often fidgets with or taps hands or feet or squirms in seat. b. Often leaves seat in situations when remaining seated is expected (e.g., leaves his or her place in the classroom, in the office or other workplace, or in other situations that require remaining in place). c. Often runs about or climbs in situations where it is inappropriate. (**Note**: In adolescents or adults, may be limited to feeling restless.) d. Often unable to play or engage in leisure activities quietly. e. Is often "on the go," acting as if "driven by a motor" (e.g., is unable to be or uncomfortable being still for extended time, as in restaurants, meetings; may be experienced by others as being restless or difficult to keep up with). f. Often talks excessively. g. Often blurts out an answer before a question has been completed (e.g., completes people's sentences; cannot wait for turn in conversation). h. Often has difficulty waiting his or her turn (e.g., while waiting in line). i. Often interrupts or intrudes on others (e.g., butts into conversations, games, or activities; may start using other people's things without asking or receiving per mission; for adolescents and adults, may intrude into or take over what others are doing).
B	Several inattentive or hyperactive-impulsive symptoms were present prior to age 12 years.
C	Several inattentive or hyperactive-impulsive symptoms are present in two or more set tings (e.g., at home, school, or work; with friends or relatives; in other activities).

D	There is clear evidence that the symptoms interfere with, or reduce the quality of, social, academic, or occupational functioning.
E	The symptoms do not occur exclusively during the course of schizophrenia or another psychotic disorder and are not better explained by another mental disorder (e.g., mood disorder, anxiety disorder, dissociative disorder, personality disorder, substance intoxication or withdrawal).

1.6 Developmental Coordination Disorder (DCD)

DCD is a neurodevelopmental disorder characterised by a significant impairment in motor coordination that negatively affects daily activities (Kirby et al., 2013). The prevalence of DCD in the UK is approximately 4.9% and it ranges from 3–6%, similar to that of developmental dyslexia and ADHD among the school population (Shalev et al., 2009; Huber et al., 2020). Despite its prevalence, DCD is frequently overlooked or misdiagnosed (Klein et al., 2024). Individuals with DCD often exhibit difficulties in both fine and gross motor skills (Wilson et al., 2013). Fine motor skills, such as writing, drawing, and using utensils, may be impaired due to poor hand-eye coordination and difficulty in planning and executing precise movements (Meachon et al., 2022). Gross motor skills, including running, jumping, and balancing, may also be affected, leading to challenges in activities like sports and physical education (Wilson et al., 2013; Meachon et al., 2022). These impairments can affect various aspects of motor skill development, including planning, execution, and feedback mechanisms (Christmas & Weyer, 2019). As a result, children with DCD may struggle with tasks that require timing, accuracy, and coordination (Wilson et al., 2013; Meachon et al., 2022). The underlying causes of DCD are not fully understood, but it is believed to result from functional impairments in brain areas such as the cerebellum and basal ganglia, deficits in visual-motor mapping and cognitive-motor integration, and abnormal maturation of motor networks (Bo et al., 2013; Kirby et al., 2013; Subara-Zukic et al., 2022).

DCD can significantly impact a child's daily life and academic performance (Linde et al., 2015; Dionne et al., 2022). Motor coordination difficulties associated with DCD can hinder various aspects of a child's life (Linde et al., 2015). Academically, DCD can impact performance, particularly in subjects requiring fine motor skills and hand-eye coordination such as writing and drawing (Meachon et al., 2022; Dionne et al., 2022). Difficulties with handwriting can lead to frustration and lower self-esteem (Dionne et al., 2022). In terms of daily living skills, children with DCD may struggle with tasks such as dressing, eating, and using utensils, affecting their independence and self-esteem (Summers et al., 2008; Linde et al., 2015). Additionally, participation in physical activities and sports can be challenging due to poor motor coordination and balance (Rivilis et al., 2011). This may limit opportunities for social interaction, physical fitness, and local community access (Rivilis et al., 2011; O'Dea et al., 2021).

1.6.1 Perceptual Impairments in DCD and Road Crossing

Children with DCD often exhibit underlying perceptual impairments that contribute to their difficulties in motor coordination and daily activities (Linde et al., 2015; Christmas & Weyer, 2019). Perceptual functions, such as visual perception and spatial awareness, are crucial for accurate motor planning and execution (Wilson et al., 2013; Meachon et al., 2022). Children with DCD may struggle with tasks requiring spatial awareness, such as judging distances, and perceiving depth (Kirby et al., 2013; Subara-Zukic et al., 2022). This can impact their ability to navigate environments and determine appropriate road crossing gaps (Purcell et al., 2012: Wilmut & Purcell, 2020). However, safe road crossing and determining appropriate temporal crossing gaps are not solely a decision of judging distances based on spatial awareness (Purcell et al., 2011).

Difficulty in distinguishing between foreground and background objects can additionally hinder their ability to identify relevant cues, such as approaching vehicles (Purcell et al., 2011; Monge, 2015; Subara-Zukic et al., 2022). Purcell et al. (2011) found that children aged 6 -11 years were not able to detect looming vehicles at similar looming rates compared to their TD peers, which might suggest a potential deficit in their ability to perceive and respond to dynamic visual information. Therefore, while DCD is not primarily an ophthalmic disorder (Mon-Williams et al., 1994), research suggests that children with this disorder may exhibit visual processing difficulties (Purcell et al., 2011; Monge, 2015; Subara-Zukic et al., 2022). In a road crossing context, perceptual difficulties can lead to errors in assessing traffic conditions, judging the TTC of approaching vehicles, reacting quickly to changing traffic situations, and making informed decisions about when and where to cross (Purcell et al., 2011; Purcell et al., 2012).

It is important to note that while there is a clear link between DCD and visual-perceptual difficulties, the exact nature of this relationship is complex and not fully understood. Some studies suggest that motor and perceptual skills are closely linked, and that difficulties in one area can impact the other (Whitall & Clark, 2018). For example, poor motor coordination may hinder a child's ability to explore their environment and gather visual information, which in turn can affect their perceptual development. Nevertheless, it is possible that underlying neurological factors, such as brain connectivity and neurotransmitter function, may contribute to both motor and perceptual difficulties (Bonifacci, 2004; Gomez & Sirigu, 2015). Therefore, while the relationship between motor and perceptual skills in DCD is complex, it is clear that both areas are intertwined and important to consider when supporting individuals with this condition.

1.7 Attention-Deficit/Hyperactivity Disorder (ADHD)

ADHD is a neurodevelopmental disorder characterised by persistent patterns of inattention and/or hyperactivity-impulsivity that interfere with daily functioning (Robe et al. 2019. These characteristics typically begin in childhood and can persist into adulthood (Sayal et al., 2017). The prevalence of ADHD ranges from 2% to 7% globally, with an average around 5% (Sayal et al., 2017). Inattention manifests as difficulties in sustaining attention, being easily distracted, and experiencing frequent forgetfulness and disorganisation (Sroubek et al., 2013) whilst hyperactivity is characterised by excessive motor activity, fidgeting, and restlessness (Kofler et al., 2016). Impulsivity involves acting hastily without thinking, difficulty waiting for turns, and interrupting others (Kim & Seo, 2021). These core characteristics can significantly impact daily life, academic performance, and social interactions (Loe & Feldman, 2007; Peasgood et al., 2016). Motor difficulties, which are common in children with ADHD, can further increase the challenges faced by these population. Studies have shown that 30-50% of children with ADHD experience motor problems, often going untreated due to behavioural factors (Fliers et al., 2010). Pitcher et al. (2003) compared the motor skills of boys with ADHD and TD peers aged 7-13. They found that boys with ADHD, particularly those with the predominantly inattentive and combined subtypes, exhibited significantly poorer movement ability and a higher prevalence of DCD-related difficulties compared to TD peers, suggesting a link between motor skills and ADHD.

Children with ADHD often face challenges in performing daily living activities due to their core characteristics, specifically at home and school (Peasgood et al., 2016). For example, children with ADHD may struggle with organising tasks, managing time effectively, and prioritising responsibilities (Durand et al., 2020). This can lead to difficulties in completing daily chores, maintaining personal hygiene, and adhering to routines (Becker et al., 2023). In an academic performance and work productivity context, completing tasks that require sustained focus such as studying, reading, or following instructions can be affected by impaired attention (Arnold et al., 2020). children with ADHD may rush through tasks, make careless mistakes, or forget important steps (Durand et al., 2020). These behaviours can be attributed to difficulties in planning and executing tasks due to impulsivity (Patros et al., 2016). Moreover, excessive motor activity (hyperactivity) and restlessness can make it difficult to sit still, focus on tasks, and follow through with plans (Kofler et al., 2016). Given that road crossing is a complex task it is also likely to be affected by these characteristics.

1.7.1 ADHD and Road Safety

While driving and pedestrian activities involve different skill sets, both require the perception of and response to affordances within dynamic environments. Given the documented difficulties adults with ADHD experience in perceiving and responding to the affordances of the driving environment (Deshmukh & Patel, 2019), it is plausible that children with ADHD may also experience challenges in perceiving and responding to the affordances of the pedestrian environment. As mentioned earlier, research suggests that children with ADHD are at a significantly higher risk of pedestrian injuries, with twice as many collisions compared to their TD peers (Clancy et al., 2006; Tabibi et al., 2021). This increased risk may be attributed to several factors. While both cognitive and perceptual factors contribute to the increased risk of pedestrian accidents in individuals with ADHD, the majority of research has focused on inattention and executive function (Clancy et al., 2006; Stavrinos et al., 2011; Toye, 2016; Tabibi et al., 2021).

Several studies have investigated the relationship between ADHD and pedestrian safety in children. For example, research has revealed that children with ADHD aged 13 – 17 years had more unsafe crossings with lower margins of safety and slower walking speeds (Clancy et al., 2006). Clancy et al. (2006) stated that inattention is the reason for this risky performance. However, a growing body of research suggests that executive dysfunction among children with ADHD aged 13 – 17 years likely influence their pedestrian performance (Stavrinos et al., 2011; Toye, 2016; Tabibi et al., 2021). Stavrinos et al. (2016), for example, indicated that children with ADHD aged 7 – 10 years tend to cross using riskier pedestrian environments, potentially due to underlying executive dysfunction. While an ecological approach emphasises direct perception of affordances, these cognitive processes likely influence how children with ADHD perceive and respond to those affordances. For example, Toye (2016) suggests that visual short-term memory (the ability to briefly hold and manipulate visual information) and working memory skills (a more general cognitive function that allows us to hold and manipulate information in our minds, including visual, auditory, and spatial information for a very short time), which are often affected in children with ADHD, are involved in tasks such as remembering traffic light locations, planning safe routes, and recalling traffic rules. Similarly, Tabibi et al. (2021) found that due to executive dysfunction, children with ADHD aged 8 – 12 years exhibited more unsafe crossing behaviours in more complex traffic environments. This could suggest an impaired ability to perceive and respond appropriately to the dynamic affordances of the road.

In conclusion, children with ADHD have additional risks of pedestrian injury and accidents when compared to TD children. However, while inattention has been implicated in their pedestrian performance, executive dysfunction seems to also play an important role in this.

1.8 The Intersection of DCD and ADHD

A significant co-occurrence exists between ADHD and DCD, with nearly half of individuals diagnosed with one disorder also meeting the diagnostic criteria for the other (Martin et al., 2006). This high rate of co-occurrence may suggest a shared genetic etiology underlying these neurodevelopmental disorders (Martin et al., 2006). Considering this, it is possible that this co-occurrence could exacerbate the challenges faced by individuals with co-occurring ADHD and DCD. In a road crossing context, Wilmut & Purcell (2020) stated that road crossing is found that road crossing was perceived as more challenging by both adults with co-occurring ADHD and DCD and parents of children with both conditions.

Furthermore, research suggests that DCD or ADHD can impair perceptual-motor skills (Jahani et al., 2016; Dyck et al., 2022). As previously mentioned, this perceptual-motor skill is vital for pedestrian safety when considering road crossing as a visually guided task (Purcell et al., 2017). By relying on visual cues such as the rate of expansion of approaching vehicle, pedestrians can make more accurate judgments about TTC to execute safe crossings (Purcell et al., 2011; Purcell et al., 2017). Purcell et al. (2017) found that children with DCD have poor perceptual-motor skills affecting their road crossings. However, much of the existing research on children with DCD or ADHD in road safety has focused on younger age groups (e.g., Stavrinos et al., 2011; Purcell et al., 2017; Tabibi et al., 2021), who are less likely to be navigating roads independently. While research has explored the impact of ADHD on road safety, particularly focusing on inattention and executive dysfunction, the role of perceptual-motor skills in this context, especially in older children who are beginning to navigate roads independently, remains relatively understudied.

To better understand the specific challenges faced by children with DCD and with ADHD in road safety, further research is needed. Direct comparisons between older children with DCD, ADHD, and TD peers would provide valuable insights into the unique difficulties in the context of road crossing associated with each disorder. Additionally, in-depth investigations into the underlying perceptual-motor deficits in these populations are essential to develop effective strategies to improve their road safety. To provide a comprehensive theoretical framework for the current study, it is necessary to first delineate the role of Executive Functions as the primary cognitive mechanism explaining the challenges faced by children with these neurodevelopmental conditions in complex, dynamic environments.

1.8.1 The Concept of Executive Functions (EF)

An understanding of the challenges faced by children with neurodevelopmental disorders in complex environments necessitates a review of EF. EFs refer to a set of high-level cognitive processes that are essential for goal-directed behaviour, adaptive responding, and effective problem-solving, particularly in novel or non-routine situations (Diamond, 2013).

The widely accepted framework identifies three core, interrelated components of EF (Diamond, 2013):

1. Inhibitory Control: The ability to intentionally inhibit dominant, prepotent, or automatic responses, encompassing both self-control (resisting temptations or impulsive actions) and interference control (selective attention). This is foundational, as deficits compromise the ability to override a natural urge, such as running after a ball.
2. Working Memory: The capacity to hold, manipulate, and update information mentally over short periods. It allows for the integration of real-time sensory data (e.g., speed of two approaching cars) with stored knowledge (e.g., crossing rules).
3. Cognitive Flexibility: The ability to shift perspective, adapt behaviour to changing demands, and switch efficiently between mental sets or tasks. In Activities of Daily Living (ADLs), this allows a child to transition smoothly from an unstructured activity like playtime to a structured task like starting homework when the parent gives the cue.

These functions are fundamental in everyday activities, enabling individuals to engage successfully in complex, goal-oriented tasks especially those requiring planning, adaptability, and problem solving (Cornelis et al., 2019; Vaughan & Giovanello, 2010) They facilitate essential self-care activities required for an individual to maintain independent function, including tasks such as self-feeding, personal hygiene, and functional mobility (Edemekong et al., 2025). However, EF is more strongly associated with Instrumental Activities of Daily Living (IADLs) and other complex adaptive tasks such as shopping and transportation, than with basic self-care ADLs (Cornelis et al., 2019; Vaughan & Giovanello, 2010). This is because IADLs demand higher-level cognitive processes, such as planning, task switching, inhibition, and working memory (Cornelis et al., 2019).

A primary application of EFs is in dynamic and risk-assessing environments (Diamond, 2013). Successful navigation of the environment, particularly tasks demanding simultaneous processing of multiple dynamic factors, such as safe road crossing, rely on intact EF (Stavrinos et al., 2011). Roadside behaviour, as an example, requires inhibitory control to prevent a child from stepping out impulsively; working memory to track the speed and distance of multiple vehicles; and cognitive flexibility to adapt to unexpected changes in traffic patterns. Therefore, a deficit in any core EF component is likely to compromise safety and decision-making in this critical real-world context.

1.8.2 Executive Function Deficits in DCD and ADHD

DCD and ADHD are NDDs primarily recognised by their defining features: difficulties with motor coordination (DCD) and challenges with attention and hyperactivity/impulsivity (ADHD). However, research consistently shows that EF deficits are also common and impactful (Bernardi et al., 2018; Leonard et al., 2015; Willcutt et al., 2005). These cognitive challenges affect daily living, academic achievement, and psychosocial well-being in children with DCD and/or ADHD (Leonard et al., 2015; Willcutt et al., 2005).

In DCD, research by Fogel et al. (2021) and Maleki & Zarei (2016) has demonstrated that motor difficulties are frequently accompanied by EF impairments in DCD. These impairments are most evident in visuospatial tasks and are linked to poorer academic and daily functioning (Bernardi et al., 2018). Children with DCD often show weakness in inhibitory control, working memory and planning (Lachambre et al., 2021). Furthermore, these EF deficits contribute to wider academic and adaptive difficulties beyond motor skills (Fogel et al., 2021). While the wide-ranging effects of EF deficits are acknowledged, the current study is designed to specifically investigate the functional impact of these challenges on perceptual-motor abilities. These findings suggest that while EF deficits contribute to the planning and sequencing difficulties observed in DCD (Lachambre et al., 2021; Fogel et al., 2021), the critical manifestation in functional tasks is a deficit in perceptual-motor ability. Specifically, the difficulty children with DCD have in executing smooth, coordinated movements and interacting with their environment is largely mediated by their challenges in integrating visual and spatial information with motor commands (Bernardi et al., 2018; Maleki & Zarei, 2016). Therefore, assessing these integrated perceptual-motor skills, such as time-to-contact judgments, is a critical area for research (Purcell et al., 2011).

In contrast to DCD, EF deficits are widely recognised as central to the diagnostic profile of ADHD, particularly impairments in inhibitory control and working memory (Craig et al., 2016; Willcutt et al., 2005). These deficits are the primary drivers of hallmark symptoms such as impulsivity, inattention, and difficulty regulating behaviour (Willcutt et al., 2005). The cognitive challenges related to EF are associated with academic underachievement, grade retention, and functional deficiencies in motivation and organisation, establishing EF impairment as a significant mediator of the reduced quality of life experienced by individuals with ADHD (Orm et al., 2023). Given that roadside navigation also requires rapid inhibition of impulsive movement and sustained vigilance toward dynamic traffic (Purcell et al., 2017), it is unsurprising that numerous studies consistently link these core EF deficits in ADHD to elevated risk-taking and increased vulnerability in complex traffic environments (Stavrinos et al., 2011; Tabibi et al., 2023).

Crucially, when DCD and ADHD co-occur, the combined effect results in a potentially compounded or cumulative EF impairment (Bernardi et al., 2018; Leonard et al., 2015). This deficit in core cognitive abilities may render this group with co-occurring DCD and ADHD significantly more vulnerable to errors in judgement, timing, and execution during complex, time-critical tasks. The current study acknowledges the crucial role of EF in these disorders while primarily investigating the manifestation of these difficulties through the lens of perceptual-motor abilities in the highly demanding context of roadside navigation.

1.9 Parents of Children with DCD and/or ADHD

In order to comprehensively explore the reasons that children with DCD or ADHD are more vulnerable at the roadside (Wilmut & Purcell, 2021), it is necessary to understand the experiences and perspectives of parents of children with these conditions in relation to pedestrian risks. However, research exploring these parental perspectives remains limited. Parents of children with DCD or ADHD can offer invaluable insights into the specific road safety challenges that their children face. Their close and continuous observation allows them to intimately understand their child's behaviour and responses to complex environments such as road crossings. This unique perspective complements traditional behavioural studies by providing a rich, contextual understanding of how DCD or ADHD manifest in real-world situations. By incorporating the valuable knowledge of parents alongside experimental behavioural research methods, we can gain a more nuanced understanding of the challenges faced by children with DCD or ADHD at the roadside.

1.10 Overall Aim

Navigating roads as pedestrians is a complex task, demanding split-second decisions and accurate perceptual-motor skills. For children with DCD or ADHD, this challenge is amplified, raising questions about their roadside behaviours. While the growing awareness of pedestrian safety risks associated with DCD or ADHD is encouraging, a critical knowledge gap persists regarding the specific components of safe road crossing behaviour most impacted by these disorders. Parental perspectives offer a valuable window into complex real-life road crossing behaviours leading to a more comprehensive exploration. This is needed to understand how DCD or ADHD affect children's choices concerning "where to cross," and "when to cross”. Therefore, this thesis aimed to enhance our understanding of the unique challenges children with DCD or ADHD encounter at the roadside. By combining qualitative and quantitative approaches, the aim was to provide a comprehensive exploration.

To achieve the overarching aim, this PhD thesis has contributed to the existing body of knowledge by exploring:

Parental Perspectives: investigating the perspectives of parents to gain insights into the challenges faced by children with DCD and/or ADHD in real-world settings. This is discussed further in Chapter 4. The following questions were formulated:

1. What are the perspectives of parents of children with DCD and/or ADHD in relation to their children’s ability to execute a safe road crossing?
2. What, if anything, are parents of children with DCD and/or ADHD concerned about regarding their children’s pedestrian safety?
3. How do parents of children with DCD and/or ADHD help to prevent or minimise their child’s involvement in pedestrian injuries?

Behavioural Analysis: A detailed analysis was conducted of specific behaviours in relation to (1) where to cross; (2) when to cross and these are detailed in Chapters 7, 8, and 9. To achieve this, the following questions were formulated.

1. Where to cross:
    1.1. Do children with ADHD or DCD select safe crossing sites compared to their typically developing peers?
2. When to cross:
    2.1. Do children with ADHD or DCD have sufficient looming sensitivity in a virtual environment to detect vehicles approaching at the speeds typically encountered in residential areas compared to their typically developing peers?
    2.2. Do children with ADHD or DCD select sufficient temporal crossing gaps in a virtual environment compared to their typically developing peers?
    2.3. Do children with ADHD or DCD select sufficient temporal crossing gaps in a virtual environment when a perceptual and perceptual-motor response is needed, compared to their typically developing peers?

2 Chapter Two: Common Methodology

2.1 Introduction

This chapter outlines the common methodology used in this thesis. It begins by explaining the study design and the use of screening tools to identify motor and attentional abilities in participating children. It then describes the sampling strategy and recruitment procedure. This chapter serves as a guide to the methodological framework that underpins the subsequent analyses and results of Phase one (Chapter 4) and Phase two (Chapters 7, 8, and 9) reported within this thesis.

2.2 Study Design

The research design employed in this study is rooted in the principles of exploratory mixed methods, a comprehensive approach that integrates both quantitative and qualitative methodologies (Johnson et al., 2007). This section provides a detailed overview of the study design, the justification for the chosen approach and philosophical foundation of this research.

2.3 Research Aim and Questions

The overarching aim of this PhD was to explore roadside behaviours of children with DCD or ADHD. As established in Chapter 1, the investigation sought to address key questions which serve as the foundation for the comprehensive approach adopted in this thesis. The aims and research questions underpinning the research are provided in Table 2.1. It is also important to note that while Phase one included parents of children with DCD, ADHD, AND both DCD & ADHD, Phase two primarily focused on children with either DCD or ADHD. This shift in focus was necessary due to challenges encountered during the recruitment process, which will be discussed further in the recruitment section (2.9 Recruitment).

Table 2.1: Aim and research questions

Aim of the research: to explore roadside behaviours of children with DCD or ADHD.	
Qualitative component (Phase one: Chapter 4)	**Quantitative component (Phase two: Chapters 6, 7, & 8)**
Aim: to explore the perspectives of parents of children with DCD and/or ADHD to gather their experiences of pedestrian risks. To achieve this, the following questions were formulated. What are the perspectives of parents of children with DCD and/or ADHD in relation to their children's ability to execute a safe road crossing? What, if anything, are parents of children with DCD and/or ADHD concerned about regarding their children's pedestrian safety? How do parents of children with DCD and/or ADHD help to prevent or minimise their child's involvement in pedestrian injuries?	Aim: to quantitatively investigate components of road crossing among children with DCD or ADHD who are reportedly more at risk at the roadside. To achieve this, the following questions were formulated. Where to cross: Do children with DCD or ADHD select safe crossing sites compared to their typically developing peers? When to cross: Do children with DCD or ADHD have sufficient looming sensitivity in a virtual environment to detect vehicles approaching at the speeds typically encountered in residential areas compared to their typically developing peers? Do children with ADHD or DCD select sufficient temporal crossing gaps in a

	virtual environment compared to their typically developing peers? Do children with ADHD or DCD select sufficient temporal crossing gaps in a virtual environment when a perceptual and perceptual-motor response is needed, compared to their typically developing peers?

2.4 Philosophical Foundation

This study used a pragmatic research paradigm (Kaushik & Walsh, 2019). Within this paradigm, the underlying belief is that while there exists an objective reality external to human experiences, encountering this reality is possible only through socially constructed human experiences, including beliefs and habits (Kaushik & Walsh, 2019). In the context of this thesis, this perspective acknowledges the consensus among researchers regarding the objective reality that children with DCD and/or ADHD face an elevated risk of preventable RTAs at the roadside compared to their TD peers (Tabibi et al., 2021; Wilmut & Purcell, 2020; Toye, 2016; Stavrinos et al., 2011; Pastor and Reuben, 2006; DiScala et al., 1998). However, it raises a crucial question about whether this acknowledged reality aligns with the perceptions of parents of children with DCD and/or ADHD. Consequently, a comprehensive exploration of their perspectives becomes imperative.

In light of this, the selection of the research methodology and methods was guided by the philosophical underpinnings of pragmatism. Pragmatism's essence lies in flexibility, allowing the adoption of multiple methods or a mixed methods approach that combines qualitative and quantitative strategies (Kaushik & Walsh, 2019). This flexibility is aimed at exploring the research topic more comprehensively (Kaushik & Walsh, 2019). By embracing a pragmatic paradigm, the research acknowledges the necessity of not only recognising the established objective reality but also exploring the subjective experiences and perspectives of parents, aligning with the overarching goal of comprehensively understanding the research problem at hand.

2.5 Rationale for Using Mixed Methods Research Design

Mixed methods research has been characterised by a diverse range of philosophical underpinnings, methodological approaches, and research objectives (Creswell, & Tashakkori, 2007; Johnson et al. 2007). Aramide et al. (2023) argue that mixed methods research is a complex approach with conceptualisation being more than a research design. It involves a more holistic approach that considers the philosophical underpinnings, research questions, and the specific goals of the research (Aramide et al., 2023). Mixed methods research is not merely a mechanical combination of techniques, but rather a strategic approach that seeks to leverage the strengths of both quantitative and qualitative methods (Johnson et al., 2007). This thesis aligns with a comprehensive perspective as articulated by Johnson et al. (2007, p. 123).

> *"Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration."*

As per Johnson et al.'s (2007) definition, the integration of qualitative and quantitative research approaches extends beyond the mere inclusion of qualitative and quantitative viewpoints; it encompasses the entirety of the research process, including data collection, analysis and inference techniques. The overarching objectives of mixed methods research are twofold: to attain a comprehensive understanding characterised by both breadth and depth and to ensure corroboration through the convergence of diverse research elements (Dawadi et al., 2021).

This perspective aligns with the complex nature of the research focuses on roadside behaviour of children with DCD and/or ADHD and the daily lived experiences of their parents. The multifaceted exploration demanded by this research topic is well-suited to the integration of both qualitative and quantitative methods.

2.6 Justification for Exploratory Sequential Mixed Methods Research Design

Building upon the broad application of mixed methods, this research adopted an exploratory sequential mixed methods design (Edmonds & Kennedy, 2017). The rationale for this choice lies in the distinctive benefits offered by the sequential integration of qualitative and quantitative phases. The exploration of roadside behaviour in children with DCD and/or ADHD requires an understanding of the intricate interplay of the characteristics of each disorder, including motor and attentional abilities, among these children within the context of roadside behaviour. Importantly, this understanding must also consider the perspectives of parents, as they play a crucial role in shaping children's road safety behaviours and can provide valuable insights into their children's specific needs and challenges. Exploratory mixed methods research is characterised by the seamless integration of qualitative and quantitative research methods, each complementing the other to provide a comprehensive understanding of the research questions (Taylor et al., 2019). By adopting a mixed-methods approach, qualitative methods can provide in-depth insights into the lived experiences of parents and children, while quantitative methods can offer a broader, more generalisable perspective. The sequential design was also utilised, where the initial qualitative phase served to identify key themes related to children's roadside behaviour from their parents' views. These findings then directly informed the development of the subsequent quantitative phase, including measuring pedestrian perceptual-motor skills among children with DCD and/or ADHD. Therefore, this sequential approach allows for a more nuanced and comprehensive understanding of the factors influencing roadside behaviour among children with DCD and/or ADHD.

The rationale for utilising an exploratory mixed methods design is that it is appropriate to begin with an initial qualitative exploratory investigation when little is understood or known in relation to specific topic (Fetters et al., 2013; Taylor et al., 2019). Due to the lack of data in the current related literature about parents or carers' perspectives of children with DCD and/or ADHD at the roadside, the initial phase was undertaken qualitatively (Chapter 4) followed by a quantitative phase (Chapters 6,7, & 8) to further elaborate and confirm the findings from the first phase (Taylor et al., 2019). The initial phase, therefore, collected and analysed qualitative data to gain an in-depth understanding of the vulnerability of children with DCD and/or ADHD at the roadside from their parents' perspective and experience. The qualitative phase (Phase one) was vital in order to confirm whether parents of children with DCD and/or ADHD are concerned about their children's involvement in RTAs and to create baseline data of understanding parents' views about their children's roadside behaviours and strategies/actions taken to prevent or minimise the risk (DeJonckheere & Vaughn, 2019). This was then followed by a quantitative phase (Phase two) designed to build upon findings in phase one. Using quantitative methods, the second phase further explored the factors and pedestrian skills that may contribute to an increased risk of pedestrian accidents in these children. Through conducting a detailed investigation of the specific behaviours in relation to (1) where to cross and (2) when to cross, more generalisable conclusions about the potential challenges faced by this population can be drawn. Figure 2.1 provides a diagram to visually represent the research phases using exploratory sequential mixed methods design.

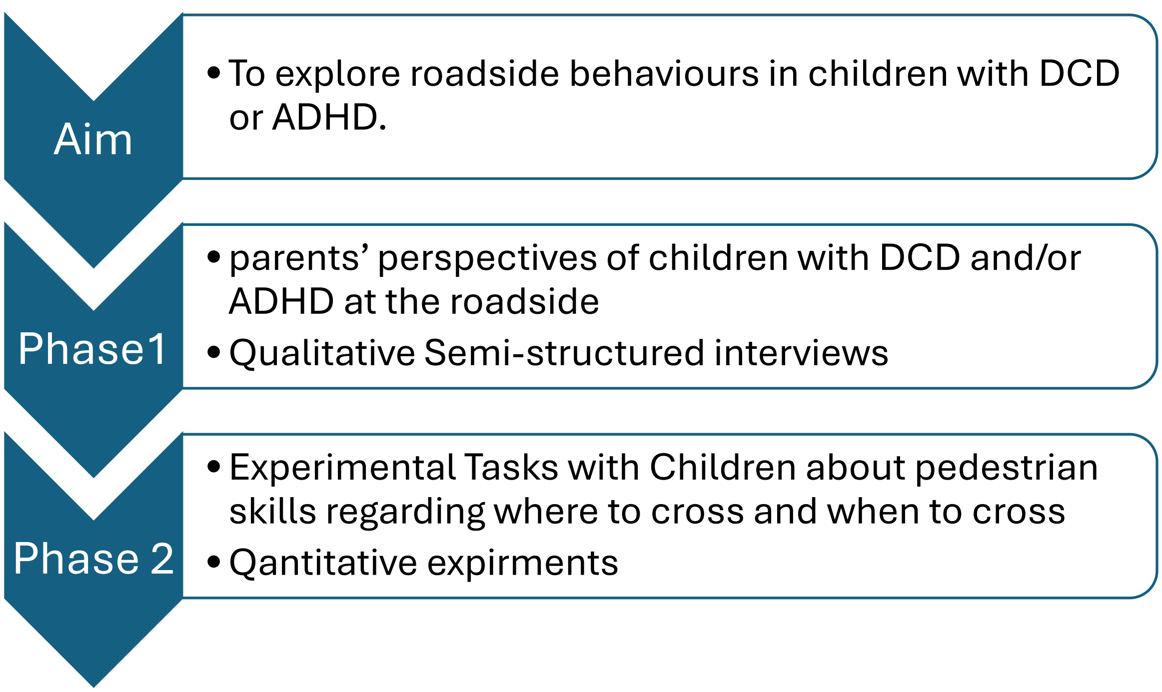


Figure 2.1, phases of the exploratory sequential mixed methods design.

2.7 Common Screening Tools for Phases One and Two

Screening tools are employed for the early identification of DCD and ADHD. These standardised instruments evaluate cognitive, motor, and behavioural skills, providing objective information. By using these tools, clinicians can identify children at risk of DCD or ADHD, plan effective treatments, and contribute to research efforts aimed at understanding and addressing these conditions (Iragorri & Spackman, 2018). The DCD and ADHD participants already had a parent-reported diagnosis of DCD or ADHD, standardised screening and assessment tools were used to confirm this diagnosis and gather additional information about the participants' specific characteristics. Two screening tools, the Developmental Coordination Disorder Questionnaire (DCDQ’7) (Wilson et al., 2007) and Swanson, Nolan, and Pelham-IV (SNAP-IV) (Gau et al., 2008) were used in both Phases one and two. The DCDQ-7 was selected to assess motor coordination difficulties characteristic of DCD (Wilson et al., 2007), while the SNAP-IV was chosen to screen for ADHD symptoms, including inattention, hyperactivity, and impulsivity (Gau et al., 2008). These tools were chosen based on their established reliability and validity in identifying children with DCD and/or ADHD (Wilson et al., 2009; Hall et al., 2020). Additional screening and assessment tools used in Phase two (Chapters 6, 7, and 8) will be discussed in further sections.

2.7.1 Developmental Coordination Disorder Questionnaire (DCDQ’7): Screening tool for DCD

According to Wilson et al. (2007), the DCDQ is a parent-reported questionnaire designed to assess the presence of motor coordination difficulties in children and provides insights into a child's motor abilities to identify potential signs of DCD. The questionnaire has demonstrated good psychometric properties, including high internal consistency and good test-retest reliability (Wilson et al., 2009). It includes 15 questions/items that are indicative of DCD characteristics, such as challenges with general coordination, balance, fine motor and gross motor skills (Wilson et al., 2007). While the first six questions refer to control during movement such as catching a ball, the second four questions cover fine motor skills, such as handwriting (Wilson et al., 2007). The last five questions concern general coordination such as sport and reaching fatigue levels when doing an activity

(Wilson et al., 2007). In each section, the child is evaluated and categorised according to a five-point Likert scale including ‘not at all like my child’, ‘a bit like my child’, ‘moderately like my child’, ‘quite a bit like my child’, and ‘extremely like my child’ (Wilson et al., 2007). A low total score on the DCDQ indicates a higher likelihood of motor difficulties (Wilson et al., 2007). While total scores on the DCDQ can range from 15 to 75, a score of 57 and below indicates greater possibility of motor difficulties (Wilson et al., 2007).

The DCDQ addresses DSM-5 (APA, 2013) criterion A and B related to motor coordination difficulties, encompassing both fine and gross motor skills. It evaluates the child's ability to perform academic and daily activities, including tasks such as dressing, writing and maintaining balance. By focusing on these aspects, the DCDQ aligns with DSM-5 criteria that emphasises observable impairments in motor coordination and developmental milestones. In Phase one, the DCDQ was used to screen for motor coordination difficulties, aligning with DSM-5 criteria A and B, and to confirm parental reports of DCD diagnoses within the context of online, semi-structured interviews. Phase two included in-person and more comprehensive assessments using additional screening tools, the Social Communication Questionnaire (SCQ) (Wiggins et al., 2007) and the test component of the Movement Assessment Battery for Children, Second Edition (MABC-2; Henderson et al., 2007), to gather information relevant to all DSM-5 diagnostic criteria. These tools will be discussed in more detail in further sections.

2.7.2 Swanson, Nolan, and Pelham-IV (SNAP-IV): Screening Tool for ADHD

The Swanson, Nolan, and Pelham (SNAP) Questionnaire (version 4; SNAP-IV) (Gau et al., 2008) is a widely recognised screening tool for assessing ADHD characteristics in children (Gau et al., 2008). The SNAP-IV has demonstrated good psychometric properties, including high sensitivity and specificity in identifying children with ADHD (Gau et al., 2008; Bussing et al., 2008; Hall et al., 2020). Studies have shown that the SNAP-IV has acceptable levels of internal consistency reliability and good test-retest reliability (Gau et al., 2008; Hall et al., 2020). These findings support the use of the SNAP-IV as a valuable screening tool for ADHD in research settings.

The SNAP-IV collects perspectives from parents or teachers for children aged 6 to 18 years (Gau et al., 2008). It comprises of 26 items classified into three main sections: two focusing on ADHD characteristics and the other on Oppositional Defiant Disorder (ODD) characteristics (Gau et al., 2008; Hall et al., 2020). While a range of questions/items are designed to assess inattention (items 1-9) and hyperactivity/impulsivity (items 10 -18), items 19 – 26 are dedicated to assessing ODD (Gau et al., 2008). Each item is framed as a statement about the child's behaviour with the frequency and severity of each behaviour categorised based on a four-point scale: 'not at all', 'just a little', 'quite a bit' and 'very much' (Gau et al., 2008; Hall et al., 2020). High scores in each of the three subsets indicate the possibility of ADHD (Gau et al., 2008; Hall et al., 2020). The SNAP-IV suggests potential ADHD if the score is above 1.2 whilst clinically significant characteristics of ADHD can be determined if the score is above 1.8 (Bussing et al., 2008).

SNAP-IV addresses the criteria specified in the DSM-5 (APA, 2013) for ADHD including criteria A, B, C, and D. The set of questions (items 1 -9) address criterion A related to inattention symptoms, items 10 – 18 address the rest of the criterion A related to hyperactivity/impulsivity symptoms. The entirety of the SNAP-IV is crafted to encompass criteria B, C, and D.

2.8 Sampling Strategy

In adhering to the principles of the chosen research design, a non-probability or judgment sampling strategy, specifically purposive sampling (Etikan, 2016), served as the foundational approach for participant recruitment in both the qualitative and quantitative phases of the study. The decision to opt for purposive sampling was rooted in the intention to selectively choose individuals with the requisite knowledge and firsthand experiences relevant to the research inquiries (Etikan et al., 2016). Unlike the random selection in probability sampling approaches, where recruitment relies on chance to avoid biases (Acharya et al., 2013), purposive sampling allowed for a targeted selection of participants, ensuring a deliberate inclusion of individuals possessing insights vital to the research questions. As such, sample composition that reflected knowledge and understanding regarding participants' characteristics relevant to addressing the research aim, using pre-defined inclusion and exclusion criteria was determined for each phase (Thomas, 2022).

This led to a targeted comprehensive exploration of the intricate aspects of roadside behaviour in children with DCD and/or ADHD. In the context of Phase one (Chapter 4), for example, this purposive sampling strategy involved the identification and recruitment of parents of children with DCD and/or ADHD and children with DCD, ADHD, and TD children in Phase two (Chapters 6, 7, and 8). The sample composition in Phase one was determined based on pre-defined inclusion criteria provided in Table 2.2. This strategy assisted in generating intensive data leading to an in-depth understanding of the experiences of children with DCD and/or ADHD as pedestrians from their parent's perspectives.

Table 2.2. Inclusion and Exclusion Criteria for Phase one (qualitative phase)

Inclusion Criteria	**Exclusion Criteria**
Parents of children with DCD and/or ADHD who: • were aged 7 to17 years • reported having a diagnosis of DCD and/or ADHD • had DCD and/or ADHD characteristics based on the DCDQ and SNAP-IV • lived in the UK • navigated the community with their children • were able to communicate in English • were able to provide informed consent	Parents of children who: • were less than 7 years of age or greater than 17 years of age • had no DCD and/or ADHD characteristics based on the DCDQ and SNAP-IV • were unable to provide informed consent • were unable to access a computer and/or the internet.

Phase two (Chapters 6, 7, and 8), also use a purposive sampling approach to ensure a targeted selection of participants. However, the qualitative interviews (in Phase one) with parents of children aged 7-17 provided valuable context. While parents of younger children (7-10) offered insights into early pedestrian development and emerging challenges, the focus in the interviews with parents of older children (11-17) was the increasing independence and associated risks of road crossing. Therefore, focusing on the 11–16-year age range in the Phase two allowed for a targeted investigation of the challenges and behaviours associated with independent road crossing. Furthermore, the focus in this phase included children with DCD or ADHD compared to their TD peers to quantitively explore their pedestrian skills. Table 2.3 provides the inclusion and exclusion criteria for Phase two.

Table 2.3. Inclusion and Exclusion Criteria for Phase two (quantitative phase)

Inclusion Criteria	**Exclusion Criteria**
For experimental and index groups children were included if they were: • ≥ 11 to16 years of age • Living in the UK • Navigating the community on foot on a regular basis • Able to communicate in English • No known visual impairment that hasn't been corrected by glasses and no known other disability	For experimental and index groups children were excluded if they were: • Less than 11 or > 16 years of age • Unable to travel to the RCCK lab • Unable to give consent for any reason • Uncorrected visual impairment and other disability • Unable to walk to places in the community, such as schools, shopping centres, and parks.
For experimental groups children needed to have a: • Confirmed diagnosis of DCD, ADHD, or Both	For experimental groups children were excluded if they had: • Unconfirmed diagnosis of ADHD or DCD • Confirmed diagnosis of other NDDs
For the index group children needed to have: • No known diagnosis (typically developing children)	For the index group children were excluded if they had a: • Diagnosis of any NDDs

However, it is important to acknowledge the limitations of purposive sampling. Since the selection of participants is based on specific criteria, there is a risk of introducing bias into the sample. The sample may not be representative of the entire population of children with DCD and/or ADHD, which could limit the generalisability of the findings. Despite its limitations, purposive sampling was deemed the most appropriate approach for this study.

By carefully considering the inclusion and exclusion criteria, the intention was to minimise potential biases and select a sample that would provide valuable insights to answer the research questions. Overall, purposive sampling strategy, tailored to the specific requirements of each phase, was instrumental in answering the research questions. It allowed for the deliberate inclusion of participants who could provide insights, contributing to a comprehensive understanding of the research questions. Participant selection for Phase one is discussed in Chapter 4, and participant selection for Phase two is discussed in the following section (Applying the Criteria).

2.9 Recruitment

In Phase one (semi-structured online interviews), the initial recruitment strategy aimed to include parents of children with DCD and/or ADHD. However, recruitment challenges were encountered, particularly in recruiting sufficient numbers of children diagnosed with both DCD and ADHD for Phase two. These logistical difficulties, coupled with the demands of Phase two, which involved quasi-experimental procedures requiring the attendance of both parents and children, led to an adjustment in the recruitment strategy for Phase two. The focus shifted to three distinct groups: children with DCD, children with ADHD, and TD children.

Participants were recruited through two distinct recruitment avenues in both phases. The first was through social media platforms. Although there are inconsistent results related to using social media platforms as a research recruitment tool (Topolovec-Vranic & Natarajan, 2016), successful social media recruitment can be linked to the careful choice of platforms and type of posts (Arigo et al., 2018; Bender et al., 2017). Given that middle to older age adults make up a large proportion of Facebook and X (formerly Twitter) active users (Darko et al., 2022), parents of children with ADHD and/or DCD in Phase one and parents of children with DCD or ADHD and their children in Phase two were recruited through these platforms (Arigo et al., 2018). Selective information about the study was posted to avoid engagement from non-targeted populations (Arigo et al., 2018; Bender et al., 2017). For example, Bender et al. (2017) successfully utilised marketing headlines, an internet marketing approach, for recruitment through Facebook posts. Both Arigo et al., (2018) and (Bender et al., 2017) agree that it is important to include enough information to trigger the curiosity of the targeted population without exposing too much information which may encourage participants to inadvertently disclose personal information on social media platforms (Arigo et al., 2018; Bender et al., 2017). Thus, this research followed the same strategy with recruitment posts. Examples of recruitment posts and tweets are provided in appendix 2.1. With regards to ethical considerations, this research applied the Privacy by Design framework for online recruitment to manage privacy risks and meet recruitment objectives (Bender et al., 2017). The social media posts included the privacy notice within the post on either X or Facebook. Cardiff University's official social media network, Yammer, was also used for recruitment along with Cardiff University's Neurodiversity and Inclusivity network.

Another recruitment avenue was through non-profit organisations, schools and institutions working with children with ADHD and/or DCD and their families. Recruitment was therefore done through schools in the UK, the ADHD foundation, ADHD UK, Dyspraxia Foundation and ADHD Action. Gatekeepers within these organisations were involved in recruitment and negotiation with prospective participants to facilitate the process of the recruitment (McAreavey & Das, 2013). The standard gatekeeping operating procedure was used throughout the recruitment process. Specifically, an email was initially sent to gatekeepers (see appendix 2.3) with the participant information sheet (see appendix 2.2) and consent form (see appendices 2.4 & 2.6). The intention of this email was to seek agreement from gatekeepers to support recruitment. Once a gatekeeper agreed to be involved, they were asked to send out the participant information sheet and provided with further information or documents, if required, such as an email with a brief description of the project to be circulated and consent to contact form (see appendices 2.5 & 2.6).

2.10 Ethical Considerations

This project adhered to the ethical guidelines outlined by the School of Healthcare Sciences Research Ethics Committee. Prior to the commencement of each phase of the research, ethical approval was obtained from the committee.

- Phase one: Ethical approval was granted for the recruitment of participants, obtaining informed consent, gatekeeping and conducting interviews with parents.

- Phase two: A separate ethics application was submitted and granted for the recruitment of participants, obtaining informed consent, gatekeeping, data collection from children and parents, including questionnaire and quasi-experimental tasks.

Throughout the research process, participant confidentiality and data security were maintained in accordance with ethical guidelines. Informed consent was obtained from all participants (parents for Phase one, children and their legal guardians for Phase two) prior to their involvement in any research activities

2.11 Shared Methods for Quantitative phase (Phase two)

This section provides information regarding the shared methods between Chapters 6, 7, and 8, which constitute the quantitative phase (Phase two). Phase One consisted of semi-structured interviews with parents of children with DCD and/or ADHD. For full details of the Phase One methodology, including participant recruitment and data collection, see Chapter 4. In this phase, participants were recruited based on the following inclusion and exclusion criteria.

2.11.1 Inclusion Criteria

As mentioned in the sampling strategy section, purposive sampling was used in which the researcher selected participants who were well-informed in relation to the phenomenon of interest and difficult to reach as a subset population (Etikan, 2016). As a result, there were three groups: ADHD group, DCD group and a TD index group. Children with a primary diagnosis of ADHD were recruited for the ADHD group, children with primary diagnosis of DCD were recruited for the DCD group. The index group included typically developing children, with no known diagnoses. To account for any co-occurrence, parents indicated the primary diagnosis, and the researcher used the results of the screening tools (detailed discussion in the following section) to confirm the diagnosis and confirm group allocation. The target age range was children between 11 to 16 years old living in the UK and able to communicate in English. While previous studies have found typically developing children aged 8 years and older exhibit safer pedestrian performance compared to younger peers and tend to become more independent in road crossing (Wang et al., 2018; Egan, 2012), studies on children with DCD or ADHD aged 8 years and older suggested that children with DCD or ADHD are typically not crossing roads safely when compared to their typically developing peers leading to elevated risk of RTAs (Stavrinos et al., 2011; Wilmut and Purcell, 2021). Therefore, this phase focused on recruiting children aged from 11 to 16 years old to compare pedestrian performance of children with ADHD or DCD with their typically developing peers. Inclusion and exclusion criteria are provided in Table 2.3. Sample size was calculated using GPower and indicated the need to recruit a total of 55 children (Faul et al., 2007) (see appendix 2.7). The target population was community based and as such NHS ethical approval was not required as indicated in the previous section.

2.11.2 Applying the Criteria

The power analysis suggested a sample size of 55 participants, as mentioned earlier, would be required to detect an effect size of 0.5 with a power of 0.8 and an alpha level of 0.05. This means that there is an 80% chance of correctly rejecting the null hypothesis if the true effect size is 0.5. However, due to logistical challenges associated with recruiting children after school and limited weekend availability, the study recruited less than the target sample size. Given these challenges, a total of 35 children participated in Phase two of the study ranging in age from 11 to 16 years old. The combined sample consisted of 74% males and 26% females (n=26 male, n=9 female). The participants were divided into three groups based on parents reported diagnosis: TD or index group; DCD group and ADHD group. The TD group consisted of 16 children whilst the DCD group included 10 children, and the ADHD group comprised 9 children. Table 2.3 provides a detailed breakdown of the sample characteristics for each group based on diagnosis reported by parents when completing a history checklist.

Table 2.3 Sample characteristics and categories based on diagnosis reported by parents

Group	Number of Participants (n)	Co-occurring Diagnosis Reported by Parents
TD	16	None
DCD	10	1 (ADHD)

ADHD	9	1 (suspected ASD)

Initially, parents completed a history checklist to gather information about participants' medical history, demographic data and any previous diagnoses. Standardised screening/assessment tools were administered to verify the accuracy of parental reports regarding diagnosis and to confirm other eligibility criteria. The screening/assessment tools included the DCDQ (Wilson, 2007), SNAP-IV (Hall et al., 2020), Social Communication Questionnaire (SCQ; Wiggins et al., 2007), Lawton-Brody Instrumental Activities of Daily Living (IADL) Scale (Lawton & Brody, 1969), and the test component of the Movement Assessment Battery for Children, Second Edition (MABC-2; Henderson et al., 2007). The DCDQ (Wilson, 2007) is a parent-reported questionnaire to screen for motor function and coordination skills in children, aiding in the identification of potential DCD. The SNAP-IV was used (Hall et al., 2020) as a standardised parent-completed rating scale designed to assess characteristics of ADHD in children. The DCDQ and SNAP-IV were described in more details in previous sections. Furthermore, the Social Communication Questionnaire (SCQ; Wiggins et al., 2007) was included to assess potential concerns related to Autism Spectrum Disorder (ASD). The SCQ is a well-established screening tool for ASD that has demonstrated good sensitivity and specificity in identifying individuals who may require further diagnostic evaluation (Wiggins et al., 2007). This 40-item parent-reported questionnaire utilises a yes/no format, with a higher score indicating a greater likelihood of ASD characteristics. A commonly used cut-off score of ≥ 15 suggests the need for further evaluation for ASD (Wiggins et al., 2007). The inclusion of the SCQ served to identify and exclude participants who may have co-occurring ASD that could confound the study's findings by introducing extraneous variables. By excluding participants with potential ASD, the research focused specifically on the target population of children with DCD or ADHD.

To gain a more comprehensive assessment of participants' functional abilities in everyday tasks, a standardised Lawton-Brody Instrumental Activities of Daily Living (IADL) Scale (Lawton & Brody, 1969) was used. This well-established screening tool, originally designed to evaluate the independence of older adults in performing daily activities, was adapted for use in this study with the target population of children aged 11-16 years. The

Lawton-Brody IADL scale focuses on eight core IADL domains: Using the telephone; Getting around in the community; Taking care of shopping needs; Preparing meals; Managing housework; Laundering clothes; Taking medications and Managing finances. For each domain, parents were asked to rate their child's level of independence using a standard scoring system. This system assigns a score of 1 (independent) or 0 (dependent) based on the response options provided for each domain. The number of options varied, ranging from 1 to 3 for some domains and 1 to 5 for others. Each option describes a different level of dependency the child might have for that specific task. In addition to the pre-defined options, an "Other" option was included to allow parents on to elaborate their child's level of independence or provide details not captured by the existing options. This scoring system allowed for a quantitative assessment of children's independence across various IADL domains. The total score for each child was calculated by summing the scores across all domains. This adaptation of the Lawton-Brody IADL scale allowed for a detailed evaluation of participants' functional capabilities in daily living tasks relevant to their age group. This adapted scoring system, while maintaining the core domains of the original Lawton-Brody IADL scale, better reflected the developmental needs and capabilities of children and provided insights into their ability to manage everyday tasks independently. A comprehensive approach to screening allowed for a thorough assessment of potential diagnoses within the target population.

All participating children undertook the test component of the Movement Assessment Battery for Children, Second Edition (MABC-2; Henderson et al., 2007). This standardised assessment objectively measured children’s motor proficiency, complementing the information gathered from parents. The MABC-2 was chosen for this study due to its well-established psychometric properties including reliability and validity (Henderson et al., 2007). While the MABC-3 (Wu et al., 2023), a newer version of the assessment, was not available at the time of participant recruitment, the MABC-2 remains a widely used and well-validated tool for identifying children with movement difficulties (Henderson et al., 2007). The MABC-2 requires children aged 3 years 0 months to 16 years 11 months to perform a series of age-appropriate motor tasks. The tasks are divided into three sub-sections: Manual Dexterity; Ball Skills and Static and Dynamic Balance. A total score and percentile rank are derived, with lower scores indicating greater motor difficulties. The MABC-2 authors suggest a percentile score below the fifth indicates a definite motor problem, scores between the fifth and sixteenth percentiles suggest potential difficulties requiring monitoring and a score above sixteenth percentile indicates no motor difficulties. However, there is ongoing debate within the research community. Some researchers argue that the 5th percentile cutoff might be too strict, advocating for including scores between the 10th and 16th percentiles within the DCD range (e.g., Wilson & Maruff, 2003). For the purposes of Phase two, participants below the 5^{th} percentile were considered to have DCD.

This comprehensive process ensured that all participants met the relevant DSM-5 criteria for their allocated groups. The battery of screening tools was employed to assess the core characteristics outlined in the DSM-5 criteria for DCD and ADHD (APA, 2013). The DCDQ assessed difficulties with motor skills typically observed in DCD. This aligns with DSM-5 Criterion A for assessing motor difficulties in DCD. Additionally, the DCDQ inquiries about the impact of these motor skill difficulties on daily activities, assessing Criterion B (interference with daily life). The test component of the MABC-2 played a crucial role in objectively measuring motor proficiency according to the age groups, complementing parental reports and aiding in confirming or ruling out DCD based on established criteria (Henderson et al., 2007). While the MABC-2 primarily focuses on Criterion A (motor skill difficulties), it might indirectly provide evidence for Criterion B. For example, the MABC-2 included tasks such as drawing, low scores could suggest difficulties that interfere with daily academic activities. For ADHD, the SNAP-IV assessed aspects of DSM-5 Criteria A, B, C and D. The SNAP-IV assesses ADHD characteristics including inattention and/or hyperactivity-impulsivity aligning with DSM-5 criteria Criterion A and B. Furthermore, the SNAP-IV is a parent-reported measure, and these criteria typically require information from multiple settings (e.g., home, school) assessing DSM-5 Criterion C and D (impact on multiple settings).

However, the impact of DCD and ADHD characteristics in different settings and on daily activities were primarily assessed by the Lawton-Brody IADL scale to fulfil DSM-5 Criterion B for DCD and C for ADHD. As ASD is commonly co-occurring with DCD and

ADHD (Sáenz et al, 2021; Panagiotidi et al, 2019), the SCQ served the vital purpose of screening for potential ASD to exclude participants with co-occurring ASD characteristics that could confound the study's focus on DCD and ADHD (Wiggins et al., 2007). The SCQ findings assessed part of the DSM-5 Criterion D for the DCD and Criterion E for ADHD.

Finally, a history checklist provided additional details about participants' medical background and diagnoses including demographic data, current medications, primary diagnosis and co-occurring conditions. This information particularly assisted in understanding the duration of characteristics (DSM-5 Criterion C for DCD and B for ADHD) based on past and the onset of the diagnoses. The history checklist also assessed DSM-5 Criterion D for DCD and Criterion E for ADHD to identify any potential causes that could better explain the characteristics. Thus, a multi-faceted approach was used to ensure that all participants met the relevant DSM-5 criteria for their allocated group, strengthening the confidence in the subsequent group comparisons and analyses. The following section will delve deeper into exploring the results of the tools to indicate the distinct characteristics of each group.

2.11.3 Measures

2.11.3.1 DCDQ

As mentioned earlier in the DCDQ section, scores below 57 on the DCDQ indicate a greater possibility of motor difficulties (Wilson et al., 2007). In line with this benchmark, the DCDQ identified that 17 out of 35 participants scored below the normative range (as shown in Table 6.3), suggesting potential motor skill challenges. Descriptive statistics revealed a mean DCDQ score of 52.57 (SD = 16.21) for all 35 participants. The median score was slightly higher at 59.00. These findings suggest a moderate range of motor skill abilities based on parental reports, with some participants scoring above and below the average. However, the Shapiro-Wilk test revealed that the DCDQ data was not normally distributed (Shapiro-Wilk = 0.015, $p < .001$). Therefore, non-parametric tests were used for further analysis.

Further analysis with the Kruskal-Wallis test revealed significant differences in DCDQ scores between the groups, $\chi^2(2) = 22.652$, $p < .001$. Post-hoc comparisons were then conducted to identify which specific groups differed. The results of pairwise comparisons of the three groups (DCD, ADHD, and TD) using the Mann-Whitney U test revealed significant differences between DCD and TD groups ($U = 10$, $p < .001$) and between DCD and ADHD groups ($U = 41$, $p = .008$). However, the difference between ADHD and TD groups was not statistically significant ($U = 105$, $p = .096$). These findings suggest that children in the DCD group experienced greater motor skill difficulties compared to both the TD and ADHD groups. Thus, these findings from the DCDQ served as preliminary confirmation of the reported diagnosis by parents. Only two participants from TD group scored below 57 on the DCDQ, prompting further investigation using the MABC-2 to confirm participant group allocation.

2.11.3.2 MABC-2

Following the DCDQ screening, the MABC-2 scores were used to objectively assess motor skills and refine participant allocation. Given the lack of consensus regarding MABC-2 score interpretation and the complexity diagnosing DCD, this study acknowledged the potential for a spectrum of motor difficulties. Therefore, participants scoring below the 5th percentile on the MABC-2 were classified as having confirmed DCD, reflecting the presence of severe motor difficulties (Henderson et al., 2007). For participants scoring between the 10th and 16th percentile on the MABC-2, additional information from the DCDQ and parental reports was used to confirm a DCD diagnosis. Participants who were identified as typically developing by their parents but demonstrated motor impairments on the MABC-2 and DCDQ were excluded from the study. Four participants from the TD group, as reported by parents, scored between the 10th and 16th percentile on the MABC-2 and were also identified as DCD according to DCDQ. These participants were excluded for not meeting the inclusion criteria for the typically developing group and not having a confirmed diagnosis needed for inclusion in the DCD group.

The potential co-occurrence of DCD with ADHD was addressed for participants initially identified with ADHD based on the parent history checklist. Participants in the ADHD group (n=9) who scored above the 16th percentile on the MABC-2 remained classified as ADHD, prioritising the primary diagnosis identified by parents and the more objective assessment of motor skills provided by the MABC-2. However, one participant from the ADHD group scored below the 16th percentile on the MABC-2. Therefore, the DCDQ results were reviewed for this participant, the parental report did not confirm motor difficulties. Furthermore, the reported ADHD diagnosis for this participant, based on the parent history checklist, did not suggest motor difficulties. Therefore, the participant remained classified as ADHD. This finding suggests that in this sample, ADHD participants with potential low motor skills on the MABC-2 did not necessarily exhibit concerns regarding DCD according to parental reports on the DCDQ and the parent history checklist. While the MABC-2 provides a valuable snapshot of motor skills, it is important to consider that performance can be influenced by factors such as time of day (e.g., after school fatigue) and the child's overall state. This approach acknowledges the possibility of co-occurrence while prioritising objective motor skill assessment and parental observations.

Refined participant allocation based on the MABC-2 scores therefore, resulted in 12 participants classified as TD with the DCD and ADHD unchanged. Statistical analysis using a one-way ANOVA revealed significant overall differences in MABC-2 total scores between the three groups ($F(2, 30) = 28.761$, $p < .001$). Post-hoc comparisons using Tukey's HSD test revealed that children with DCD displayed significantly lower MABC-2 scores (indicating greater motor difficulties) compared to both the TD group (mean difference = 29.029, $p < .001$) and the ADHD group (mean difference = 20.100, $p < .001$). There were no significant differences in MABC-2 scores between the TD and ADHD groups (mean difference = 8.929, $p = .080$). These findings support the utility of the MABC-2 in objectively differentiating motor skill performance between TD children, those with confirmed DCD and those with ADHD.

2.11.3.3 SNAP-IV

Having explored motor skills, SNAP-IV was also used to confirm ADHD characteristics. According to Bussing et al. (2008), SNAP-IV scores above 1.2 are associated with an increased probability of ADHD, whereas scores exceeding 1.8 suggest clinically significant ADHD. All participants in the ADHD group (N=9) scored above 1.8 on the SNAP-IV, exceeding the cut-off indicative of clinically significant ADHD characteristics. Additionally, the 12 children in the TD group scored below 1.2 on the SNAP-IV, supporting the absence of ADHD characteristics as reported by parents. This highlights the importance of considering multiple sources of information, including standardised assessments and parental reports, when allocating ADHD.

The SNAP-IV results for the DCD group were mixed. While the majority of participants (N=10) scored below 1.2, suggesting minimal ADHD characteristics, one participant scored above 1.2 but below 1.8. While showing potential ADHD traits on the SNAP-IV, the participant remained in the DCD group based on the combination of DCDQ and MABC-2 scores, as well as parental reports. The parent's primary concern and the clear evidence of motor difficulties on standardised assessments led to this classification.

The Shapiro-Wilk test for normality yielded a significance value of Shapiro-Wilk = .950, $p = .153$, suggesting that the SNAP-IV scores were likely normally distributed. Therefore, a one-way ANOVA was performed and revealed a statistically significant difference in SNAP-IV scores between the three groups ($F(2, 28) = 35.473$, $p < .001$). Further investigation using Tukey's HSD test explored group differences. The TD group had significantly lower SNAP-IV scores compared to the DCD group (mean difference = -0.617, $p = .011$) and ADHD group (mean difference = -1.714, $p < .001$). This suggests that children in the TD group did not have ADHD characteristics. There were significant differences in the SNAP-IV average scores between the ADHD and DCD groups (mean difference = -1.096, $p < .001$) indicating significantly higher ADHD characteristics in the ADHD group. Overall, the findings revealed that there was one group with higher ADHD characteristics, the ADHD group, and the other two groups had no or significantly less ADHD characteristics.

2.11.3.4 SCQ

The SCQ scores were examined to assess potential ASD, which could influence the study's findings. Scores of 15 or higher on the SCQ warrant further ASD evaluation (Wiggins et al., 2007). Based on this, all participants in the TD group scored less than 15 on the SCQ, suggesting no potential ASD within the group. One participant in the ADHD group was identified by parents as suspected ASD but the SCQ score suggested no ASD. Therefore, parent history checklists were used for confirmation and revealed that the parents reported primary diagnoses for their child as ADHD. However, in the absence of confirmed ASD the group allocation remained unchanged, with 12 participants classified as TD, 10 with DCD and 9 with ADHD. Table 2.4 presents the means and standard deviations of the SCQ scores for each group.

Further analysis was performed, the Shapiro-Wilk test for normality yielded a value of Shapiro-Wilk = .974, p = 0.622, suggesting that the SCQ scores were most likely normally distributed. A one-way ANOVA revealed no statistically significant difference in the mean SCQ scores between the TD, ADHD and DCD groups $F(2, 28) = 1.936$, p = .163. This absence of a significant group difference could be due to the recruitment strategy focusing on identifying participants with confirmed diagnoses of DCD and ADHD, aiming to minimise the potential influence of co-occurring ASD on the results. This might also suggest that any potential ASD characteristics were similarly distributed across groups.

Table 2.4. SCQ total score by group

Group Comparison	n	Mean of SCQ total score	Standard Deviation (SD)
TD	12	6.75	4.63
DCD	10	10.30	4.92
ADHD	9	9.56	3.68

2.11.3.5 Lawton-Brody IADL

The Lawton-Brody IADL scale provided further insight into the participants' functional abilities in everyday tasks. Scores range from 0 (dependent) to 8 (independent), with higher scores indicating greater independence in daily activities (Lawton & Brody, 1969). The TD group (n = 12) had an average IADL score of 6.75 (SD = 1.05), while the ADHD group (n = 9) displayed an average score of 4.33 (SD = 1.87) and the DCD group (n = 10) had an average score of 4.90 (SD = 1.60). The internal consistency of the IADL scores in this study was marginal (Cronbach's alpha = 0.62), suggesting that some items might not be measuring the same construct well within the adapted scale. The Shapiro-Wilk test indicated that the IADL scores were not normally distributed (.926, p = 0.033). A Kruskal-Wallis test revealed a statistically significant difference in IADL scores between the TD, ADHD, and DCD groups ($\chi^2(2)$ = 11.013, p = .004). To further explore this post-hoc tests were conducted. The results revealed that the DCD group scored significantly lower than the TD group (p = 0.010). While the ADHD group also scored significantly lower than the TD (p = 0.003), there was no significant difference between the DCD and ADHD groups (p = 0.627). These findings suggest that children with DCD and ADHD may experience greater difficulty performing daily activities independently compared to their typically developing peers. Table 2.5 showed the averages of each domain and groups.

Table 2.5. IADL Scale Performance by group and domain

Task Category	TD - Average (%)	DCD – Average (%)	ADHD – Average (%)
Transportation	1 (100%)	0.70 (70%)	0.78 (77.8%)
Medication	0.83 (83.33%)	0.50 (50%)	0.56 (55.6%)
Finances	0.92 (91.67%)	0.90 (90%)	0.67 (66.7%)
Food Preparation	0.50 (50%)	0.50 (50%)	0.33 (33.3%)
Shopping	0.92 (91.67%)	0.80 (80%)	0.33 (33.3%)

Housekeeping	0.92 (91.67%)	0.50 (50%)	0.44 (44.4%)
Laundry	0.67 (66.67%)	0.40 (40%)	0.22 (22.2%)
Telephone	1 (100%)	1 (100%)	1 (100%)

2.11.3.6 Final Allocation

Overall, the screening process, which was undertaken to confirm group allocation, guided by DSM-5 criteria, ensured that participants were accurately classified into their respective groups, thereby strengthening the confidence in the subsequent group comparisons and analyses presented in Chapters 6, 7, and 8. A slight adjustment to the initial recruitment targets occurred during the screening process. Four participants initially included in the TD group were subsequently excluded. These participants, as reported by parents, scored between the 10th and 16th percentile on the MABC-2, suggesting potential motor difficulties. Furthermore, the DCDQ also indicated potential DCD concerns. As these participants did not meet the inclusion criteria for the TD group and did not have a confirmed diagnosis of DCD, they were excluded from the study. This resulted in a slight decrease in the TD group. The final allocation resulted in 12 participants in the TD group, 10 in the DCD group, and 9 in the ADHD group.

2.11.4 Apparatus for Phase Two

Eye movements provide valuable insights into the underlying perceptual processing of visual information (Egan, 2012). Therefore, it is important to explore the visual behaviours and engagement of children with DCD or ADHD in relation to crossing site decisions. A Tobii Pro Spectrum eye-tracking system was used to record participants' eye movements during the tasks of safe crossing identification (Chapter 6) and looming detection (Chapter 7) (BIOPAC, 2024). This system is equipped with high-resolution cameras that track pupil position and gaze direction (BIOPAC, 2024). The eye-tracking system was calibrated prior to each testing session to ensure accurate measurement of eye movements during two quasi-experimental tasks: identification of safe crossing sites (Chapter 6) and looming detection (Chapter 7). The Tobii Pro Spectrum system offers a sampling frequency of up to 1200 Hz, allowing for the precise capture of eye movements, including fixations, saccades, micro-saccades, and tremors (Nyström et al., 2021; BIOPAC, 2024). Additionally, the system records pupil diameter and eye openness data (Nyström et al., 2021; BIOPAC, 2024). It maintains accurate tracking performance in various lighting conditions and allows for natural head movements during data collection (BIOPAC, 2024).

The system was integrated with Tobii Pro Lab software, dedicated eye tracking software designed for conducting experimental research with Tobii eye trackers (Tobii, 2024). Tobii Pro Lab provides a comprehensive set of tools for data analysis and visualisation, supporting the entire research workflow (Tobii, 2024). This allowed for the calculation of eye tracking metrics, creation of visual representations of data, and the exporting of data for further analysis in other software (Tobii, 2024). By leveraging the capabilities of the Tobii Pro Spectrum system and Tobii Pro Lab software, the quasi-experiments were able to obtain accurate and detailed eye movement data, which provided valuable insights into the visual processing strategies employed by participants during the tasks in Chapter 6 (identification of safe crossing sites) and Chapter 7 (looming detection).

2.11.5 Connected Device

The identification of safe crossing sites and looming detection tasks in Chapters 6 and 7 utilised a Tobii Pro Spectrum eye-tracking system (Tobii, 2024), connected to a Dell Alienware X16 laptop, to record participants' eye movements during the tasks. The Alienware X16 laptop, equipped with an Intel Core i9-12900H processor, NVIDIA GeForce RTX 4090 graphics, 32GB of RAM, and a 16-inch display, provided a powerful computing platform for data collection and analysis. Tobii Pro Lab software, installed on the Alienware X16, was used to design and conduct the experiments, as well as to analyse the collected eye tracking data. The laptop specifications ensured the smooth operation of the eye-tracking system and the stimulus presentation software. The powerful processor and ample RAM allowed for efficient data processing and analysis. The stimuli were presented on the Tobii Pro Spectrum connected to the laptop.

2.11.6 Psychophysical Procedure (Best-PEST):

For looming detection and temporal gap acceptance quasi-experiments in Chapters 7 and 8, a Best Parameter Estimation by Sequential Testing (Best-PEST) staircase procedure was employed. Best-PEST is an adaptive psychophysical procedure designed to efficiently determine a participant's threshold for detecting a stimulus (Lieberman & Pentland, 1982). The staircase procedure used a step-by-step approach with 1000 levels of difficulty. The difficulty level increased with each correct response and decreased with each incorrect response, gradually narrowing down to the participant's threshold (Lieberman & Pentland, 1982). This adaptive method involved presenting stimuli with varying degrees of looming or temporal crossing gaps, adjusting the difficulty level based on the participant's previous responses to determine the exact thresholds. For example, in the looming detection task in Chapter 7, stimuli were initially presented at a high rate of expansion to ensure easy detection by children (highest interval value 999). Following a correct response, the rate of expansion was decreased (higher speed), which increases the difficulty of the looming detection task. If a response was incorrect, a higher rate of expansion (lower speed) was presented to make the task easier. This process continued until a stable threshold was reached after six reversals and a threshold value was estimated by taking the maximum likelihood value. Similarly in Chapter 8 (gap acceptance), if a child accepted a temporal crossing gap, the next gap presented was smaller; if they rejected it, the next gap was larger. The maximum and minimum gap sizes were set at 20 and 2 seconds, respectively. This resulted in different distances between vehicles at different speeds: 142 meters for 20 mph and 213 meters for 30 mph. The first presentation always had a gap of 2 seconds to discourage an initial unsafe crossing. The algorithm ended after nine reversals, and the maximum likelihood value was taken as each participant's temporal gap acceptance threshold. Figure 2.1 illustrates a typical example of how the stimulus intensity was adjusted using the Best-PEST procedure (Purcell, 2011).

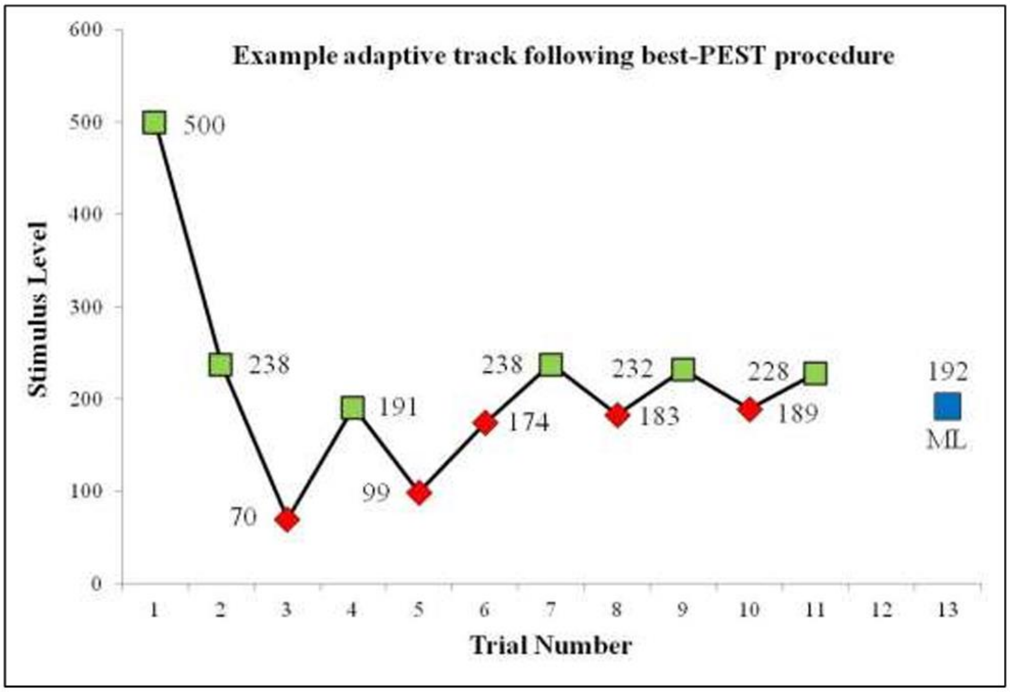


Figure 2.2, taken from Purcell et al. (2011), illustrates a typical example of the adaptive tracking process used in Best-PEST with the threshold set at the maximum likelihood value (ML). Red diamonds: incorrect/no response; green squares: correct/yes response.

2.12 Summary of the Chapter

This common methodology chapter has provided a comprehensive overview of the research design, study aims and research questions, incorporating both qualitative and quantitative components. The chapter began by introducing the exploratory mixed methods approach, emphasising its integration of qualitative and quantitative methodologies to achieve a deeper understanding of roadside behaviours in children with DCD and/or ADHD. The research aims and questions were provided, outlining the qualitative exploration of parental perspectives in Chapter 4 (Phase one) and the quantitative investigation of road crossing components in Chapters 6, 7, and 8 (Phase two).

The chapter also explained the rationale for adopting a mixed methods research design, rooted in pragmatism, to address the complex nature of the research. The justification for an exploratory sequential mixed methods design has been explained, emphasising the sequential integration of qualitative and quantitative phases allowing for a detailed exploration of the interplay between motor and attentional abilities in children with DCD and/or ADHD within the context of roadside behaviour. The philosophical foundation of pragmatism was highlighted, aligning with the study's goal of understanding both the subjective experiences of parents and objective reality.

Additionally, the sampling strategy section discussed the use of non-probability purposive sampling, aligning with the chosen research design. The intentional selection of participants with specific knowledge or experiences relevant to the research questions has been emphasised. The purposive sampling approach is illustrated in both phases, with Phase one focusing on parents of children with DCD and/or ADHD and Phase two including parents and children with DCD, ADHD or TD. The chapter concludes by highlighting the common methods for the quasi-experimental chapters - Chapters 6, 7, and 8. The following chapter will explore the influence of parents on child pedestrian safety.

3 Chapter Three: Parental Influences on Child Pedestrian Safety: A Literature Review

3.1 Introduction

To explore the unique experiences of parents of children with DCD and/or ADHD, this chapter and Chapter 4 explore how parental perspectives, attitudes, and beliefs may differ from those of parents of TD children. By understanding these differences, specific road safety challenges faced by children with these conditions can be identified and inform future activities to support safe pedestrian behaviours. Therefore, this review focused on parents of TD children.

Ensuring the safety of children on the road remains a significant public health challenge worldwide. Despite considerable efforts, including infrastructure improvements and educational programs, children are still vulnerable to preventable road traffic accidents (WHO, 2018). Among the various factors influencing children's road crossing behaviours, parental involvement stands out as a critical element (O'Neal, 2017). Parents play a multifaceted role in shaping their children's understanding and practice of safe road crossing. They serve as primary role models, influencing children's attitudes and behaviours through observation and imitation (Thomson et al., 1989). During children's early forays into independent mobility, parents are responsible for supervision, providing direct guidance and instruction (Barton & Schwebel, 2006). As children progress through developmental stages, a heightened desire for autonomy manifests, leading them to exert greater control over their mobility choices (Shaw et al., 2015). This highlights the evolving nature of parent-child dynamics in relation to independent community mobility.

Research spanning 14 countries has documented this growing autonomy in mobility choices (Shaw et al., 2015). By the age of 11 years, children in the majority of the surveyed nations were reported to be capable of independently crossing major roads (Shaw et al., 2015). This autonomy expands further by age 12 years, with children exhibiting the freedom to travel independently within walking distance (Shaw et al., 2015). By the age of 13 years, children are reportedly navigating their way home from school unaccompanied or utilising local public transportation systems (Shaw et al., 2015).

Furthermore, parental influence adapts to these developmental shifts. For example, initially parents focused on direct supervision and instruction. Then, parental strategies evolve towards communication, fostering awareness of traffic risks, and setting rules for safe road crossing (Shaw et al., 2015). Therefore, understanding parents' perceptions, attitudes, and beliefs of these evolving needs is crucial as it can influence their guidance and support for promoting safe pedestrian behaviours in children.

Parental perceptions can influence their supervision practices and the effectiveness of their guidance (Lam, 2001). Parents who underestimate their children's skills might be overly cautious, hindering their children's development of independent road crossing abilities (Yang et al. 2006). Conversely, parents with overly optimistic views might expose their children to unnecessary risks (Gielen et al, 2004; Plumert, 1995). While research exploring parents' perspectives of their children's road crossing behaviours dates back to studies like Van der Molen et al. (1983), which demonstrated that participating in a pedestrian training program improved parents' own road crossing behaviours and made them more likely to provide verbal instructions to their children, surprisingly few studies have comprehensively explored this topic in recent years. This relative lack of current research suggests a potential gap in the current literature and highlights the need for further investigation. Thus, improving parents' knowledge and understanding can positively affect their child's road safety. Soole et al. (2011) also found that parents believed in the preventability of road injuries and had specific age-related expectations for their children's independent road crossing abilities. Furthermore, Lam (2001) highlighted the importance of parental perception of the road environment in influencing safe road behaviour with their children. These studies suggest that parents' perspectives of their children's road crossing behaviours are shaped by a complex interplay of factors, including, children's developmental stage, parents' road safety knowledge and parents' perceptions of the road environment. Recognising this interplay can inform the development of future research activities related to children's safety as pedestrians (Morrongiello et al., 2009). By identifying parents' common concerns, knowledge gaps, and exploring parents' daily experiences, researchers can develop more effective interventions that align with parents and their child needs.

To comprehensively explore parents' perceptions of their children's road crossing behaviour, a literature search was conducted to identify existing relevant reviews studies including previous and ongoing systematic reviews or scoping reviews on this topic. Google scholar, PubMed, Cochrane Library, and PROSPERO databases were searched for this purpose. However, the search revealed a notable absence of existing systematic reviews or scoping reviews specifically addressing the perspectives, attitudes, and beliefs of parents regarding the road crossing behaviours of their TD children, highlighting the need for the present literature review. Thus, this systematic literature review aimed to establish a baseline understanding of typical pedestrian behaviours. It focused on examining the road crossing behaviours of TD children. By understanding the typical pedestrian skills in TD children, the unique challenges and strategies employed by parents and children with DCD and/or ADHD can be better identified. Knowledge, gained from the literature review, informed the development of the subsequent qualitative phase (Chapter 4). The review followed the guidelines recommended by the Joanna Briggs Institute (JBI) and has been reported according to PRISMATIC-ScR guidelines (Peters et al., 2020).

3.2 Methods

3.2.1 Objective

This review aimed to explore the perspectives, attitudes, and beliefs of parents regarding the road crossing behaviours of their typically developing children.

3.2.2 Inclusion and Exclusion Criteria

This literature review focused on studies that involved parents or caregivers of TD children. Studies were considered if they included parents or caregivers regardless of their own age, ethnicity, socioeconomic status, or educational background, as the focus was on their perspectives regarding their children's road crossing behaviours. The review centred on studies that investigated the perspectives, attitudes, or beliefs of parents or caregivers regarding their children's road crossing behaviours and pedestrian skills. Studies that explored parental concerns, knowledge, expectations, or strategies related to road safety and their children's independent mobility were also included. Studies investigating parents' perceptions regarding other modes of transportation such as cycling were excluded from this review. To be included, studies needed to be focused on TD children. TD children refer to children who have not been diagnosed with any developmental or cognitive impairments that could significantly impact their ability to learn and acquire road crossing skills (Johnston et al., 2012). In this context, studies that included parents of children aged between 6 to 17 years old were considered. This ensured a targeted exploration of parental perspectives relevant to different developmental stages where children gain increasing independence in road crossing and have a clearer understanding TD children's road crossing behaviours (Shaw et al., 2015).

To gain a comprehensive understanding of parental perspectives, this review prioritised studies employing qualitative research, survey methodology, and the qualitative part of mixed methods approaches. Therefore, the focus was on qualitative data of any included research design. Qualitative data facilitates the in-depth exploration of parental attitudes, beliefs, and experiences concerning their children's road crossing behaviours. The review focused on original research findings published in peer-reviewed journals, PhD theses, or dissertations. This excluded studies that summarised existing research such as review articles, commentaries, and editorials or those that lacked original data collection (unpublished studies). Additionally, quantitative studies, while valuable in other contexts, were not included in this review as the focus was on capturing the qualitative aspects of parental perspectives. Furthermore, the review only included studies published in the English language. This was due to resource constraints associated with translating and analysing studies in multiple languages. Focusing on the English language ensured efficient and thorough analysis within the available resources. Additionally, analysing studies in the English language ensured consistent interpretation of the findings and avoided potential biases introduced through translation, facilitating a more cohesive and accurate review process (Petticrew and Robert, 2008). By limiting the timeframe to studies published within the last 10 years (2014- 2024), the review ensured the findings reflected current knowledge and practices related to child pedestrian safety.

3.2.3 Search Strategy

This review employed a three-step search strategy. The initial search was conducted across three key online databases relevant to the topic PubMed, Medline and PsycINFO. This preliminary search utilised a combination of controlled vocabulary, such as MeSH terms and Thesaurus terms, and keywords related to the review's objective. Following the retrieval of relevant articles, the title, abstract, and index terms were analysed to identify additional keywords and refine the search strategy. The initial search was conducted on 06/05/2024 using PubMed database and the following terms:

(("Child"[Mesh] OR "Child Behavior"[Mesh] OR Child* OR "normal children" OR "typical children" OR "typically developing child*") AND ("Accidents, Traffic"[Mesh] OR "Safety"[Mesh] OR "Pedestrians"[Mesh] OR Road* OR "Road crossing" OR Roadside OR Street* OR Traffic accident*OR "Pedestrian safety" OR Pedestrian* OR "pedestrian skills" OR "Road safety")) AND ("parents perspectives" OR "parents experience" OR "parents beliefs" OR "parents attitudes "OR" parent perception")

However, the search retrieved only three unrelated articles. After refinement, the following search strategy was conducted in PubMed, Medline and PsycINFO to complete the second search:

(((Child*) AND (pedestrian)) OR ("road crossing*")) AND (parent*) AND ((y_10[Filter]) AND (fft[Filter]) AND (english[Filter]))

The final search on 16/08/2024 expanded this search strategy utilising the identified keywords and index terms from the previous search. Table 3.1 provides the keywords used for the search. This expanded search was conducted in PubMed, PsycINFO, Medline, Embase, Scopus and AMED.

Table 3.1 Keywords used for the literature search.

Children	Road Crossing	Parents perspectives
Child*	Pedestrian "road crossing*"	parent*

The reference lists of all retrieved articles were searched for additional sources. This step ensured a comprehensive capture of relevant studies. While a comprehensive search was the goal, this review excluded grey literature sources such as governmental road safety websites. The focus of this review was on capturing in-depth parental perspectives, and these websites are likely to provide broader road safety information which was not the specific focus of this review. However, PhD theses and MSc dissertations, which can offer valuable insights, were included. Ethos and ProQuest were used for this purpose.

3.2.4 Source Selection

A systematic search of eight databases (Ethos, ProQuest, PubMed, PsycINFO, MEDLINE, Embase, Scopus, and AMED) was conducted using the described pre-specified search strategy. Retrieved records were imported into EndNote reference management software. Duplicate records were removed. A two-stage screening process was employed, and the selection of studies was conducted following the pre-specified inclusion criteria outlined previously. Initially, titles and abstracts were screened against the inclusion and exclusion criteria. Studies unrelated to children’s road crossing behaviour were excluded. Full-text screening was conducted independently by two reviewers (RF and AQ) to verify eligibility based on the predetermined criteria. Disagreements were resolved through discussion and, if necessary, consultation with a third reviewer (CP). Studies that primarily reported data from children, interventions, or quantitative methods were excluded. Additionally, reference lists of included studies were hand-searched for potential additional sources. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram was utilised to outline the study selection process at each stage (Haddaway et al., 2020).

3.2.5 Sources Quality Assessment

While this literature review followed the JBI scoping review guidelines to ensure rigour, the JBI framework does not specify a particular tool for critical appraisal and is not a core component of scoping reviews (Peters et al., 2020), however incorporating critical appraisal can offer significant advantages (Critical Appraisal Skills Programme, 2023). Additionally, While JBI critical appraisal tools provide a structured framework for assessing the quality of research (Moola et al., 2017), CASP offers greater flexibility in commenting on specific strengths and weaknesses in the methodology and reporting of qualitative research (CASP, 2023). This flexibility allowed for a better evaluation of the qualitative studies included in this review, enabling a deeper understanding of their strengths and limitations. By systematically assessing the methodological rigour of included studies, researchers can gain a deeper understanding of the evidence base (Petticrew & Roberts, 2006). This process helps identify strengths and weaknesses in the existing research, thereby informing the interpretation of findings and highlighting areas where further research is needed (CASP, 2023). Furthermore, critical appraisal can enhance the overall credibility of the literature review by demonstrating a rigorous approach to evaluating the quality of the included studies (CASP, 2023). To enhance the understanding of the methodological rigour of the included studies in the current review, critical appraisal was conducted. This involved assessing the quality of research designs and reporting using the CASP checklist tools (CASP, 2023).

3.2.6 Data Extraction

A data extraction form was developed to systematically capture key information from each included study. This form encompassed study characteristics such as title, citation, location, participant demographics, study design, objectives, sample size, and primary findings. This form was piloted on two included studies to assess its effectiveness and identify necessary refinements. Following necessary refinements based on the pilot results, the final form was subsequently used to extract data from all included studies. Given the focused scope of this review, data extraction was conducted by a single researcher to maintain consistency and depth in data analysis. To enhance reliability, potential discrepancies or ambiguities were resolved through consultation with the supervisory team. The completed data extraction forms are presented in Appendix 3.1 and Appendix 3.2.

3.3 Results

3.3.1 Source Selection Results

The database searches yielded 727 records (Ethos: 3, ProQuest: 13, PubMed: 122, PsycINFO: 81, MEDLINE: 152, Embase: 205, Scopus: 150, AMED: 1). After 117 duplicate records were removed, the titles of 610 remaining studies were screened, studies focusing on road environments and irrelevant to road crossing were excluded. The remaining 379 papers underwent abstract screening using the inclusion and exclusion criteria. This resulted in 116 papers that were retrieved and assessed for eligibility, on full text screening 110 papers were excluded as they were not focused on parents, but instead focused on collecting data from children or focused on interventions, quantitative methods and experiments. Reference list screening identified three additional potential studies. However, two were excluded: one was a conference abstract, and the other did not focus on parents. Therefore, a total of seven studies were included in this review. The PRISMA flow diagram (Figure 3.1) outlines the study selection process at each stage (Haddaway et al., 2020). However. one study was initially included but subsequently excluded during data extraction as it primarily relied on quantitative data collected through a questionnaire, rather than qualitative data. Although the study included a qualitative component (interviews), the primary focus was on the development of the questionnaire based on these interviews. Thus, six studies were included for the further analysis.

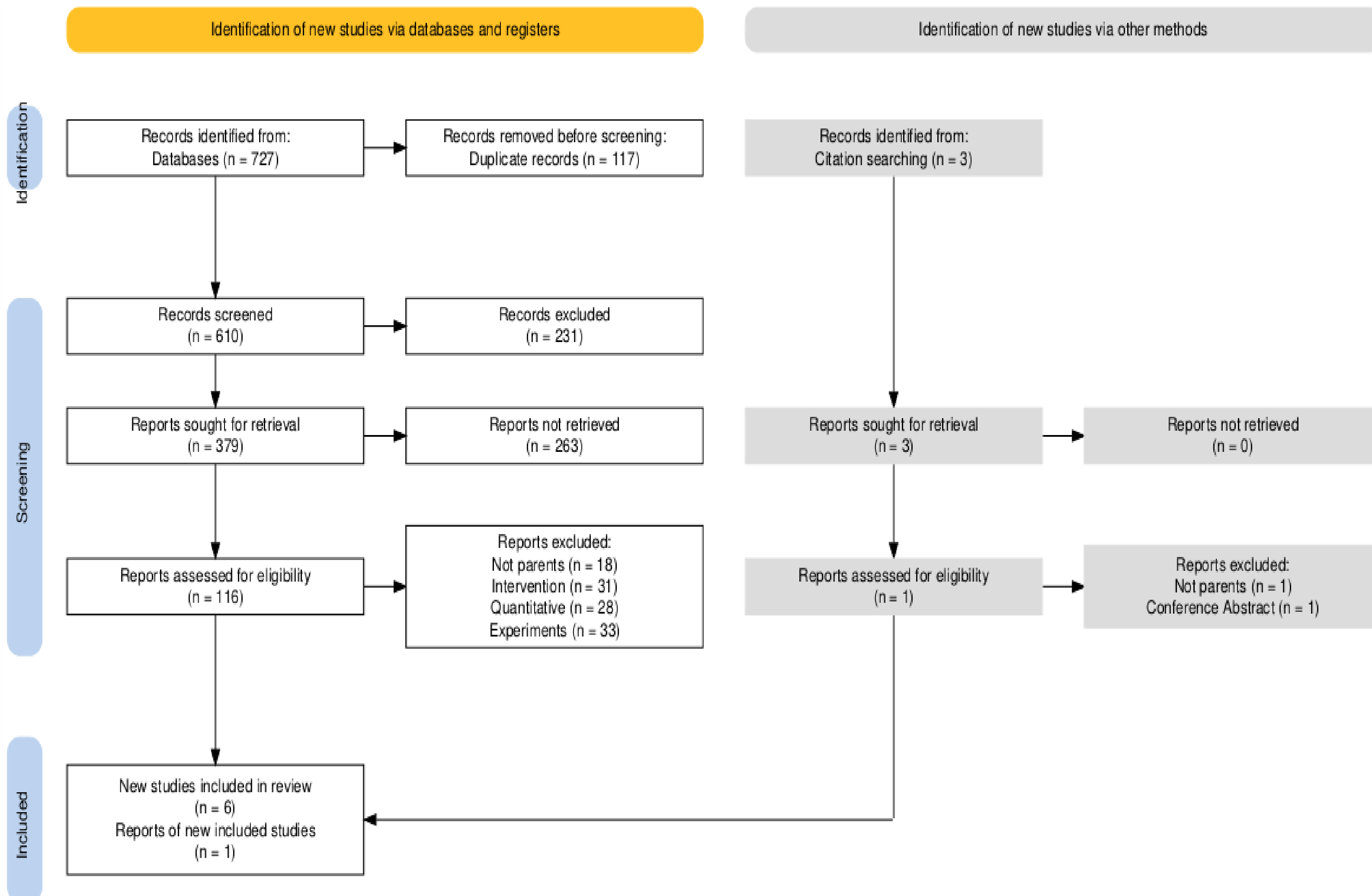


Figure 3.1. PRISMA flow diagram.

3.3.2 Study Characteristics

The characteristics of the included studies are presented in Table 3.2. The studies varied in terms of geographical location, study design, sample size, and focus. While most studies employed qualitative methods, one study combined both quantitative and qualitative approaches. For the purpose of this review, only the qualitative component of this study was included. The sample populations included parents and, in some cases, children, with a focus on their experiences and perspectives related to school travel safety and active transportation.

Table 3.2: General characteristics of the included studies

Citation	Country	Method	Sample Size	Sample Characteristics	Focus
Al-Najjar et al., 2022	Jordan	Focus Group Discussion	10 mothers and a group of 7 fathers and 2 grandfathers	Parents of refugee school children aged 6 to 15 years form Jerash camp.	School travel safety in refugee camps.
Atrooshi, 2017	Canada	Semi-Structured Interview	16 parents of students	Parents of students from elementary school.	Parental perceptions and facilitators for promoting active school travel.
Swain et al., 2024	Australia	Survey	91 parents of students	Parents of and children aged 12 – 18 years from two schools in Australia	Parental and child perceptions of school travel including modes, safety, and infrastructure.
Nakanishi et al, 2017	Australia	Semi-Structured Interview	99 parents' interviews (Sydney: 24, Canberra: 57, Melbourne: 18)	Parents of children from Sydney, Canberra and Melbourne.	Parental concerns about school travel safety.
Teller, 2018	US	Interviews	45 parents of schoolchildren	Parents of children who participated in a walking school bus program.	Parent and child attitudes and opinions on a walking school bus.
Poku-Boansi et al., 2019	Ghana	Semi-Structured Interview & questionnaire	370 parents and their children, 53 teachers	Pupils aged 6–15 years and their parents, teachers.	School children's Road Safety Risks in Accra, Ghana's capital.

US: United States

3.3.3 Quality Assessment Results

The quality of the included studies was evaluated using the CASP qualitative checklist (CASP, 2023). CASP supports the quality evaluation of qualitative, survey and mixed methods studies serving the purpose of this review. The CASP checklist was selected for critical appraisal due to its suitability for evaluating a wide range of study designs and its user-friendly format (CASP, 2023). CASP emphasises key methodological considerations, enabling a comprehensive assessment of study quality and informing subsequent interpretations and research directions (CASP, 2023). Although CASP is not intended to provide an overall rating of the quality of studies (CASP, 2023), providing the rating of the included qualitative, survey, and mixed methods studies can still assist in presenting and evaluating the overall quality of research. Therefore, the quality of the studies were categorised and rated as high (meeting more than 70% of criteria), moderate (50-70%) and weak (meeting less than 50% of criteria). It is important to note that no paper was excluded based on the assessed quality due to the aim of exploration and mapping out of the topic.

As a result of applying this procedure, the overall quality of the included studies was generally high based on CASP ratings. As shown in the Table 3.2, two studies out of six had high quality on all ten aspects of the CASP (CASP, 2023). There were four high quality studies with unclear reported relationships between researchers and participants (Nakanishi et al., 2017; Teller, 2018; Poku-Boansi et al., 2019; and Swain et al., 2024). While minor methodological limitations were identified in several studies, these did not substantially compromise the overall quality of the evidence base.

Table 3.2: CASP appraisal results of the studies. Appraisal questions: 1. Was there a clear statement of the aims of the research?; 2. Is a qualitative methodology appropriate?; 3. Was the research design appropriate to address the aims of the research?; 4. Was the recruitment strategy appropriate to the aims of the research?; 5. Was the data collected in a way that addressed the research issue?; 6. Has the relationship between researcher and participants been adequately considered?; 7. Have ethical issues been taken into consideration?; 8. Was the data analysis sufficiently rigorous?; 9. Is there a clear statement of findings?; 10. How valuable is the research?; Y: Yes; C: Can’t tell; N: No

Citation	A. Study Validity						B. The results			C. Local implication	Total
	1	2	3	4	5	6	7	8	9	10	
Al-Najjar et al., 2022	Y	Y	Y	Y	Y	Y	Y	Y	Y	By exploring parental perspectives and identifying key factors influencing children's exposure to hazards, this study contributes to a deeper understanding of this critical issue. The findings can inform the development of targeted interventions to improve school travel safety in similar contexts. While the study provides a foundation for future research, it offers practical recommendations for enhancing the safety of school routes, such as improving infrastructure and implementing educational programs.	10/10
Atrooshi, 2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	The research offers valuable insights into parental perspectives on Walking School Buses (WSBs). By delving into parents' experiences and attitudes, the study contributes to a deeper understanding of the factors supporting children's physical activity and addressing safety concerns.	10/10
Swain et al., 2024	Y	Y	Y	Y	Y	C	Y	Y	Y	The identification of road safety concerns as a primary barrier to active travel, coupled with specific recommendations for infrastructure improvements, directly addresses a local issue. By providing data on parents' and children's perceptions of safe routes, the research can inform targeted interventions to enhance the walking and cycling environment.	09/10
Nakanishi et al., 2017	Y	Y	Y	Y	Y	C	Y	Y	Y	Theoretical contribution: The research contributes to the understanding of the complex relationships between individual, environmental, and societal factors influencing travel behavior. The research offers valuable contributions to the field of transport and has the potential to inform policies aimed at promoting active travel among children.	09/10
Teller, 2018	Y	Y	Y	Y	Y	C	Y	Y	Y	The research offers valuable contributions to the field of active transportation and has the potential to inform the development of effective WSB programs.	09/10
Poku-Boansi et al., 2019	Y	Y	Y	Y	Y	C	Y	Y	Y	The study contributes to the growing body of knowledge on child travel safety in developing countries.	09/10

3.3.4 Themes

Three main themes emerged based on a narrative analysis approach recommended by the Cochrane Consumers and Communication Review Group (Ryan, 2019): parental perceptions of child pedestrian safety; parental attitudes towards their children walking; and the influence of the built environment. To identify these themes, data from each study were examined to uncover recurring patterns and concepts related to parental perspectives and behaviours.

3.3.4.1 Parental Perceptions of Child Pedestrian Safety

Parental concerns about child pedestrian safety emerged as a central theme across the included studies. Traffic safety consistently ranked as a primary concern, with studies highlighting traffic congestion, speeding drivers (Al-Najjar et al., 2022), and the absence of safe crossings (Poku-Boansi et al., 2019) as significant contributors to parental anxiety. Beyond traffic, concerns encompassed factors such as crime, stranger danger, and inadequate infrastructure (Atrooshi, 2017; Teller, 2018; Swain et al., 2024). This theme highlights the perception of the parents with regards to child pedestrian safety. Al-Najjar et al. (2022) identified traffic congestion and speeding drivers as primary hazards, significantly impacting parents' perceptions of safety. The risk of crime, including harassment, bullying, and kidnapping or stranger danger, further heightened these concerns (Teller, 2018; Al-Najjar et al., 2022). While the study by Al-Najjar et al. (2022) provides valuable insights, it is important to note that the focus on refugee camps may limit the generalisability of findings to other contexts (Al-Najjar et al., 2022). That said, similar findings were reported by Poku-Boansi et al. (2019), who identified that parents and guardians expressed significant concerns about the safety of children traveling to and from school in Ghana. This is believed to be due to the absence of designated pedestrian crossings and traffic wardens near schools which exacerbated these worries (Poku-Boansi et al., 2019). Children's risky behaviours, such as playing while crossing roads, being distracted and failing to look both ways, compounded the problem (Poku-Boansi et al., 2019). Overcrowding and speeding public transport vehicles further increased perceptions of safety risks (Poku-Boansi et al., 2019). Unaccompanied children were identified as particularly vulnerable to traffic accidents, while weak enforcement of traffic regulations and the poor condition of school buses contributed to perceptions of unsafe conditions (Poku-Boansi et al., 2019).

Beyond traffic safety, parents expressed concerns about the broader environment. Atrooshi (2017) and Teller (2018) highlighted the significance of weather conditions, and poorly designed roads in shaping parental perceptions of risk. For example, Teller (2018) stated that concerns related to extreme weather such as cold weather were presented and this could be related to a decrease in children's active transportation. Although these studies focused on a walking to school program, parents suggested that the broader environment could exacerbate the problem and increase the risk of collisions (Atrooshi, 2017; Teller, 2018). In the study by Swain et al. (2024) conducted in Australia, many parents expressed a preference for walking as well as cycling as a mode of transport for their children due to the associated health benefits. However, safety concerns, including traffic hazards and a lack of suitable infrastructure, significantly limited the appeal of these options (Swain et al., 2024). Moreover, parents' biggest concerns for allowing their children to walk in communities in several different cities in Australia were pedestrian safety including fear of traffic and stranger danger (Nakanishi et al., 2017).

These studies collectively emphasise the complex interplay of factors influencing parental perceptions towards child pedestrian safety. Traffic safety, crime, and environmental conditions emerged as key concerns. These factors substantially influenced parents' decisions regarding their children's mode of transportation, with safety often outweighing the desire for independent community mobility.

3.3.4.2 Parents' Attitudes Towards Their Children Walking Independently

Parental attitudes towards child pedestrian safety were predominantly characterised by concern and caution. The study by Al-Najjar et al (2022) offered a unique perspective on parental attitudes within a challenging context, specifically Jordanian refugee camps. The findings highlight the heightened safety concerns among refugee camp residents, with traffic collisions, crime, and exposure to animals as primary worries (Al-Najjar et al., 2022). While the study found that mothers were more concerned about crime, fathers prioritised traffic safety (Al-Najjar et al., 2022), their attitude towards their children's safety were the same, reflecting the nature of child pedestrians in refugee camps. Parents felt a free bus service, better pedestrian infrastructure and education programs would significantly improve safety (Al-Najjar et al., 2022). It can be inferred that children were limited to walking as a mode of transportation, even though their parents expressed safety concerns. Similarly, parents in urban Ghana emphasised the dominance of walking as a mode of transport, coupled with safety concerns related to traffic and infrastructure, indirectly reflecting parental attitudes (Poku-Boansi et al., 2019). While many parents recognised the potential positive impacts of walking for their children's health and well-being, safety considerations often took precedence. Concerns about traffic hazards, interacting with adult strangers, and weather conditions emerged as significant barriers to walking, as evidenced in the studies by Atrooshi (2017) and Teller (2018). These factors contributed to a cautious approach among parents from Canada and the US, with many opting for alternative transportation modes to ensure their children's safety.

Across all studies, parents' attitudes towards child pedestrian safety were consistently shaped by factors primarily focused on safety concerns. While the specific manifestations of these concerns varied across different contexts, a common thread emerged in the prioritisation of child protection over promoting independent community mobility.

Studies conducted in diverse settings, including Jordanian refugee camps (Al-Najjar et al., 2022), urban Ghana (Poku-Boansi et al., 2019), North America (Atrooshi, 2017; Teller, 2018), and Australia (Swain et al., 2024; Nakanishi et al., 2017), converged in highlighting the significant influence of traffic safety on parental perceptions. The fear of accidents, coupled with concerns about crime and other hazards, created a cautious approach among parents, often leading to a reliance on car-based transportation.

In contrast, parents in refugee camps and urban areas with limited resources and infrastructure leading to a reliance on walking, exhibited heightened levels of anxiety, reflecting the direct impact of environmental factors on their perceptions of safety (Al-Najjar et al., 2022; Poku-Boansi et al., 2019). These findings underscore the importance of parents' attitude impacting the transportation preference for their children and addressing the physical dimensions of child pedestrian safety to encourage a safer and more active mode of travel.

3.3.4.3The Influence of The Built Environment

The built environment plays a pivotal role in shaping parental attitudes and behaviours regarding child pedestrian safety. Included studies consistently demonstrated that well-designed urban spaces can significantly influence parental perceptions of risk and encourage children to walk independently.

Traffic environment was mentioned consistently. Studies have shown that high traffic volumes, speeding drivers, and a lack of traffic calming measures contribute to increased parental anxiety about child pedestrian safety (Atrooshi, 2017; Nakanishi et al., 2017; Teller, 2018; Poku-Boansi et al., 2019; Al-Najjar et al., 2022; Swain et al., 2024). Conversely, areas with lower traffic volumes and effective speed management strategies are more likely to be perceived as safe for children to walk (Nakanishi et al., 2017).

Furthermore, the presence of well-maintained sidewalks, clearly marked crosswalks, and traffic signals are crucial in fostering parental confidence in child pedestrian safety (Poku-Boansi et al., 2019; Swain et al., 2024; Nakanishi et al., 2017). In Australia, parental attitudes towards child pedestrian safety were significantly influenced by the perceived safety of the surrounding environment. The studies by Swain et al. (2024) and Nakanishi et al. (2017) underscored the importance of well-designed urban spaces in shaping parental decisions about their children's mode of transport. Parents were more likely to permit independent travel in areas with safe pedestrian infrastructure, such as well-maintained sidewalks, designated crossing points, and traffic calming measures (Nakanishi et al., 2017). Conversely, the absence of such infrastructure can significantly deter parents from allowing their children to walk independently (Al-Najjar et al., 2022). Moreover, concerns about traffic congestion, speeding drivers, and a lack of safe routes fostered a culture of caution and reliance on car-based transportation (Swain et al., 2024; Nakanishi et al., 2017). However, the studies revealed that in contexts with better-developed infrastructure and lower levels of crime, such as Australia, parents were more inclined to allow their children to walk or cycle (Swain et al., 2024; Nakanishi et al., 2017).

These findings highlight the critical role of the built environment in influencing parental attitudes and behaviours regarding child pedestrian safety.

The overall design of neighbourhoods and how land is used influence parental perceptions of safety. Mixed-use developments that combine residential, commercial, and recreational spaces within walking distance can create a more pedestrian-friendly environment (Nakanishi et al., 2017). On the other hand, sprawling urban environments with car-oriented infrastructure may contribute to increased parental reliance on driving (Swain et al., 2024). Moreover, the presence of parks, playgrounds, and other green spaces can enhance the appeal of walking and cycling for both children and parents. These amenities can create a more inviting and safer environment for pedestrians, fostering a positive parental attitude towards active travel (Nakanishi et al., 2017; Swain et al., 2024).

In conclusion, the built environment is a critical factor shaping parental attitudes towards child pedestrian safety. By creating safe, pedestrian-friendly communities, policymakers and urban planners can encourage more parents to allow their children to walk to school, thereby promoting physical activity and reducing reliance on less active mode of transportation such as cars.

3.3.5 Parental Decision-Making and Child Pedestrian Safety

Considering the identified themes, the parents' decision to allow their children to travel independently or not depends on the balance of multiple factors. Understanding how these factors influence parental decisions regarding their children's pedestrian safety is crucial for developing effective interventions to promote safe independent community mobility. To this end, a novel Parental Road Crossing Decision-Making Model (PRCDM) is proposed. The PRCDM posits that parental decisions are shaped by a complex interplay of core factors, moderating factors, parental attitudes and beliefs, and ultimately, a decision output. Core factors include perceived child vulnerability and safety concerns. While child vulnerability encompasses age, developmental stage, and awareness of traffic rules, safety concerns include traffic hazards, children's unpredictable behaviour, and stranger danger (Atrooshi, 2017; Teller, 2018; Swain et al., 2024). Another important aspect that influences parents' decision in relation to their children's pedestrian safety is moderating factors. From a parent's perspective, moderating factors comprise parents perceived benefits of active travel, such as increased physical activity and social interaction, as well as environmental factors such as infrastructure, distance, and traffic enforcement process (Saunders et al., 2013). Parental attitudes and beliefs, including risk tolerance and perceived age for independent travel, further shape the decision-making process (Gielen et al., 2004). The final decision output reflects parental permission for independent travel, accompanied travel, or restrictions on independent mobility. For a visual representation of the PRCDM and its key components, please refer to Figure 3.2. The PRCDM highlights the interconnectedness of these factors and emphasises the dynamic nature of parental decision-making. By examining how these elements interact, we can gain valuable insights into the barriers and opportunities for promoting child pedestrian safety. For example, while parents may recognise the benefits of walking, safety concerns often outweigh these considerations (Atrooshi, 2017; Nakanishi et al., 2017; Teller, 2018; Poku-Boansi et al., 2019; Al-Najjar et al., 2022; Swain et al., 2024;). This leads to a reliance on alternative modes of transportation as a decision made by parents to mitigate the risk.

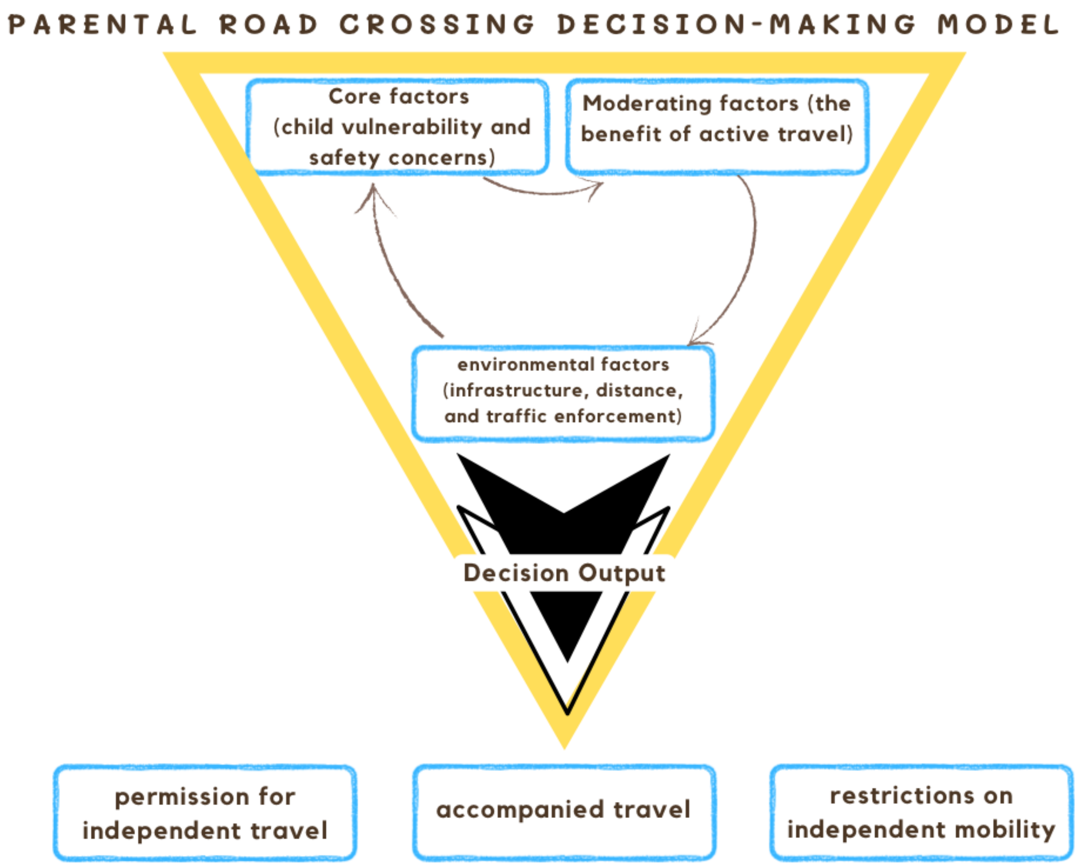


Figure 3.2. Parental Road Crossing Decision-Making Model diagram.

3.4 Discussion

A comprehensive literature search was conducted across multiple databases, yielding a substantial initial dataset of 727 records. Following a screening process involving title, abstract, and full-text reviews, a total of six studies met the inclusion criteria for this review. These studies primarily employed qualitative methodologies to explore parental perspectives of child pedestrian safety. It is important to note that while some studies included quantitative components, the focus of this review was on qualitative data to gain a deeper understanding of parental attitudes and experiences. Parental perceptions of child pedestrian safety were predominantly shaped by concerns about traffic safety, crime, and environmental factors. The studies by Al-Najjar et al. (2022), Poku-Boansi et al. (2019), Atrooshi (2017), Teller (2018), Swain et al. (2024), and Nakanishi et al. (2017) consistently highlighted the importance of safety as a primary concern among parents. However, variations in parental attitudes were evident across different contexts, with factors such as the level of urban development, traffic congestion, and crime rates influencing parental perceptions of risk (Atrooshi, 2017; Nakanishi et al., 2017; Teller, 2018; Poku-Boansi et al., 2019; Al-Najjar et al., 2022; Swain et al., 2024;). While parents expressed a desire for their children to be physically active, the prevailing attitude was prioritisation of safety. This often led to a reliance on other modes of transportation such as car-based transportation, even for short distances (Atrooshi, 2017; Nakanishi et al., 2017; Teller, 2018; Poku-Boansi et al., 2019; Al-Najjar et al., 2022; Swain et al., 2024;). The lack of pedestrian-friendly infrastructure and traffic calming measures further reinforced these attitudes. Therefore, the built environment also played a critical role in shaping parental attitudes and behaviours. Well-designed urban spaces with safe pedestrian infrastructure were associated with greater parental confidence in allowing children to walk independently (Nakanishi et al., 2017). Conversely, areas with heavy traffic, poor road conditions, and limited sidewalks contributed to increased parental anxiety and reliance on car-based transportation (Atrooshi, 2017; Teller, 2018; Poku-Boansi et al., 2019; Al-Najjar et al., 2022; Swain et al., 2024).

Parents increased anxiety and conservative attitudes towards their children’s pedestrian safety can be justified by the vulnerability of their children as pedestrians. The heightened risk faced by TD children as pedestrians can be attributed to the complex demands of safe road crossings, influenced by environmental conditions and the limited ability of children to safely execute the road crossing task (Schwebel et al., 2014). For safe road crossing execution, a child requires skills such as the ability to assess traffic conditions, make rapid decisions, and execute appropriate actions (Schwebel et al., 2018). Children's developmental limitations in these areas are cited as one of the main reasons for poor pedestrian performance amongst children (Schwebel et al., 2016: Tapiro et al., 2014).

While the current body of research on pedestrian safety primarily focuses on TD children, emerging evidence highlights the specific challenges faced by children with DCD and with ADHD. Although direct comparisons are limited due to the relatively small number of studies focusing on these populations, research on children with DCD and/or ADHD emphasise the crucial role of parental perceptions in shaping their child pedestrian safety behaviours (Brook and Boaz, 2006; Wilmut and Purcell, 2020). Current studies found that children with DCD and/or ADHD are at higher risk of pedestrian injuries and accidents when compared with TD children (Stavrinos et al., 2011; Wilmut and Purcell, 2021; Tabibi et al., 2022). However, there are limited studies exploring the concerns of parents of children with DCD and/or ADHD. Therefore, parents' perspectives, attitudes and experiences of children with DCD and/or ADHD require further investigation for a deeper understanding of parents' concerns and their impact on children's pedestrian behaviours. This literature review provides a contextual backdrop for exploring the unique challenges and perspectives of parents of children with DCD and/or ADHD.

3.5 Conclusion

This review has examined parents' perceptions and attitudes towards child pedestrian safety in TD children, highlighting the complex interplay between safety concerns, environmental factors, and child pedestrian behaviours. Parents' perceptions of children's pedestrian safety were predominantly shaped by concerns about traffic safety, crime, and the broader environment. While parents acknowledged the potential benefits of walking for their children's health and well-being, safety considerations often took precedence. The built environment emerged as a critical factor influencing parents' attitudes and behaviours. Well-designed urban spaces with safe pedestrian infrastructure were associated with greater parental confidence in allowing children to walk independently. Conversely, areas with heavy traffic, poor road conditions, and limited sidewalks contributed to increased parental anxiety and reliance on other modes of transportation. These findings align with previous research highlighting the importance of safety concerns among parents of TD children (Schwebel et al., 2014, 2018; Tapiro et al., 2014). While this review has focused on the experiences of parents with TD children, it is crucial to acknowledge the unique challenges faced by parents of children with DCD and/or ADHD. There are limited studies exploring the concerns of parents of children with DCD and/or ADHD regarding pedestrian safety (Brook and Boaz, 2006; Wilmut and Purcell, 2020) and this area requires further investigation. Therefore, this review focuses initially on the broader context of parental perceptions of child pedestrian safety within the typically developing population. This foundational understanding is crucial for contextualising the specific challenges faced by parents of children with DCD and/or ADHD, which are explored in detail in the subsequent chapter. This two-part approach allows for a more comprehensive understanding of the topic as parents of children with DCD and/or ADHD are likely to encounter heightened safety concerns and require tailored support to navigate the complexities of pedestrian safety. The subsequent chapter (Chapter 4) will delve deeper into these experiences, providing valuable insights into the specific needs and perspectives of this population.

4 Chapter Four: Roadside Experiences of Parents of Children with DCD and/or ADHD

This chapter has been published in Frontiers in human neuroscience:

Falemban, R., Wilmut, K., Hurst, H., & Purcell, C. (2024). Roadside experiences of parents of children with developmental coordination disorder and/or attention deficit hyperactivity disorder. Frontiers in human neuroscience, 18, 1339043.

4.1 Introduction

While the risks associated with DCD and/or ADHD in relation to pedestrian safety are increasingly recognised, there is a gap in our understanding of parental perspectives on this issue. Parents, as primary caregivers, offer a valuable perspective on the specific challenges and concerns related to their children's road safety. Their firsthand observations of their children's behaviour and interactions with the environment provide valuable insights into the impact of DCD and/or ADHD on pedestrian skills. Parental perspectives offer a rich and nuanced understanding of the challenges faced by children with DCD and/or ADHD in real-world road safety situations. Research exploring parental perspectives on this issue remains limited. Using a questionnaire, Brook and Boaz (2006) found that parents of adolescents, aged 16 to 17 years, with ADHD expressed heightened concerns about their child's involvement in road accidents compared to parents of TD children. To mitigate these risks, parents often employed strategies such as increased supervision, avoidance of dangerous play, and the use of medication to enhance attention and behaviours (Brook and Boaz, 2006).

Moreover, using a quantitative parent-reported questionnaire, Wilmut and Purcell (2020) identified similar results among parents of children with DCD. Parents indicated that their children with DCD displayed reduced attention while crossing roads, which may be attributed to underlying perceptual-motor difficulties, leading to a lack of confidence and increased risk-taking behaviours (Wilmut and Purcell, 2020). Additionally, the co-occurrence of ADHD characteristics in children with DCD was associated with further declines in attention and an increase in risk-taking behaviours (Wilmut and Purcell, 2020). While these studies provide insights into parental perspectives on the challenges faced by children with DCD and/or ADHD in relation to road safety, a more comprehensive investigation is needed to fully understand parental experiences and concerns. Therefore, the aim of Phase one of this thesis was to explore parents' experiences of children with DCD and/or ADHD to obtain a deeper understanding of the elevated risk of pedestrian injuries among these children.

4.2 Methods

4.2.1 Aim and Questions

Phase one of the thesis aimed to investigate the experiences of parents of children with DCD and/or ADHD regarding pedestrian safety. To achieve this goal, the following research questions were explored.

- What are the perspectives of parents of children with DCD and/or ADHD in relation to their children's ability to execute a safe road crossing?
- What, if anything, are parents of children with DCD and/or ADHD concerned about regarding their children's pedestrian safety?
- How do parents of children with DCD and/or ADHD help to prevent or minimise their child's involvement in pedestrian injuries?

4.2.2 Reflexivity

This research employed a reflexive thematic analysis approach (Braun and Clarke, 2023) to explore the experiences of parents of children with DCD and/or ADHD. Reflexive thematic analysis is an interpretive approach that prioritises researcher self-awareness and acknowledges the subjective nature of knowledge construction (Braun and Clarke, 2023). Therefore, the researchers' personal experiences and perspectives shaped the study's design and interpretation. Post-interview notes were maintained (see appendix 4.1 for an example) and played an important role during the reflective analysis in assisting an understanding of the participants experiences and to reflect on personal biases while acting as valuable reference points for further analysis. Furthermore, regular discussions with the supervisory team helped to ensure the management of opinions within the research process and enrich insights. Collaboration and reflection were essential components of the research process, shaping every stage from initial design to final analysis and writing.

4.2.3 Recruitment

Recruitment for this study was conducted between January and July 2022. As detailed in Chapter 2, a purposive sampling strategy was employed to recruit parents of children with DCD and/or ADHD. This ensured that the participants had relevant knowledge and experience to provide valuable insights (Etikan et al, 2016). Recruitment was conducted through social media platforms and organisations working with children with these conditions. Participants were provided with information sheets and screening tools before their involvement. More information regarding the recruitment procedure was provided in Chapter 2 (Common Methodology).

4.2.4 Screening Tools

As detailed in Chapter 2, all parents/participants provided written informed consent and completed the DCDQ (Wilson et al., 2009) and the SNAP-IV (Hall et al., 2020). These measures were used to screen participants for DCD and ADHD to confirm the parents' reported diagnosis, ensuring that only parents of children meeting the diagnostic criteria outlined in the DSM-5 (APA, 2013) were included in the study (see Table 4.1 for specific inclusion and exclusion criteria). Following confirmation of DCD and/or ADHD diagnoses based on the pre-interview screening tools, interviews were conducted online via Microsoft Teams at a mutually convenient time.

Table 4.1 Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
Parents of children with DCD and/or ADHD who: • were aged 7 to17 years • had DCD and/or ADHD characteristics based on the DCDQ and SNAP-IV • lived in the UK	Parents of children who: • were less than 7 years of age or greater than 17 years of age • had no DCD and/or ADHD characteristics based on the DCDQ and SNAP-IV • were unable to provide informed consent

• navigated the community with their children • were able to communicate in English • were able to provide informed consent	• were unable to access a computer and/or the internet.

4.2.5 Procedure

Semi-structured interviews were conducted online via Microsoft Teams. The semi-structured format was specifically chosen to facilitate a deep and flexible exploration of parental experiences, balancing the need for consistency across interviews with the opportunity for emergent themes (DeJonckheere & Vaughn, 2019). The interview process was designed to be conversational and participant-led, allowing parents to elaborate on the main aspects of their experiences (Kvale & Brinkmann, 2009). While conducted using a pre-determined, topic-based interview guide, the order and wording of questions were intentionally adapted in real-time to pursue rich lines of inquiry introduced by the participants, reflecting a flexible, co-constructed approach (Braun & Clarke, 2022). This fluidity was essential to capture the nuanced and unique challenges faced by parents of children with DCD and/or ADHD at the roadside. Parents were asked to find a quiet space with a stable internet connection to facilitate a smooth interview process. Interviews lasted approximately 60 minutes. The interview questions were developed through an iterative process before the interviews were conducted. Initially, the researcher developed interview questions based on a review of existing literature on TD children (Chapter 3) and children with DCD and/or ADHD as pedestrians (Chapter 5). Drawing on the initial literature review, the interview questions were refined and expanded through further discussion among the researcher and the supervisory team. Piloting the interview questions ensured their clarity, comprehensibility, and effectiveness in eliciting the desired information from parents or participants. The piloting phase involved conducting interviews with three participants similar to the target population in terms of their roles and experiences as parents. The feedback from the pilot interviews were used to refine and finalise the interview questions, for example rewording questions, ensuring their clarity and relevance to the research aims. The final interview questions were developed through a collaborative process involving multiple revisions and discussions between the researcher and the supervisory team. Once consensus regarding the final set of questions was reached, the questions were used to guide the semi-structured interview. The full semi-structured interview questions are provided in the appendix 4.2.

4.2.6 Coding and Data Analysis

A reflexive approach was used to analyse the interview data. Reflexive thematic analysis prioritises researcher reflexivity, allowing for a dynamic interaction between the researcher and the data to identify and interpret patterns or themes. To ensure data accuracy and completeness, all interviews were digitally audio-recorded and transcribed verbatim using Microsoft Teams built-in audio recording and transcription features. The researcher actively listened to the audio recordings to ensure accurate transcriptions. To enhance the trustworthiness of the findings, member checking was conducted. Parents were invited to review their respective transcripts and provide feedback on the accuracy and completeness of the recorded information. This approach facilitated a comprehensive analysis of the data, allowing for the identification of subtle themes.

Thematic Analysis is a widely used approach to find patterns and themes within qualitative data (Braun and Clarke, 2023). Therefore, it was selected as the method of analysis. However, it is important to note that inconsistencies and less cohesive themes can be generated if not conducted rigorously as it is considered a flexible method (Holloway & Todres, 2003). To address this, a reflexive thematic analysis was conducted, following the six phases outlined by Braun and Clarke (2023), while acknowledging the plurality of thematic analysis and recognising its iterative process rather than strictly linear (Braun and Clarke, 2023). The analysis commenced with data familiarisation including an in-depth immersion in the data and reviewing it. The familiarisation phase entailed multiple readings and re-reading of the transcripts and listening to the audio recordings to develop a deep understanding of the participants' experiences and perspectives alongside making initial notes and recording key ideas and emerging patterns. During the coding phase, the data was organised, and descriptive codes were assigned to encapsulate essential elements and meaningful information. Subsequently, personal stance was regularly examined and refined in relation to the emerging insights from the data. This was achieved through reflective discussions between the researcher and the supervisory team. This step involved a rigorous and iterative process to ensure that the codes accurately captured the nuances and complexities of the data. The third phase focused on identifying and developing overarching themes by grouping together related codes. These themes were refined by collating relevant data extracts associated with each possible theme to ensure their accuracy and alignment with the overall dataset. A thematic map was created to visually represent the relationships between codes and themes, facilitating a deeper understanding of the data. A copy of handwritten codes and maps are provided in the appendix 4.3. This visual representation facilitated discussions and iterative refinement of the themes including extensive re-coding and re-mapping until a consensus was reached. In the fifth phase, each theme was defined and named, providing a clear and concise representation of the underlying patterns within the data with interpretative explanations that shed light on the specificities within each theme and the overarching narrative that emerged from the data. The final stage involved the coherent synthesis of the findings, offering a clear and insightful interpretation of the themes resulting from the experiences of the parents of children with DCD and/or ADHD.

4.3 Findings

A total of 14 parents of children with DCD and/or ADHD were recruited and interviewed. This included parents of five children with ADHD, three children with DCD, and six children with both conditions. The majority of the participants children were male, accounting for 71% of the sample, while 29% were female. Participants' children demographics are summarised in Table 4.2.

Table 4.2 Demographics of the participants' children.

Primary Condition	Gender of the child		Children's age range	Total number of participants
	Male	Female		
ADHD	3	2	7- 13	5
DCD	1	2	10 - 17	3
DCD & ADHD	6	0	7 - 16	6
Total	10	4	7 - 17	14

Table 4.3 provides an overview of the participants, including pseudonyms used for their names and children's characteristics.

Table 4.3. Parents' information (pseudonyms used for names)					
ADHD		DCD		ADHD + DCD	
Parents' pseudonyms	Children information	Parents' pseudonyms	Children information	Parents' pseudonyms	Children information
1- Alex:	daughter 9 years old	1- Isabella:	daughter 17 years old	1- Maryam:	son 10 years old
2- Ava:	son 12 years old	2- Mia:	son10 years old	2- Charlotte:	son 16 years old
3- Olivia:	daughter 9 years old	3- Lily:	daughter 16 years old	3- Harper:	son 7 years old
4- Sophia:	son 13 years old			4- Amelia:	son 7 years old
5- Emily:	son 7 years old			5- Evelyn:	son 13 years old
				6- Harry:	son 8 years old

Three distinct themes were developed. The first theme explored parents' observations of their children's roadside behaviour and road crossing performance, revealing unique challenges related to these conditions. The second theme examined parental perceptions, unveiling their concerns and emotions about their children's pedestrian safety. The third theme highlighted parents' resourcefulness in developing strategies to safeguard their children.

These themes provide insights about parental perspectives of pedestrian roadside safety of children with DCD and/or ADHD. A summary of the generated themes and sub-themes are presented in Figure 4.1. These will now be discussed.

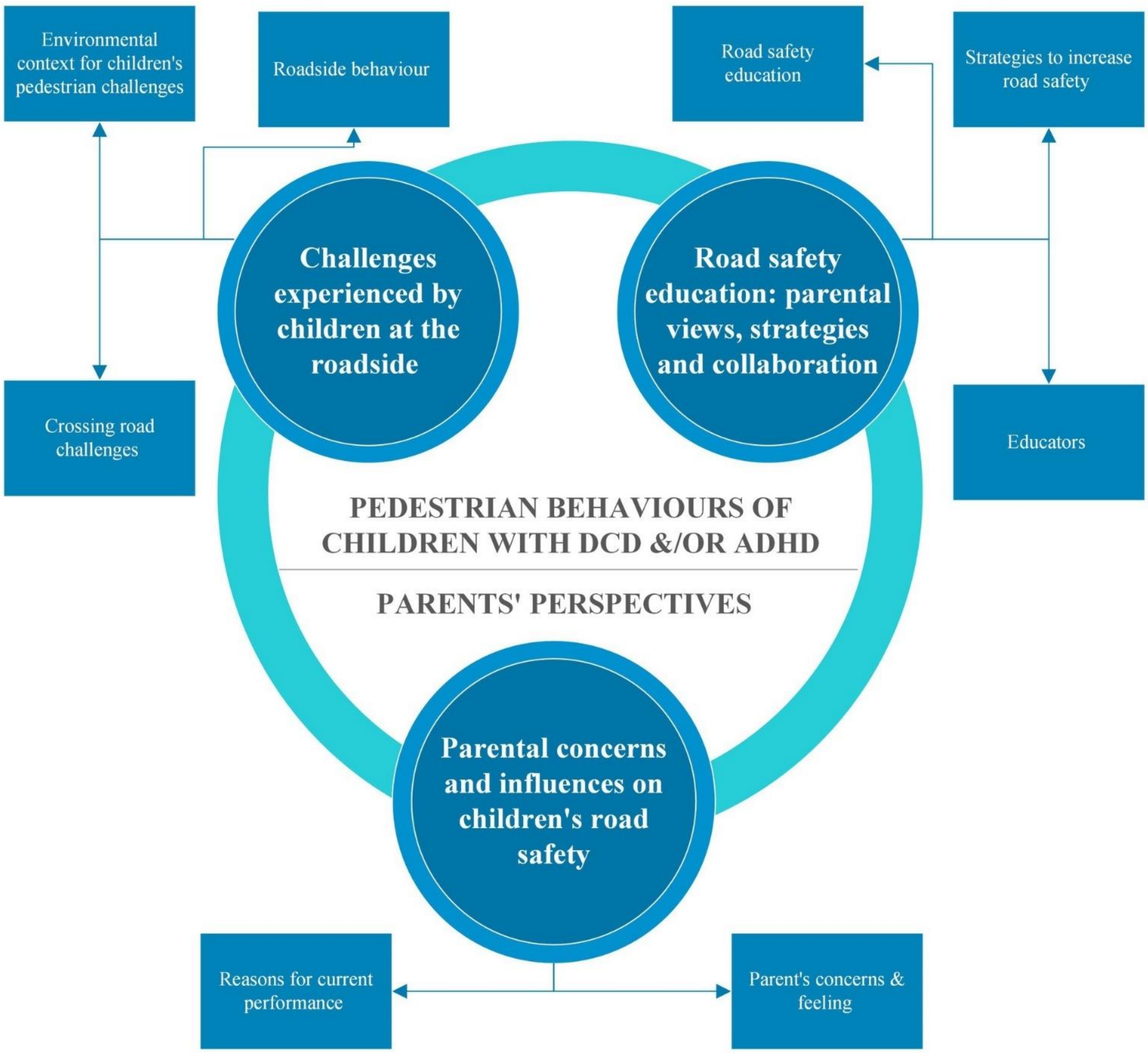


Figure 4.1: Summary of the themes & sub-themes

4.3.1 Theme 1: Challenges Experienced by Children at The Roadside

This theme highlights descriptions parents of children with DCD and/or ADHD gave in terms of their children's roadside behaviour and road crossing performance. Although many participants experienced similar pedestrian environments, parents from each group reported different pedestrian behaviours which related to whether their child had DCD and/or ADHD.

4.3.1.1 Environmental Context for Children's Pedestrian Challenges

To provide context for a deeper understanding of their children's pedestrian challenges, the environmental context in which these challenges unfold was initially discussed. Among the 14 participants in the study, 10 resided in urban areas, while the remaining four lived in rural or village settings. However, participants from rural areas lived in close proximity to a town and were exposed to similar transport infrastructure. One participant, Sophia, from the ADHD group, described living in a:

> *"…village or close to countryside but there are transport infrastructure buses, roundabout, signalised crossing, zebra crossing, and alleyway" (13-years old).*

All participants agreed that zebra crossings, signalised crossings and human controlled crossings are safer crossing sites when compared to midblock crossing sites.

> *"For signalised crossing, he likes to press the button and waits" (Emily, 7-years old, from the ADHD group)*

> *"those [referring to Zebra and signalised crossing], she's okay because all you have to do is wait for the cars to stop, don't you? And when you can clearly see that they've stopped, then you can go. So, the decision …. She's not having to judge" (Isabella, 17-years old, from the DCD group)*

> *"He will wait by the lollipop lady and he knows because he's learning that rule" (Maryam, 10-years old, from the co-occurring group)*

However, parents of children with ADHD expressed concern about their children's safety when crossing driveways due to previous near-miss incidents.

> *"The most important is the driveways as Emma runs across all those driveways." (Olivia, 9-years old, from the ADHD group)*

Parents in the ADHD group also reported that their children exhibit less dangerous behaviours when using zebra and signalised crossings as long as they are not distracted. However, parents reported that children with ADHD tend to exhibit risky behaviour, such as standing at the edge of the pavement.

“He does stop, but what he does do is he stands at the very edge of kerb. So, he will really push the limit and be like, I am here.” (Emily, 7-years old, from the ADHD group)

Conversely, parents reported that children with DCD showed a greater inclination to wait for others to cross with them at these crossing sites. Parents reported that their children followed parents, groups of pedestrians and the instructions of road crossing patrols.

"Because she's frightened of the traffic, she'll just follow other people [other pedestrians]” (Lily, 16-years old, from the DCD group)

According to parents, children with co-occurring DCD and ADHD also relied on others when using zebra crossings, signalised crossings and human controlled crossings, unless they were distracted by something on the other side of the road.

“He will wait by the lollipop lady and he knows because he’s learning that rule, that he sits and waits there for me. So, he will never cross without me” (Maryam, 10-years old, from the co-occurring group)

In summary, parents highlighted similar pedestrian infrastructure in both urban and rural areas. However, they articulated a range of challenges experienced by their children with DCD and/or ADHD in relation to these infrastructures. While zebra crossings and signalised crossings were considered safer, concerns about driveways were common among parents of children with ADHD, highlighting potential attentional issues characteristic of ADHD. Children with ADHD tended to exhibit risky behaviours near pavements possibly due to difficulties associated with hyperactivity, whereas those with DCD showed a greater inclination to wait for other pedestrians or pedestrian signals leaving the crossing decision to other people or road architecture. This could indicate that children with DCD have less confidence in their perceptual and motor abilities. Children with co-occurring DCD and ADHD showed a combination of these behaviours such as relying on others for crossing and distracting easily.

4.3.1.2 Roadside Behaviour

Common roadside behaviours reported by parents across the three groups were difficulties when multitasking, such as talking and walking, which could exacerbate the problem and negatively affect their roadside safety. For example:

> *"When he is absorbed in what he is doing, e.g. talking to his brother, I need to grab his attention first by tapping his shoulder or the back of his neck, or I'll try and get near him and say, like, hey, John [child's pseudonym], just to try and cut through what's going on in his brain." (Emily, 7-years old, from the ADHD group)*

> *"It's that concentration she can't seem to multitask. She can't talk and walk at the same time because it just takes her concentration away from what she's doing." (Lily, 16-years old, from the DCD group)*

Furthermore, parents of children with ADHD described their children as very active, energetic and tending to run around, jump and engage in non-stop talking, making it difficult to focus on road safety. As a result, parents observed their children running or walking without noticing the edge of the kerb, leading to walking or running on the road instead.

> *"But she's that energetic and she's that bouncy. She will run ahead and go straight across the driveway without even thinking that the pavements changed" (Olivia, 9-years old, from the ADHD group)*

> *"They [John and his brothers] just like wander off the pavement into the road and start walking in the road instead of on the pavement. Especially John likes to walk right on the edge of the kerb." (Emily, 7-years old, from the ADHD group)*

On the other hand, parents of children with DCD reported a lack of spatial awareness, which often resulted in them bumping into people and things. As parents report, they tend to rely on someone walking beside or in front of them. As a result, parents suggested that they lacked confidence in their children's ability for independent mobility and decision-making at the roadside. Examples from parents when discussing walking on the pavement include:

“She’s always covered in bruises, where she’s constantly bumping into things.” (Lily, 16-years old, from the DCD group)

“She always tends to stay by the side of someone. She's never one to take the lead. If this only one person can fit through, she tends to stay back and follow.” (Isabella, 17-years old, from the DCD group)

Parents of children with co-occurring DCD and ADHD reported a combination of these behavioural characteristics. While they were reported to have similar characteristics to the DCD group, including relying on others for decision making and exhibiting poor spatial awareness, leading to children bumping into people and things, those with co-occurring DCD and ADHD were described as often running, jumping and climbing. They were also observed to be unaware of the edge of the kerb, which increased their likelihood of walking on the road.

“So, I'm always reminding him to walk near the wall, not the edge of the road. All the time bumping into people. So, he's just got no concept of where his body is” (Maryam, 10-years old, from the co-occurring group)

“Because of the big thing with Malcom [child’s pseudonym] is his spatial awareness. He doesn't realise where his body is in the space. He is just sort of floating about and he would just not realise that the pavement had ended, and the road had start.” (Amelia, 7-years old, from the co-occurring group)

This sub-theme highlighted distinct challenges faced by parents of children with DCD, ADHD and co-occurring DCD and ADHD regarding road crossing behaviour. Parents across the three groups commonly reported challenges with multitasking during roadside activities, which could worsen the situation and pose risks to roadside safety. Parents of children with ADHD noted their high activity levels, making them prone to running or walking on roads without noticing hazards. Conversely, parents of children with DCD reported a lack of spatial awareness, leading to frequent collisions with objects/people. Those with co-occurring DCD and ADHD were reported by parents to display a combination of both behaviours, poor spatial awareness and high activity levels, emphasising the added complexity of pedestrian safety for these children.

4.3.1.3 Crossing Road Challenges

The behaviour of children with DCD and/or ADHD when crossing roads was also reported by parents. Parents of children with ADHD discussed how their children tend to run or walk straight across the road without looking at oncoming vehicles or checking both ways. Parents believed that their attention is often directed towards their intended destination only, resulting in a disregard for the environmental cues and hazards in the immediate surrounding environment. This phenomenon was frequently referred to by parents as "tunnel vision".

> *"Not able to pay attention around about his surroundings, so he will literally just walk straight across the road without looking, he does not look" (Ava, 12-years old, from the ADHD group)*

> *"When I went to pick him up from school, he ran into the road not looking." (Sophia, 13-years old, from the ADHD group)*

> *"She's just she tends to look at the point she wants to get to and it's almost like she gets tunnel vision. Nothing else is there. She just needs to get from where she is to that thing over there" (Olivia, 9-years old, from the ADHD group)*

All parents of children with DCD, on the other hand, noticed their children move their head right and left as a visual scan before crossing but described how their children have difficulties in interpreting the visual cues to make an appropriate decision.

> *"She would turn her head like this. But she wasn't actually looking at the cars and making a judgment. She was doing the movement. And she would stand there, and she would do the head movement only." (Isabella, 17-years old, from the DCD group)*

The parents further explained that they either rely on other pedestrians to make the decision or they make a random decision to cross the road, thereby increasing their vulnerability to accidents.

> *"She hasn't got the confidence and because she's frightened of the traffic, she'll just follow other people [other pedestrians], which sometimes is not a good thing*

because if they run out in front of something, she's trailing behind" (Lily, 16-years old, from the DCD group)

Parents reported observing their children either running across or looking down during road crossing. Parents suggested that their children lack confidence in their decision-making ability which may contribute to the variation in their crossing styles. Moreover, they stated children with DCD lack the ability to judge the speed of an approaching vehicle and cannot determine whether vehicles are far enough away to safely cross the road.

"She walks head down, she's like, I made my decision, and my head is down, and I am going. She doesn't run but she does walk very fast" (Isabella, 17-years old, from the DCD group)

"She cannot make that judgment. She cannot tell if that car is far enough away." (Lily, 16-years old, from the DCD group)

According to parents, children with both DCD and ADHD demonstrated relatively similar behaviours to the ADHD group and DCD group. Children may look both ways before crossing but face difficulties in processing the visual cues to make an appropriate decision.

"So, he was standing at the edge of the road, and he would turn his head. But he wouldn't necessarily spot that the car was coming" (Maryam, 10-years old, from the co-occurring group)

Similar to the DCD group, parents of children with both DCD and ADHD observe safe road crossing when amongst a group of pedestrians and tend to walk behind other people. Furthermore, children with DCD and ADHD were described as experiencing difficulties in judging the speed of approaching vehicles relative to their own walking speed, potentially leading to dangerous situations.

"I don't think he can judge how fast he's going. You know, if there's a car coming, if there's a car at the end of the road, he wouldn't know that car was far enough away that you could cross." (Maryam, 10-years old, from the co-occurring group)

Parents also observed their children stopping in the middle of the road or expecting the car to stop for them, like at a zebra and signalised crossing.

> *"He doesn't really know how to react to traffic, so I'm trying to give an example of something that happened. We were crossing quite a busy road and as we were crossing the road, he stopped right in the middle of the road because there was a bus approaching. But it was a red light so the bus would have stopped but he stopped dead in the middle of the road" (Amelia, 7-years old, from the co-occurring group)*

Parents of children with DCD and ADHD reported that their children might engage in impulsive behaviour when crossing roads. For instance, they may exhibit a tendency to run across the road if they perceive something of interest on the other side or if they recognise someone they know.

> "*He might run across the road if he saw somebody he knew on the other side, or a dog that he wanted to speak to, he wouldn't think it was a road." Maryam, 10-years old, from the co-occurring group)*

Overall, it is evident that visual-motor/attention challenges play a substantial role in the pedestrian safety of all children from the perspective of these participants. Whether due to issues related to attention or as described "tunnel vision" (in the case of ADHD), difficulties in processing visual cues (in the case of DCD), or a combination of these factors (in the case of co-occurring ADHD and DCD). These challenges underscore the importance of addressing visual perception and attention in enhancing road safety for these children.

4.3.2 Theme 2: Parental Concerns and Influences on Children's Road Safety

Parental perceptions are critical aspects in understanding their children's road safety behaviour and performance. This theme explores parents' concerns and feelings about their children's pedestrian safety and possible underlying causes of roadside performance through two subthemes.

4.3.2.1 Parent's Concerns and Feelings

The first subtheme revealed that parents of children with ADHD experience apprehension regarding their child's independent travel abilities, even when utilising public transport from remote locations, such as buses.

> *"We've just been quite nervous about him doing that on his own and organising himself to get on a bus that's 10 miles away to come home. Don't feel quite yet, he's ready to do that. So, I suppose we supervise him a lot and he doesn't really go anywhere on his own without us." (Sophia, 13-years old, from the ADHD group)*

These parents monitor their children closely and restrict them from going out unsupervised. They also frequently hold their child's hand, fearing potential traffic accidents.

> *"I probably held his hand a lot because I was very worried about him running off onto the road" (Sophia, 13-years old, from the ADHD group)*

Furthermore, the situation may be further complicated by the fact that the parent may be a single parent with the child and their siblings, making it even more challenging.

> *"I would assume that it is usually me with my three kids. So, it's not only me and John. So yeah, it it's kind of hard." (Emily, 7-years old, from the ADHD group)*

Parents of children with DCD noted that road crossing may not be a priority initially, due to other pressing developmental issues, but as their children enter adolescence, the significance of safe road crossing becomes increasingly apparent. These Parents expressed concern about their children's ability to navigate roads safely.

> *"When she was very small, it wasn't something we thought about so much because of the range of problems that Claire had, it was not a top priority. We had other more pressing issues like skills, milestones that were late, that were more important than crossing the road. It really started to be an issue. I think when she got to be a teenager. So, by the time she was in secondary school, 12 couldn't cross the road and it wasn't even close to being able. When we attempted to teach*

her to cross the road. She wasn't even close to being able to do it safely and to make safe decisions" (Isabella, 17-years old, from the DCD group)

"What happens as the children get older is that their independence is very restricted by this. Basically, a child that can't cross the road can't leave the house on their own. And you suddenly find that you have this child, who is 16, who is 5 feet tall who still needs their mum to take them." (Lily, 16-years old, from the DCD group)

These concerns can heighten parental anxiety, leading to increased supervision and potentially hindering children's development of independent mobility. Moreover, parents stated driving children to school can hinder their development when they want their children to gain more road safety experience. Therefore, parental concerns regarding their children's road safety are difficult when balancing children's independence with road safety. Based on insights shared by parents, effective strategies to teach their children how to cross roads safely while still allowing them to develop the independence they require for community mobility can facilitate this goal.

"I don't think it's helped because, we've had to take her back and forth to school every single day because of the distance of the school from where we live to where the school is and like I said, there's no way she could have walked safely back and forth. It's way too far and the roads are too busy, and I don't think it's helped her, and this is why I want to really encourage her to start going out with her friends now. So, because the more experience she's got on the road, the better it's going to be for her. She can't live in a bubble with her parents walking behind her for the rest of her life." (Lily, 16-years old, from the DCD group)

Likewise, parents of children with co-occurring DCD and ADHD expressed concern and fear for their children's road safety. These concerns demonstrate the complexities and challenges of fostering independence in children while ensuring their safety. Parents recognised that their children's safety depends not only on their own actions but also on the actions of others, such as drivers and pedestrians.

“It's my biggest fear that Malcolm [child’s pseudonyms] is going to get run over because it's so likely to happen. I can see it happening based on how I see him every single day near roads. As he gets older, and he becomes more independent, and he starts wanting to do more things independently, my fear grows.” (Amelia, 7-years old, from the co-occurring group)

Additionally, parents were aware of the impact of their child's mood and fatigue levels on their judgment, making it essential to consider their emotional and mental well-being in addition to their physical safety.

“So generally, I'm quite nervous and scared, but some days he's good, really good and really receptive and really responsive. And then the other days are just because he gets fatigued in the afternoon because of how on-the-go it is in the afternoon, it's like a bit of a clouds formed his judgment and his mind. So, it depends on the time of day, and it depends on his mood.” (Amelia, 7-years old, from the co-occurring group)

Overall, this sub-theme highlighted parents’ concerns of children with DCD, ADHD and co-occurring DCD and ADHD in ensuring their child's safety during road crossing. Parents of children with ADHD expressed concern regarding their child's independent travel abilities, leading to increased parental supervision and a possible decrease in the opportunity for children to learn safe road crossing behaviours. Parents of children with DCD initially prioritised other developmental issues over road crossing but later express concerns about their child's ability to navigate roads safely. Parents of children with co-occurring DCD and ADHD also described their fear for their children's road safety, emphasising the complexities of fostering independence while ensuring safety. Thus, all parents faced the demanding challenge of finding the balance between fostering their children's independence while prioritising their pedestrian safety. The parents' expressions of fear and concern illustrate the importance of recognising the complexities of the road crossing task and the need for effective strategies to teach children how to cross roads safely as they develop independence.

4.3.2.2 Reasons for Current Performance

Parents of children with ADHD perceive their children's poor performance as pedestrians to be linked to ADHD characteristics, which is affected by their mood and temperament. Specifically, parents reported that during episodes of bad mood or inability to self-regulate, their children's impulsiveness and inattention of their surroundings may lead to unsafe crossing behaviours, such as darting across roads without checking for oncoming traffic.

> *"Worse during the bad temperament, more like oppositional defiant disorder, leading to not stop and shoot across roads and I think he did not hear anything around." (Ava, 12-years old, from the ADHD group)*

However, during periods of good mood, these parents reported that their child's road safety behaviour could be adequate, highlighting the critical role of mood fluctuations in performance. Despite these challenges, parents expressed optimism about their children's ability to develop strategies as they grow older leading to improved pedestrian performance.

> *"If she's in a good frame of mind, she's like a professor of it. She will tell you exactly how you should cross the road. But if she's in a bit of a bad mood or whatever, it's like fight or flight response, and the matter of fact is that she can tell me perfectly she will just go." (Olivia, 9-years old, from the ADHD group)*

Similarly, all parents of children with DCD believed that their child's poor pedestrian performance is related to their inability to judge distance and speeds accurately. They also reported that their children may struggle with spatial awareness, which can make it difficult to navigate around obstacles and people on the pavement. Additionally, fatigue, lack of confidence and forgetfulness can further impact their children's judgement and spatial awareness.

> *"She [referring to Isebella's daughter] can't always tell where other people are properly. So, walking into people is a real problem. So, she constantly has this fear that people are gonna walk into her because she can't tell where she is. So, she doesn't know where they are." (Isabella, 17-years old, from the DCD group)*

“My feeling is that she cannot judge the speed of the car. So, you know if you or I look, you can tell and you learn through experience how fast the car is going. And is that car far enough, and have I got time to cross?” (Isabella, 17-years old, from the DCD group)

For parents of children with both DCD and ADHD, the characteristics of DCD and ADHD are perceived to be contributing factors to their children's poor performance as pedestrians. They expressed concern about their child's lack of focus and impulse control, which can lead to unsafe behaviour on the road. Moreover, parents acknowledged that their child's spatial awareness, concentration, attention difficulties and motor skills may affect their ability to judge distances and navigate their environment safely.

“If he's tired, if he's worried, you know? So, if he's anxious about something, then he's more likely to be dysregulated on edge and more bouncy, and all over the place, as we say” (Harry, 8-years old, from the co-occurring group)

“I think it's both [referring to ADHD and DCD]. So, the impulse bit is obviously ADHD, but because he has no idea of what his body is doing, you know he can't stay upright. He doesn't know where he is in space, which is more of the DCD I think…When he’s focused, he can cross the road safely. But you never know which day he’s going to be focused, or you know which minute he’ll be focused, and which minute he won’t.” (Maryam, 10-years old, from the co-occurring group)

Despite these challenges, some parents remained hopeful that with time and support, their child can improve their pedestrian performance. However, they currently would not feel comfortable allowing their child to walk to school independently or with friends, as they believe it would be unsafe.

“So next year, when he goes to secondary school, I won’t let him walk to school on his own or even with a group of friends because I wouldn’t put them in that position where they have to keep him safe.” (Maryam, 10-years old, from the co-occurring group)

In general, parents of children with ADHD link poor pedestrian performance to ADHD traits such as impulsivity and inattention which is affected by mood fluctuations. For those with DCD, spatial awareness, motor skills and fatigue pose challenges for appropriate pedestrian behaviours. Children with both conditions face a combination of limitations related to concentration, attention difficulties, motor skills and spatial awareness, leading to significant parental concerns about their road safety.

4.3.3 Theme 3: Road Safety Education: Parental Views, Strategies and Collaboration

This theme explores parents' perspectives of current road safety education and the various strategies they developed themselves to ensure their children's safety. Despite concerns, parents have developed invaluable pedestrian safety strategies that can be adopted to enhance the practical aspects of road safety education.

4.3.3.1 Road Safety Education

Parents of children with DCD and/or ADHD discussed their children's road safety education and also suggested some elements to facilitate the effectiveness of the education. Parents of children with ADHD believed that while their child received some road safety education, it may not be sufficient. They suggested that stories, which provide an emotional connection, may have a greater impact on their child than generic videos.

> *"I know they had that Bobby Colleran [campaign] that Slow Down for Bobby [Bobby Colleran is a local road safety campaign in the UK aimed at promoting safe travel to schools]. The family go to her school, and they were there a couple of weeks ago, going through everything again and sharing the books and we've got the books at home as well. We've read them... So, she's [Olivia's daughter] quite compassionate, so that will make her think more than just watching a video of someone that she doesn't know." (Olivia, 9-years old, from the ADHD group)*

> *"You know the old adverts that used to be on the television about if you didn't buckle in... we had to show her things like that to make her understand the implications of those choices. From that point onwards, she wore a seat belt. No question. She gets straight in and buckles up." (Olivia, 9-years old, from the ADHD group)*

Moreover, parents stressed the importance of teaching road safety in a way that their child can understand, with step-by-step instructions and minimal distractions. They reported that one-to-one or small group sessions can be most effective.

> *"Instructions need to be step by step, otherwise, his brain gets overloaded." (Emily, 7-years old, from the ADHD group)*

Parents of children with DCD stated that they found ways to adapt to their children's needs. They were involved in the school's Kerbcraft program to reinforce road safety practices and took the initiative to teach their child about road safety during outings.

> *"Well, in school they do the same thing. They do Kerbcraft once from five or six years of age where they take them out in the community, and they cross busy roads." (Lily, 16-years old, from the DCD group)*

They also mentioned a transition training program preparing their child for the transition from primary to secondary school, where road safety awareness is essential. Additionally, they emphasised the active role of parents in teaching their children road safety.

> *"They do a transition at the last year. So, when they go from year six to year seven and the road safety officer will go into the primary schools and speak to them and tell them, think how you're going to get to your new school when you start in September, plan your route, look for the safest route, don't look for the shortest route, it's gotta be the safest route. So, she did that as well." (Lily, 16-years old, from the DCD group)*

While parents of children with both DCD and ADHD saw road safety education as crucial, their experiences revealed significant challenges in transferring theoretical knowledge into practical implementation. These parents, for example, reported that their children had received some road safety education at school and scout club. However, they agreed that their children might not put what they had learned into practice, particularly if they were not familiar with the roads.

"Theoretically, it doesn't work. For it to be slightly muscle memory, you need to do things physically. And that means practicing it, getting in the habit of doing it, and seeing it in practice." (Amelia, 7-years old, from the co-occurring group)

They further believe that simulation, one to one training and a training program with movement activities and visual materials would be more effective.

"Somehow exposing him to dangers in a safe way. Like through simulation, might help him understand and remember road safety lessons better. You can do visual social stories with him, but he doesn't relate to that if it is presented on a page, I think you know if you put him through some kind of road safety simulation, that would work because he'd remember it and he'd be in it." (Maryam, 10-years old, from the co-occurring group))

"I believe that learning should come from an angle where it's kind of like a visual, auditory, reading, and kinesthetic experience. So, it would involve a lot of movement, a lot of walking around, a lot of like activities, things that are visual, things that give context to the situation. You know, like when they do, first aid, you've gotta practice doing the CPR and stuff like that" (Maryam, 10-years old, from the co-occurring group)

"You're talking one teacher to 30-odd children, so Malcolm doesn't concentrate very well in school but he benefits greatly from one-on-one support." (Amelia, 7-years old, from the co-occurring group)

Some of them proposed that such training should be continuous, daily and revisited every few weeks or months with catchy campaigns and ads promoting road safety education. They also emphasised the importance of preparing their children for adulthood and for independent pedestrian mobility.

"Missed days with Malcom, it becomes out of his routine and then you just gotta start again. So doing things daily is really important. In school, it might be different, though. Say, if they were doing lessons on road safety in school, I think weekly would be fine if they got into a habit of it." (Amelia, 7-years old, from the co-occurring group)

In discussing road safety education, parents of children with DCD and/or ADHD highlighted various challenges specific to their respective children. Parents of children with ADHD emphasised the need for more impactful educational materials, such as emotionally engaging stories, to supplement existing programs. They also stressed the importance of providing step-by-step instructions and minimising distractions during training sessions. Parents of children with DCD described their efforts to adapt to their child's needs, including participation in school-based programs like Kerbcraft and transition training. They emphasised the significance of practical training and one-on-one support, as well as the need for continuous and frequent reinforcement of road safety concepts. Parents of children with co-occurring DCD and ADHD expressed similar viewpoints, underscoring the importance of personalised training approaches that incorporate visual and kinaesthetic elements. They also advocated for increased frequency and scope of road safety campaigns, along with real-life stories to highlight the risks associated with road traffic accidents. Overall, while parents across all groups recognised the importance of road safety education, they identified specific challenges and recommended tailored approaches to address the unique needs of their children.

4.3.3.2 Strategies To Increase Road Safety

Parents of children with DCD and/or ADHD developed various strategies to mitigate the risk of pedestrian injuries. Table 4.4 contains a summary of the strategies used by parents.

Table 4.4 parents' strategies

Group	Strategies mentioned by parents
ADHD	• Constant forward planning • Selecting quieter roads • Driving to school • Verbal cues and prompts • Assigning responsibility • Use of disability blue badges • Crossing with peers

	• Walking in the middle of the group
DCD	• Repetition or repeated practice • Familiarizing with environment and roads • Crossing with peers • Focus teaching on specific roads • Avoiding traffic
ADHD + DCD	• Verbal cues and prompts • Hand gestures • Physical guidance • Repetition or repeated practice • Familiarizing with environment and roads

Parents of children with ADHD expressed the need for constant forward planning to reduce the risk of pedestrian injuries. They select quieter roads when possible and minimise the number of roads their child needs to cross. Some parents opted to drive their child to school and drop them off on quieter roads due to their child's behavioural characteristics.

> *"It's just having to constantly forward plan, even if it's just like a walk before bedtime, it's constantly forward planning because you can just never plan what she's gonna do." (Olivia, 9-years old, from the ADHD group)*

> *"If there's a certain way, we'll walk, and we'll try and do it to the way where there's less roads to cross." (Alex, 9-years old, from the ADHD group)*

To draw their child's attention to the road, parents often use verbal cues, such as talking through the situation and shouting ahead. Additionally, assigning responsibility to their child, such as asking the child to tell them when it is safe to cross the road, was reported to help children with ADHD to pay more attention. To increase safety, some parents use disability blue badges to park closer to their destinations. Crossing with peers and walking in the middle of the group were reported as tactics they use.

"…you'd have to shout ahead. So, lots of talking it through, drawing his attention to look at the road." (Sophia, 13-years old, from the ADHD)

"I need to grab his attention first by tapping his shoulder or the back of his neck, or I'll try and get near him and say, like, hey, John, just to try and cut through what's going on in his brain" (Emily, 7-years old, from the ADHD group)

"So, like if I ask him say like, you're gonna tell us when it's OK to cross the road, he will give more attention to the task" (Emily, 7-years old, from the ADHD group)

Parents of children with DCD emphasised the importance of repetition and familiarity in mitigating the risk of pedestrian injuries. They noted that their child would become overcautious in unfamiliar places and wait until there was no traffic before crossing the road. To address this, they identified the roads their child would need to cross and familiarised them with these roads, starting at a quiet time of day. One parent described how they repeatedly crossed the same main road with their child for about two weeks until the child was comfortable making the decision to cross safely.

"We went down to the main road and we just crossed it again and again and again. And all we did every day for like an hour a day, for about 2 weeks, was to just go to that road, cross to one side and then cross back again and then cross back again. But it was forcing her to make the decision. So, it was very time consuming." (Isabella, 17-years old, from the DCD group)

Due to their child's need for repeated learning, the parents emphasised the importance of repeating the practice several times to ensure their child was familiar with the route. Another parent mentioned that they would walk the route with their child several times to ensure they were comfortable and familiar with it before allowing their child to volunteer in that area.

"With her DCD, she needs to have repeated learning. So, you couldn't just do it once and then think she's OK. It needs to be repeated. So, four or five times because she's... for example, she's volunteering for play scheme to look after younger… So, we're gonna walk it about three or four times with her to make sure that she's familiar with the route." (Lily, 16-years old, from the DCD group)

Isabella further suggested implementing environmental changes such as adding more zebra crossings on main roads, particularly at roundabouts, to increase safety. She also suggested the use of indicators on the kerb to identify the safest place to cross. For example, these indicators could be a distinct marking on the pavement edge, clearly indicating the safest area for pedestrians to cross.

> *"I think the other thing that's helpful with zebra crossings and Pelican crossings is because it's like a set piece wherever you go... I think we need more Zebra crossings on main roads." (Isabella, 17-years old, from the DCD group)*

However, parents noted that transferring skills from one road to another is challenging for their children. To address this issue, they suggested changing the teaching mindset from general life skills to specific roads that the child needs to cross.

> *"So that for every road that she's gonna need to cross, she has to work out a specific sort of skill set for that particular road." (Isabella, 17-years old, from the DCD group)*

Finally, parents reported avoiding traffic whenever possible, for example, by driving to school earlier to park in a safer location.

> *"After the near misses. What I started doing was I started driving to the school 20 minutes earlier so that I could make sure I could park somewhere where she wouldn't have to cross the car park to get to the car." (Isabella, 17-years old, from the DCD group)*

> *"She'll only go at certain times of day, so she wouldn't go when it was busy. So, sort of, you know, 4:30 she wouldn't go because the road is too busy. So, she's picking times when it's not busy." (Isabella, 17-years old, from the DCD group)*

Parents of children with both DCD and ADHD also discussed strategies to minimise the risk of pedestrian injuries. Verbal prompts were considered useful, as they help create awareness for the child, but constant reminders were necessary, especially when crossing the road.

“There is some awareness, but I always have to remind him to look both ways, because there’s always that possibility that a car may not stop still. So, yeah, there’s a lot of prompting.... so I’ll give him a heads up if we’re going to go left or we’re going to cross. So, sort of hand gestures.” (Evelyn, 13-years old, from the co-occurring group)

Hand gestures were used to indicate the direction of movement and sometimes physical guidance was needed to help the child stay on track, especially when navigating unfamiliar environments. Repetition was also found effective, with one parent (Evelyn) noting progress over the past year by practicing crossing two specific roads to school every morning. Familiarity with the environment can also play a role, as the child may feel more confident and aware in familiar surroundings.

“Yeah, I’ve noticed progress definitely, especially over the last year in the two roads that we crossed to get to school with practice every single morning crossing those roads and when I’m with him, I’m telling him what to do and I’m watching him and trusting him to cross the roads safely. But it’s gonna be a long time before we get to in being able to do anything like that on a busier road”. (Evelyn, 13-years old, from the co-occurring group)

“It depends where he is. It depends whether he’s familiar with that environment.” (Charlotte, 16-years old, from the co-occurring group)

Overall, parents employed a range of strategies to ensure their child's pedestrian safety according to their needs. Children with ADHD seem to thrive with forward planning, verbal prompts and attention management techniques, while those with DCD benefit from repetitive practice, familiar routines and environmental modifications. For the unique challenges posed by co-occurring DCD and ADHD, parents blend these approaches, adapting to unfamiliar situations, noting incremental progress.

4.3.3.3 Educators

The parents of children with DCD and/or ADHD discussed the responsibility of delivering road safety education for their children. Parents of children with ADHD believed that involving professionals such as the police and transport companies were crucial. In particular, courses for bus drivers would be beneficial since buses are often used to transport children to and from school. Various delivery options were discussed, but parents believed that they ultimately had the most frequent opportunities to put education into practice and walk with their children every day, while teachers and scout leaders could reinforce the message.

> *"Parents, teacher and Beaver's leader but the parents have the responsibility more than any other as they have more opportunity to put everything in practice and they walk everyday. Teacher and others should re-enforce." (Emily, 7-years old, from the ADHD group)*

When it comes to children with DCD, the parents felt that the responsibility of delivering road safety education fell on them, as they knew their children best and could adapt to their needs accordingly. However, they also suggested that local authorities could play a role in delivering extra lessons in schools to supplement what parents were teaching at home, ensuring that children with DCD were equipped with the necessary road safety skills.

> *"This is our job, you know. You are the parent and yes, it takes longer with these children. But you know that's called being the parent of a dyspraxic child" (Isabella, 17-years old, from the DCD group)*

> *"And with active travel, it's all very well put these roots in place, but if people are not learning their children to use them because the children got disabilities and they can't use them, I think local authorities should help step in. I know the primary responsibility lies with parents at the end of the day, it is their children and they should make sure they're safe. But I think if the local authority can help by delivering extra lessons in school, it might be beneficial." (Lily, 16-years old, from the DCD group)*

For children with ADHD and DCD, some parents believed that external professionals like the police would be more effective, while others suggested involving both parents and teachers. They also agreed that road safety education should be accessible to parents at home and delivered in schools by teachers, with the suggestion that teachers could incorporate it into the curriculum. While some parents believed that an external professional was needed, others felt a teacher with proper guidance documents could deliver a program effectively. Therefore, the parents felt that schools should take the lead in delivering road safety education, with parents and teachers working together to ensure their children's safety on the road.

> *“I think he probably responds better to external people. You know, if the police came and did it, he listens. You know the problem with parents doing things like that is you only have so much time in your day to do the things you need to do including therapy as well." (Maryam, 10-years old, from the co-occurring group)*

> *“I think what would be really helpful if it's something that parents could access themselves, but also to be delivered in schools.” (Harper, 7-years old from the co-occurring group)*

> *“By default, they're probably say at schools, but I think if you can get into computer games, something where it's leisurely and doesn't feel like it's forced upon them. Because sometimes if you put it through, say, it's just for schools, it just schools teach it. It doesn't necessarily go in because it feels like you're forcing it in for information upon me instead of me understanding that it's valuable to me in life. So, it's getting that balance of doing it in a way that feels like it's fun.” (Evelyn, 13-years old, from the co-occurring group)*

Parents of children with DCD and/or ADHD discussed the responsibility of delivering road safety education for their children. Parents of children with ADHD felt that it was important to involve professionals like the police and transport companies, while also acknowledging their own role in daily practice. Parents of children with DCD felt primarily responsible but suggested local authorities supplement education. For children with co-occurring DCD and ADHD, parents had mixed views about involving professionals versus teachers but agreed on the importance of accessible education delivered at home and in schools. Overall, ensuring road safety for children with DCD and/or ADHD was seen as a responsibility shared by parents, schools and local authorities. While parents saw themselves as playing a critical role in adapting education to their children's needs and reinforcing the message, schools can provide accessible education to supplement what parents teach at home. Additionally, local authorities can offer extra lessons and support to ensure children have the necessary skills to navigate the roads safely. By working together, parents, schools and local authorities can ensure the safety of all children on the roads.

4.4 Discussion

The aim was to explore the perspective of parents of children with DCD and/or ADHD with the goal of gaining a better understanding of the pedestrian risks faced by their children. Semi-structured interviews were conducted with parents and three main themes were generated, each aligning with a specific objective. In the first theme, parents' perspectives of the challenges faced by children at the roadside, addressed the objective of exploring the unique perspectives of parents of children with DCD and/or ADHD regarding their children's abilities and challenges in executing a safe road crossing. Additionally, the theme parental concerns and influences on children's road safety, sheds light on the worries and concerns parents have regarding their children's pedestrian safety covering the second objective. Finally, the objective of investigating the diverse strategies parents employ to minimise their child's involvement in pedestrian injuries was addressed in the road safety education: parental views, strategies, and collaboration theme. Although there was some overlap in the experiences shared by the participants, each parent provided a unique perspective and experience that contributed to a more comprehensive picture of the behaviour of children with DCD and/or ADHD at the roadside. Importantly, the identified themes were not isolated from one another; they interacted and impacted the overall understanding of pedestrian behaviour in this population to tell the everyday story of the parents of children with DCD and/or ADHD.

It is also important to note that the specific challenges and concerns varied depending on whether the child had DCD, ADHD or both DCD and ADHD. For example, parents of children with DCD primarily focused on difficulties with spatial awareness and motor skills, often struggling with judging distances and manoeuvring safely around obstacles. Children with ADHD, on the other hand, faced challenges with impulsivity and inattention, which could lead to sudden dashes into traffic or difficulty focusing on potential dangers. Parents of children with co-occurring DCD and ADHD faced a complex interplay of these challenges, requiring constant vigilance and proactive measures to mitigate risks. This highlights the importance of tailoring interventions and support to the specific needs of each group, ensuring effective strategies that address their unique vulnerabilities and promote safe pedestrian behaviour.

4.4.1 Challenges Experienced by Children at The Roadside

The first theme uncovered important insights into the experiences of parents of children with DCD and/or ADHD in relation to roadside behaviour and road crossing. The findings suggest that parents of children with ADHD are concerned about their children's safety specifically when crossing driveways. Meanwhile, parents of children with DCD were more anxious about complex pedestrian environments like roundabouts. For parents of children with co-occurring DCD and ADHD, the concerns were compounded, encompassing both impulsivity at driveways and difficulties navigating complex environments. Notably, all three groups of parents (children with DCD, children with ADHD, and children with DCD and ADHD) shared a common agreement that zebra crossings, signalised crossings and road crossing patrols are perceived as safer options compared to midblock crossings. The finding aligns with previous research demonstrating that the presence of well-maintained sidewalks, clearly marked crosswalks, and traffic signals is crucial in fostering parental confidence in child pedestrian safety in TD children (Poku-Boansi et al., 2019; Swain et al., 2024; Nakanishi et al., 2017). This finding emphasises the significance of structured and controlled crossing sites for enhancing the safety of children with DCD and/or ADHD while navigating roads. This is consistent with previous research indicating that midblock crossings can pose greater risks because of the complexities involved in judging distances, vehicle speeds, walking speeds and making accurate decisions (Purcell et al., 2011: Schwebel et al., 2014).

Regarding roadside behaviour, children with ADHD exhibited high levels of activity and energy, which often led to a lack of attention to their surroundings and unintentionally walking or running on the road instead of the pavement. Conversely, a previous study conducted in an experimental setting by Stavrinos et al. (2011) found that children aged 7 – 10 years with ADHD-Combined Type demonstrated adequate pavement pedestrian behaviour. The differences may be attributed to the inherent limitations of the laboratory setting, which may not fully replicate the complex and dynamic real-life environment characterised by a high volume of sensory stimuli as reported by parents in this study. This can be supported by Öhrström and Skånberg's (2004) exploration of the effects of traffic noise on sleep, where conflicting outcomes between field studies and laboratory experiments were highlighted, indicating potential limitations in the accuracy of results obtained solely from lab-based settings. When discussing road crossing behaviour, parents of children with ADHD reported their children's tendency to walk or run across the road, disregarding oncoming vehicle's and environmental cues while crossing, which led to an increased possibility of engaging in unsafe crossings. Previous studies support this finding showing that children with ADHD aged 7 – 10 years and 13 – 17 years are more likely to engage in unsafe road crossing behaviours, such as crossing when it is not safe, neglecting to look both ways before crossing and running across the road (Clancy et al., 2006; Stavrinos et al., 2011; Wilmut and Purcell, 2020). Furthermore, parents described their child as having "tunnel vision" in which children with ADHD focused solely on their intended destination. However, considering the characteristics associated with ADHD, including inattention and executive dysfunction, the concept of *cognitive tunnelling* may provide a more accurate description (Briggs et al, 2016).

On the other hand, children with DCD struggled with spatial awareness and relied heavily on others for guidance, leading to reduced independence and decision-making at the roadside as reported by their parents. Furthermore, parents of children with DCD observed their children when crossing roads visually scanning before crossing but struggling to interpret the visual cues and make appropriate decisions. A study conducted by Purcell et al. (2012) found that children with DCD aged 6 -11 years had lower looming detection thresholds compared to typically developing children, meaning they struggle to recognise an approaching object's potential threat as quickly as typical children, indicating weaker visual-motor processing skills that could lead to inaccurate crossing decisions. For example, children with DCD might misjudge a vehicles speed and assume a longer available traffic gap, potentially leading to risky situations (Purcell et al., 2012). Therefore, the parents of children with DCD reported in their interviews that they often relied on other pedestrians or made random decisions, which increased their vulnerability to accidents.

According to parents, children with co-occurring DCD and ADHD displayed a combination of these behavioural characteristics, further increasing their vulnerability at the roadside and when crossing roads. The lowered awareness in the DCD and co-occurring groups, but not in the ADHD group, is supported by Loh et al. (2011) who stated that impaired visual-spatial ability may be associated with DCD, while no similar association has been observed with ADHD. Parents spoke about the presence of behaviours attributed to ADHD. Parents of children with both DCD and ADHD reported that they engaged in more risky behaviour and displayed significantly less attention compared to those with DCD alone (Wilmut and Purcell, 2020). Thus, the presence of ADHD further exacerbates these difficulties, leading to a potential increase in their vulnerability to accidents.

4.4.2 Parental Concerns and Influences on Children's Road Safety

The second theme captured parental understanding and emotional responses regarding their children's pedestrian safety, as well as their exploration of potential factors influencing their children's roadside performance. During the interviews, parents of children with DCD, ADHD and co-occurring DCD and ADHD expressed concerns about their children's roadside performance, which aligns with findings from Wilmut and Purcell (2020) who explored the lived experience of adults with DCD and parents of children with DCD using a self-report questionnaire. Brook and Boaz (2006) also found heightened concerns among parents of individuals with ADHD aged 8 – 15 years compared to a typically developing control group. These findings have implications for road safety, as parents may be more inclined to limit their children's independent community mobility due to their concerns. Previous studies linked independent community mobility to enhanced physical health through active exploration, boosted mental well-being via cognitive development and independent play and stronger social bonds formed through peer interaction and community connection (Pacilli et al., 2013: Qiu and Zhu, 2017). In fact, the parents of children with DCD and/or ADHD that were interviewed reported closely monitoring their children's community movements, limiting community mobility while relying on vehicles and limiting unsupervised outings because of these concerns. Moreover, the compromised coordination and communication between parents and children with ADHD when crossing, often exacerbated by anxiety and fear, can directly impact their attention and decision-making (O’Neal et al., 2022). These negative emotions, further heightened by situations where parents and children choose different crossing gaps, can impair children's ability to process information and make safe choices leading to increased collision risk and unsafe behaviours (O'Neal et al., 2022). Similarly, the emerging evidence indicating the effect of higher task-specific anxiety on motor behaviour in children with DCD aged 8 – 14 years leading to poor gaze patterns, stepping behaviour and gait, could increase the risk of accidents, further emphasising the potential impact of emotional factors on roadside performance (Harris et al., 2022). Overall, these factors may result in parents adopting an overly protective approach towards their child, potentially leading to increased isolation and delayed development of independent mobility skills. Therefore, parents of children with DCD and/or ADHD were concerned about finding the balance between promoting their children's independence and prioritising their safety and well-being as pedestrians.

Furthermore, parents believed that traits related to DCD and/or ADHD seemed to influence their children's pedestrian performance and road crossing behaviours. Parents of children with ADHD mentioned the influence of mood and temperament on their child's pedestrian safety. They observed that their child's impulsiveness, inattention and difficulty concentrating during negative mood episodes can contribute to engaging in unsafe crossing behaviours. Conversely, periods of improved mood and enhanced focus were associated with better performance in pedestrian tasks. Skirrow et al. (2009) conducted a study suggesting that mood instability and ADHD traits may be interconnected and that mood instability could be considered a fundamental aspect of ADHD. However, Clancy et al. (2006) suggested that inattention may have a greater significance in predicting safety in the context of road crossing when compared to a typically developing control group aged 13 – 17 years. Further studies found a positive correlation between executive dysfunction and unsafe pedestrian crossings for both children with ADHD and typically developing children (aged 7 – 10 years and 8–12 years) (Stavrinos et al., 2011; Tabibi et al., 2022; Tabibi et al., 2023). Additionally, Tabibi et al. (2023) stated that attentional abilities did not have a substantial impact on determining unsafe behaviours as measured by the Integrated Visual and Auditory Continuous Performance Test (IVA+Plus), a computerised test that assess different components of attention (Sanford and Turner, 1995). Generally, poor pedestrian performance among children with ADHD can collectively be attributed to a combination of ADHD characteristics, such as inattention, impulsivity and lowered concentration, which are influenced by mood and temperament, as well as executive dysfunction leading to the increased risk of unsafe crossing behaviours in children with ADHD. Therefore, findings suggest that parents perceive that it is a combination of ADHD traits, executive dysfunction, mood and temperament which can influence the pedestrian safety of children with ADHD.

Conversely, parents of children with DCD believed that their child's pedestrian performance is related to their inability to judge distance and speed accurately. This aligns with research on looming sensitivity observed in the study by Purcell et al. (2012), as accurate perceptions of approaching vehicles to avoid collisions requires accurate judgment of the optical equivalent of distance and speed. This is further supported by the finding that children with DCD aged 6 – 11 years select insufficient temporal crossing gaps when presented with a virtual task simulating road crossing scenarios across different vehicle approach speeds, indicating difficulties in accurately judging and selecting appropriate temporal crossing gaps (Purcell et al., 2017) and demonstrating deficits in visuomotor adaptation skills (Bo and Lee, 2013). Additionally, the parental interviews indicate that the reported difficulties with body position awareness further contribute to the challenges faced by their children in navigating obstacles and people on the pavement. The presence of fatigue, forgetfulness and diminished self-confidence can further influence the roadside behaviours of children with DCD as reported by parents. Recent research using self-reported questionnaires also found a decrease in confidence in road crossing skills among both adults and children with DCD (Wilmut and Purcell, 2020), supporting the findings from parents. However, earlier studies showed no difference in self-reported confidence in children aged 6 to 12 years with DCD to independently and safely cross the road compared to their typically developing peers (Purcell, 2012; Purcell and Romijn, 2017). The differences in confidence levels between parents in this phase of the research and studies showing no difference in confidence may be attributed to the older age of participants included here. Therefore, developmental changes and the reliance on parent perspectives could contribute to the observed differences in confidence among individuals with DCD. Furthermore, while executive function deficits are also known in DCD (Sartori et al., 2020), their link to pedestrian performance remains unclear despite some associations with poor driving (Kirby et al., 2011). This suggests a potential role of executive functions in pedestrian safety, but more research is needed to understand its specific influence in this context. Overall, the challenges related to spatial awareness and accurate perception experienced by children with DCD could be the main contributors to the elevated likelihood of engaging in unsafe pedestrian behaviours.

For parents of children with co-occurring DCD and ADHD, understanding the underlying causes are more complex due to various factors related to the characteristics of ADHD and DCD. Parents reported that the pedestrian performance of their children can be influenced by inattention and impulsivity, which is related to inhibitory control, in addition to poor perceptual-motor skills and spatial awareness. Previous studies highlighted the presence of overlapping characteristics between DCD and/or ADHD (Bernardi et al., 2015; Harrowell et al., 2018; Wilson et al., 2020; Meachon et al., 2021). For instance, hyperactivity was identified as a co-occurring difficulty among children with DCD aged 16 years (Harrowell et al., 2018). Sartori et al. (2020) also found that children with DCD aged 8 – 10 years have poor performance in multiple executive functions including cognitive flexibility, working memory and inhibitory control. However, Meachon et al. (2021) explored the underpinning neurological mechanisms among individuals with DCD and/or ADHD aged 17 – 33 years in relation to inhibitory control and found that each group has a distinct executive mechanism despite the overt behavioural similarities. These findings suggest that although individuals with DCD and ADHD may present with similar behaviours, including roadside behaviours, their underlying neurological mechanisms are distinct and should be addressed differently.

In summary, parents of children with DCD and/or ADHD are facing the challenge of balancing between fostering children's independence and ensuring their safety as pedestrians. These parents attributed the current pedestrian performance of their children to the characteristics related to DCD and ADHD. However, emerging evidence indicates that executive dysfunction may serve as the underlying cause of their performance at the roadside. While the results are not conclusive, this implies that the road crossing behaviours of children with DCD and/or ADHD should be approached differently to ensure their road safety or when aiming to develop pedestrian skills. By recognising the potential influence of executive dysfunction, interventions and strategies tailored to the specific needs of these children could be developed to optimise their road safety and pedestrian abilities.

4.4.3 Road Safety Education: Parental Views, Strategies, and Collaboration

The third theme explored the approaches adopted by parents and the importance of educational interventions in promoting pedestrian safety among children with DCD and/or ADHD. The findings revealed several key aspects in this domain.

Firstly, parents of children with DCD and/or ADHD expressed concerns about the inadequacy of current pedestrian safety programs in meeting their child's unique needs. They emphasised the importance of addressing additional needs in preparing their children for the transition to becoming an independent pedestrian through using tailored approaches and multiple modes of delivery. Parents suggested the implementation of customised programs that specifically address the distinctive traits associated with DCD and/or ADHD. For instance, in the case of children with DCD, previous studies identified specific elements that should be considered to enhance pedestrian safety. Notably, research conducted by Purcell et al. (2012) revealed lower looming detection thresholds among children with DCD aged 6 – 11 years, which has implications for their ability to perceive and respond to approaching objects or vehicles. Additionally, Purcell and Romijn (2017) suggest that a multimodal approach, involving both allocentric (environment-centred) and egocentric (self-centred) approaches, may be necessary to effectively teach road safety to children with DCD aged 7 – 9 years. These findings are closely linked to the reported difficulties in visual processing of perceived information and spatial awareness experienced by children with DCD. Repetition was also reported by parents as an effective element to improve the pedestrian safety of children with DCD and co-occurring DCD and ADHD. For example, parents suggested that simulated environments, which can be virtual or physical, can provide safe repeated opportunities to learn pedestrian skills. Emerging evidence also suggests that virtual reality can be an effective approach for creating a safe environment that facilitates repetitive practice and improves pedestrian safety, benefiting both typically developing children and those with DCD and/or ADHD (Clancy et al., 2006; Purcell and Romijn, 2017; Schwebel et al., 2018; Morrongiello et al., 2018). By incorporating these insights and strategies into tailored programmes, the specific challenges faced by children with DCD and/or ADHD could be effectively addressed.

Secondly, parents of children with DCD and/or ADHD implemented various strategies to enhance their children's pedestrian safety and decrease the risk of road crossing injuries. Despite efforts to provide pedestrian safety training, the alarming rate of fatalities among children on our roads remains a significant cause for concern and it is evident that implementing behavioural strategies can be cost-efficient and play a crucial role in enhancing safety (Schwebel et al., 2014). Furthermore, adopting these strategies to incorporate the distinct requirements of children can be effective in fostering their pedestrian skills and formulating tailored interventions. Therefore, it is imperative to understand the strategies used by parents to mitigate the risk of child pedestrian injuries. A summary of the parent strategies identified by each group is provided in Table 4.5. Common strategies used by parents of children with DCD and/or ADHD include constant forward planning, selecting quieter roads, driving to school, using verbal prompts, crossing with peers, walking in the middle of a group, repeated practice, avoiding traffic, using hand gestures, offering physical guidance and fostering familiarity with the environment. However, it is important to note that some of these strategies may not be feasible for all parents, depending on their individual circumstances. It is also worth considering that some of these strategies, while prioritising pedestrian safety, may hinder the development of road crossing skills necessary for future independent mobility. For example, parents who consistently drive their children to school may not be able to provide an opportunity for their children to practice crossing the road safely in an unsupervised environment. Therefore, it is important for parents to identify strategies that are suitable for their children and their circumstances, while also considering the long-term impact of these strategies.

Moreover, the responsibility of ensuring pedestrian safety for children with DCD and/or ADHD extends beyond parents alone and involves collaboration among schools and local authorities. While parents of children with DCD and/or ADHD face time constraints, they actively take on the responsibility of teaching their children pedestrian skills and ensuring their safety on the roads. These parental efforts align with previous research (Morrongiello et al., 2015; Ngu et al., 2016; Zare et al., 2019), which underscores the crucial role of parental involvement in enhancing pedestrian skills and mitigating the risk of accidents. Additionally, collaborative efforts involving schools and local authorities showed effective results in promoting road safety education. Studies investigating the impact of road crossing programmes involving the active participation of school teachers and police officers in enhancing pedestrian skills (Zare et al., 2018; Schwebel et al., 2018; McLaughlin et al., 2019; Jiang et al., 2021) show the valuable contribution of educational institutions and local authorities in fostering pedestrian skills among typically developing children. Additional research is needed to further explore the collaborative efforts between these stakeholders specifically focusing on children with DCD and/or ADHD. Another crucial obstacle to consider when promoting pedestrian safety training for children with DCD, in particular, is the lack of widespread awareness and knowledge about the condition, even among medical and educational professionals (Hunt et al., 2021; Meachon et al., 2023). Therefore, fostering collaborative efforts must include raising awareness and providing targeted training for educators, healthcare professionals and local authorities, to equip them with the knowledge and skills necessary to support children with DCD as well as the other two groups. By recognising the shared responsibility and fostering collaboration among parents, schools and local authorities, comprehensive and effective measures could be implemented to promote the pedestrian safety of children with ADHD and/or DCD.

Whilst the findings have provided insights into the lived experience of parents of children with DCD and/or ADHD in the context of road crossing, there are certain limitations to consider. One limitation is that the sample size was relatively small, with only 14 participants, which may limit the variability and diversity of perspectives represented. Furthermore, the limited subgroup size of only three participants with DCD presents a specific challenge. Given the known complexity and heterogeneity of DCD, this small sample may not adequately capture the full range of experiences and challenges faced by this group within the context of road crossing. This limits the ability to confidently generalise findings to the broader population of parents of children with DCD and may mask potentially specific perspectives or concerns unique to this subgroup. Moreover, while the intention was to understand parental perspectives across different age groups, the age ranges within each group varied slightly (DCD: 10-17 years, ADHD: 7-13 years, Co-occurring: 7-16 years). This variation may have influenced parental perspectives of age-related differences in pedestrian behaviours and limits the ability to draw qualitatively based conclusions about age-based trends from the current dataset. Nonetheless, the study offers valuable preliminary findings that warrant further investigation. Moreover, the study focused solely on parents' perspectives regarding road crossing, overlooking the child's perspective and the broader experiences and challenges parents face in other aspects of parenting. Future research could explore the perspectives of children with DCD and/or ADHD regarding road crossing and investigate additional dimensions of parenting challenges and examine the impact of DCD and/or ADHD on other daily activities beyond pedestrian safety. Additionally, it is worth noting that the semi-structured interviews were conducted online, potentially excluding individuals without internet access or those less comfortable with online communication. This could introduce bias, as those with different access or preferences may possess unique perspectives or experiences related to road crossing.

In conclusion, the findings revealed several key insights that represent parents' perspectives of children with DCD and/or ADHD regarding the pedestrian risks faced by their children. Firstly, the importance of structured and controlled pedestrian crossing sites was emphasised by parents. Secondly, parents expressed heightened concerns about their children's performance and safety at the roadside, leading to increased monitoring and a more protective approach. Addressing these concerns is essential to promote the independence and well-being of these children. Additionally, while the underlying causes are not yet fully understood, it is evident that the reported road crossing behaviours of children with DCD and/or ADHD require a distinct approach to better develop their pedestrian skills effectively. Furthermore, parents implemented various strategies to mitigate the risks associated with roadside activities, but it is important to balance independence and the development of pedestrian skills. Lastly, promoting pedestrian safety for children with DCD and/or ADHD will require collaboration and shared responsibility between parents, schools and local authorities to implement comprehensive measures to ensure their safety and well-being. These findings contribute to the understanding of the perspectives of parents and provide valuable guidance for the development of targeted interventions and policies to promote the road safety of children with DCD and/or ADHD.

While the underlying causes of these concerns require further investigation, the qualitative findings suggest that children with DCD and/or ADHD may exhibit unique challenges in pedestrian skills. These challenges, such as difficulties with spatial awareness, motor coordination, and attention, may contribute to increased parental anxiety and influence their decision-making regarding their children's independence. The subsequent chapters will delve deeper into these challenges starting with a systematic quantitative review of pedestrian skills in children with DCD and/or ADHD. By examining empirical evidence from existing research, this review provides a more in-depth understanding of the specific pedestrian skills that may be impacted in these children, such as gap selection and visual-motor skills. This knowledge will be crucial for informing the development of existing body of knowledge.

5 Chapter Five: Navigating Traffic: A Systematic Quantitative Review of Pedestrian Skills in children with DCD and/or ADHD

5.1 Introduction

Understanding how children with DCD and/or ADHD navigate traffic is crucial for ensuring their safety and well-being. The qualitative findings in Chapter 4 (Phase one) provided valuable insights into the challenges and strategies employed by parents of children with DCD and/or ADHD to navigate road crossings. The findings revealed that parents of children with DCD and/or ADHD expressed concerns about their children's road safety due to their unsafe pedestrian behaviours (Falemban et al., 2024). They often attributed their children’s pedestrian behaviours to difficulties in judging distance and speed accurately, poor spatial awareness, attention difficulties, and impulse control (Falemban et al., 2024). Given that, parents used a range of strategies to mitigate the risk. For example, parents of children with ADHD report that their children often benefit from strategies such as forward planning, verbal prompts, and attention management techniques (Falemban et al., 2024). Conversely, children with DCD may thrive with repetitive practice, familiar routines, and environmental modifications (Falemban et al., 2024). For children with co-occurring DCD and ADHD, parents often blend these approaches, adapting to unfamiliar situations and celebrating incremental progress (Falemban et al., 2024). The qualitative results in Chapter 4 provided valuable insights into parental perspectives, to explore in more depth quantitative data on the pedestrian behaviours exhibited by children with these conditions needed to be examined. Road crossing is a visually guided task, and parents of children with DCD reported that their children might look at approaching cars but struggle to accurately process the visual information, and parents of children with ADHD indicated that their children often fail to look both ways before crossing, exhibiting a more focused or tunnel-vision approach (Falemban et al., 2024). Therefore, it was necessary to explore the visually guided behaviours of children with DCD or ADHD quantitively.

Chapter 4 presented insights from qualitative studies that had highlighted some of the challenges children with DCD and/or ADHD face as pedestrians. Separately, several quantitative studies have previously investigated road crossing challenges in children with these conditions. For example, children with DCD exhibit challenges in road crossing due to their difficulties in selecting appropriate temporal gaps, poor accuracy in identifying safe crossing sites, and difficulties with visual motion detection (Tabibi, & Pfeffer, 2007; Purcell et al, 2017). These perceptual-motor limitations can lead to risky behaviours, making road crossing a particularly hazardous activity for this group (Purcell et al, 2017). Furthermore, children with ADHD demonstrate significantly more unsafe crossings compared to TD peers (Tabibi et al., 2021). Their difficulties with attention, impulse control, and motor timing contribute to this increased risk, especially in complex traffic situations (Tabibi et al., 2021). While these quantitative studies may justify the reported challenges described by parents, a systematic literature review of quantitative studies was conducted to gain a more comprehensive and in depth understanding of the specific pedestrian behaviours exhibited by children with DCD or ADHD.

A comprehensive preliminary search was conducted using Google Scholar, PubMed, Cochrane Library, and PROSPERO. The search was conducted 8/9/2024, to include the most recent literature. No existing systematic reviews or scoping reviews specifically focus on addressing this topic related to children with DCD or ADHD were found. Although Wilmut & Purcell (2020) conducted a systematic review in relation to NDDs and pedestrian safety, the systematic review was not specifically structured to capture studies specifically related to DCD or ADHD. Therefore, this review aimed to comprehensively map the available quantitative research examining pedestrian skills in children with DCD or ADHD. By identifying key themes, research gaps, and methodological approaches, this review informed the design of the subsequent quantitative quasi-experiments conducted for this study. Understanding the current state of knowledge in this area was essential for developing a focused and impactful next phase through finding the unexplored road crossing components related to DCD or ADHD. The review adhered to the guidelines recommended by JBI and was reported according to PRISMATIC-ScR guidelines to ensure the rigour and transparency of the review process (Peters et al., 2020).

5.2 Methods

5.2.1 Objective

The aim of this review was to investigate the quantitative existing literature relating to how children with DCD or ADHD navigate road crossings.

5.2.2 Inclusion and Exclusion

The review included only quantitative studies that investigated pedestrian skills in children with DCD or ADHD. The age range of 6 – 17 years was chosen to capture a wider range of developmental stages. This period represents a critical stage in children's development of pedestrian skills (Shaw et al., 2015). During this time, children are typically transitioning from being primarily supervised by adults during road crossings to gaining more independence (Shaw et al., 2015). This age range encompasses both childhood and adolescence, allowing for a comprehensive exploration of how pedestrian skills evolve in children with DCD or ADHD. Quantitative studies that involved parents or caregivers were excluded. This ensured that the focus remained on the children's abilities and behaviours leading to fulfilling the review aim, to find the gaps in the literature related to road crossing components in children with DCD or ADHD. Given that, this review included studies exploring pedestrian skills in children with DCD or ADHD. Pedestrian skills refer to the abilities and behaviours necessary for safely navigating roads and road crossings (Miller et al., 2004). These skills are crucial for preventing accidents and ensuring safety, especially for vulnerable populations such as children with DCD or children with ADHD (Wilmut and Purcell, 2020; Wilmut and Purcell, 2021). The review specifically included literature that quantitively investigated pedestrian skills impacted by the characteristics of DCD or ADHD including motor coordination, visual-spatial skills, attention, and impulsivity challenges. This broad approach was taken to ensure that the findings were applicable to a diverse range of contexts where children with DCD or ADHD might reside and navigate traffic. Only, studies in English were included.

Given that the qualitative component of the current thesis focused on the perspectives of parents of children with DCD and/or ADHD, this quantitative literature review aimed to complement that work by examining the specific pedestrian skills exhibited by children with these conditions creating a foundation for the next empirical Phase two. By focusing exclusively on quantitative primary research studies, such as randomised controlled trials, observational studies, and experimental studies, a comprehensive and rigorous analysis of the factors influencing pedestrian safety in children with DCD or ADHD was examined. Qualitative studies, systematic reviews, meta-analyses, conference abstracts, letters, guidelines, websites, and blogs were excluded to ensure that the review was based on the most reliable and relevant quantitative evidence. However, PhD and MSc theses and dissertations were considered if they met the inclusion criteria. Grey literature such as reports, working papers, conference papers, were excluded. This helped to ensure a comprehensive search of the available peer reviewed literature that measured pedestrian skills in children with DCD or ADHD.

5.2.3 Search Strategy

To find the most relevant studies, a three-step search process was used as recommended by the JBI guidelines (Peter et al., 2020). The search started in two databases: PubMed, and Medline. A combination of specific search terms and controlled vocabulary, such as MeSH terms and Thesaurus terms, were used to find articles that were closely related to the research question. The initial search using PubMed and Medline was conducted on 10/9/2024. The following search strategy was used.

((("Developmental Coordination Disorder" OR DCD OR "Motor coordination disorder" OR Dyspraxia OR Clumsiness OR "Motor learning difficulties") AND ("attention deficit hyperactivity disorder" OR ADHD OR "Attention Deficit Disorder" OR ADD OR Hyperactivity OR Impulsivity OR Inattention)) AND (Pedestrian* OR Road* OR "Gap acceptance" OR Street)) AND ("Child"[Mesh] OR "Child Behavior"[Mesh] OR Child*)

Table 5.1 shows the concepts and key words that were used for the initial search.

Table 5.1 the initial search key words and concepts

DCD	**ADHD**	**Parents skills**	**Children**
“Developmental Coordination Disorder" OR DCD OR "Motor	"attention deficit hyperactivity disorder” OR ADHD OR	Pedestrian* OR Road* OR “Gap acceptance” OR Street	"Child"[Mesh] OR "Child

coordination disorder" OR Dyspraxia OR Clumsiness OR "Motor learning difficulties"	"Attention Deficit Disorder" OR ADD OR Hyperactivity OR Impulsivity OR Inattention		Behavior"[Mesh] OR Child*

However, the initial search strategy, focusing on specific terms related to DCD, ADHD, children and pedestrian skills, yielded limited results, with only 18 studies retrieved. Of these, only four were directly related to road crossing, and only one was quantitative in nature. This outcome suggested that the search was overly restrictive and required refinement. Therefore, after the initial search, the titles, summaries, and keywords of the four retrieved articles were examined. This assisted in identifying additional search terms to capture a broader range of relevant studies. Furthermore, the search strategy was modified accordingly and conducted in both PubMed and Medline again. Additionally, separate searches were conducted for pedestrian skills AND DCD, and pedestrian skills AND ADHD. These search strategies were then combined to identify studies that addressed all three concepts including Pedestrian skills, DCD, and ADHD. As an example, the identified studies of the expanded search using PubMed are shown in Table 5.2.

Table 5.2 the modified search strategies used for Pubmed.

Concepts	PubMed Search Strategies	Results
ADHD + Pedestrian skills	("attention deficit hyperactivity disorder" OR ADHD OR "Attention Deficit Disorder" OR ADD OR Hyperactivity OR Impulsivity OR Inattention) AND ("Accidents, Traffic"[Mesh] OR "Safety"[Mesh] OR "Pedestrians"[Mesh] OR Road* OR "Road crossing" OR Roadside OR Street* OR Traffic accident*OR "Pedestrian safety" OR Pedestrian* OR "pedestrian skills" OR "Road safety")	186

DCD + Pedestrian skills	("Developmental Coordination Disorder" OR DCD OR "Motor coordination disorder" OR Dyspraxia OR Clumsiness OR "Motor learning difficulties") AND ("Accidents, Traffic"[Mesh] OR "Safety"[Mesh] OR "Pedestrians"[Mesh] OR Road* OR "Road crossing" OR Roadside OR Street* OR Traffic accident*OR "Pedestrian safety" OR Pedestrian* OR "pedestrian skills" OR "Road safety")	14
DCD +ADHD + Pedestrian skills	(("Developmental Coordination Disorder" OR DCD OR "Motor coordination disorder" OR Dyspraxia OR Clumsiness OR "Motor learning difficulties") AND ("Accidents, Traffic"[Mesh] OR "Safety"[Mesh] OR "Pedestrians"[Mesh] OR Road* OR "Road crossing" OR Roadside OR Street* OR Traffic accident*OR "Pedestrian safety" OR Pedestrian* OR "pedestrian skills" OR "Road safety") AND ("attention deficit hyperactivity disorder" OR ADHD OR "Attention Deficit Disorder" OR ADD OR Hyperactivity OR Impulsivity OR Inattention)	4

This final expanded search was then conducted in Ethos, ProQuest, PubMed, MEDLINE, PsycINFO, EMBASE, Scopus, and AMED. The reference lists of all retrieved articles were examined to identify additional relevant studies.

5.2.4 Source Selection

The search included eight databases: Ethos, ProQuest, PubMed, PsycINFO, MEDLINE, EMBASE, Scopus, and AMED. Retrieved records were imported into EndNote reference management software. Duplicate records were removed. A two-stage screening process was employed, and the selection of studies was conducted following the pre-specified inclusion criteria previously outlined. Initially, titles and abstracts were screened against the inclusion and exclusion criteria. Studies unrelated to pedestrian skills in children with DCD or ADHD were excluded. Full-text screening was conducted independently by the main reviewer (RF) to verify eligibility based on the predetermined criteria. Consultation with a second reviewer (CP) was done whenever needed. Studies that did not use quantitative approaches or did not include children aged 6-17 years were also excluded. Additionally, reference lists of included studies were hand-searched by (RF) for potential additional sources. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram was utilised to outline the study selection process at each stage (Haddaway et al., 2020).

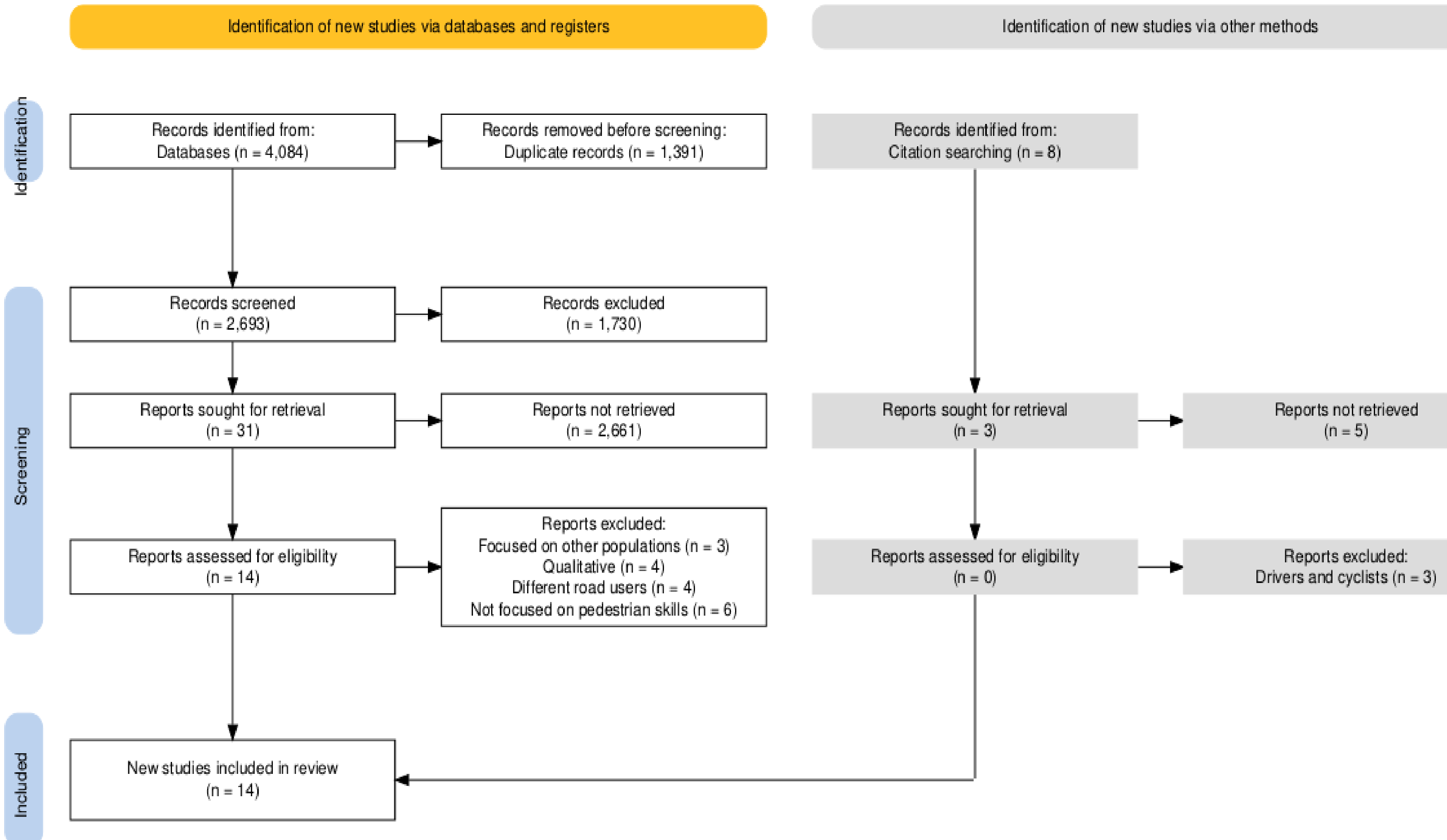


Figure 5.1. PRISMA flow diagram. | *Note: Three additional studies were excluded during data extraction due to their qualitative nature.*

I

5.2.5 Quality assessment

Although this literature review followed JBI scoping review guidelines, quality assessment is not included in the guidelines (Peters et al., 2020). However, critically evaluating the studies can be helpful to examine the methodological strength and limitation of studies (Petticrew & Roberts, 2006). JBI Critical Appraisal Tools were used to evaluate the quality of the included PhD theses (Moola et al., 2017). While JBI critical appraisal tools provide a structured framework for assessing the quality of research (Moola et al., 2017), CASP offers more flexibility in identifying specific strengths and weaknesses in the methodology and reporting of the studies, which is appropriate for deeper assessment of peer-reviewed articles (CASP, 2023). By carefully examining the methods used in studies, researchers can better understand the evidence (Petticrew & Roberts, 2006).

5.2.6 Data extraction

A data extraction form was adapted from the form used in the Chapter 3 to systematically collect key information from each included study. The completed data extraction forms are included in appendices 5.1 and 5.2 for reference. The adapted form included the study's title, citation, location, study design, objectives, sample size, sample characteristics, outcome measures and primary findings related to pedestrian skills in children with DCD or ADHD. The form was also piloted on two studies to ensure its effectiveness and make necessary adjustments. The sample size and sample characteristics as well as outcome measures and primary findings were combined. After refining the form, it was used to extract data from all included studies. To maintain consistency and depth in data analysis, data extraction was conducted by a single researcher. Any disagreements or uncertainties were resolved through consultation with a member of supervisory team (CP)..

5.3 Results

5.3.1 Sources selection results

A total of 4,084 records were retrieved from the database searches. After removing 1,391 duplicates, the titles of 2,693 remaining studies were screened, and studies focusing on parents or irrelevant to the pedestrian behaviour of children with DCD or ADHD were excluded. The remaining 963 papers underwent abstract screening using the inclusion and exclusion criteria. This resulted in 32 papers that were retrieved and assessed for eligibility. Upon full-text screening, 17 papers were excluded as they were not focused on pedestrian skills of children with DCD or ADHD but instead focused on collecting data from adults or focused on interventions, different road users, and non-quantitative methods. Reference list screening identified no additional potential studies. Therefore, a total of 14 studies were included in this review. The PRISMA flow diagram (Figure 5.1) outlines the study selection process at each stage (Haddaway et al., 2020). During data extraction, two PhD theses and one study were excluded due to their qualitative nature, in which instance the published work was used. This reduced the total number of included studies to 11.

5.3.2 Study characteristics

The review included 11 quantitative studies investigating the pedestrian skills of children with DCD or ADHD aged 6-17 years. The included studies were conducted in Iran (N=2), New Zealand (N=1), the USA (N=3), and the UK (N=5). This diverse range of locations suggests that the findings can provide a comprehensive overview of the pedestrian behaviour of children with DCD or ADHD from various cultural and environmental contexts. The sample sizes, study designs and focus were also varied in the included studies. This comprehensive approach aimed to provide a rigorous analysis of the factors influencing pedestrian safety in children with DCD or ADHD. The characteristics of the included studies are presented in Table 5.3.

Table 5.3: General characteristics of the included studies

Citation	Country	Study design	Sample	Focus
Clancy et al., 2006	New Zealand	Matched Case-control	48 children (**ADHD** = 24 | 24 TD). Equal number of boys & girls in each group. all aged 13 to 17. Additionally, ADHD participants did not take stimulant medication on the day of testing.	determining whether ADHD adolescents exhibit more unsafe road crossing behaviour than controls using an immersive virtual reality traffic gap-choice task
Tabibi et al., 2022	Iran	Matched case-control	38 children aged 8-12 years, including 17 with **ADHD** and 21 TD controls. The ADHD group was slightly younger (mean age 9.47 years) and had a higher proportion of girls (58%) compared to the control group (mean age 10.05 years, 43% girls). There were no significant differences in age between the two groups.	To examine the pedestrian behaviour of children with ADHD in comparison to TD children, particularly in relation to traffic complexity.
Parr et al., 2021	US	Cross sectional	The study included 92 children aged 9 to 11 years old (average age: 10.3 years). There were 52 male and 40 female participants. Regarding **ADHD**, 7 children were diagnosed with ADHD/ADD according to parental report, while 3 children were taking medication for ADHD symptoms but did not have a formal diagnosis.	Examining the relationship between individual variation in inattention and hyperactivity, motor timing difficulties, and performance in a virtual road crossing task.
Tabibi et al., 2023	Iran	Case-control	50 children (28 children with **ADHD** and 22 TD). Age: Mean age: 9 years old (range: 7-12 years). Gender: 54% boys, 46% girls. Diagnosis: 56% diagnosed with ADHD, 44% TD. No ADHD medications.	Investigating differences in pedestrian behaviour between children with ADHD and TD children, and to investigate the relationship between pedestrian skills and attention, inhibition, and executive function in both groups.
Stavrinos et al., 2011	US	Matched case-control	78 children. Mean age: 9.16 years (range: 7-10 years). Gender: 71% boys (n = 56). 39 children with **ADHD**, 39 TD children. Children with ADHD were off medication for 24 hours before participation	To examine the differences in pedestrian behaviour between children with ADHD and TD children, and to investigate the mediating factors that might link ADHD with pedestrian injury risk.

Purcell et al., 2012	UK	Matched case-control and within-subjects design	Total: 22 children (11 with **DCD**, 11 TD). Age: 6-11 years old. Matched for age and gender between groups	To investigate the relationship between DCD and looming sensitivity in children, and to explore the potential impact of this on road crossing behaviour
Purcell et al., 2011	UK	Matched case-control and within-subjects design	Total: 30 children, **DCD** group: 9 children and At-risk group: 6 children (those with M-ABC-2 scores between 5th and 16th percentile), TD group: 15 children. Age: 6-11 years old. Gender: Matched for age and gender between groups. Four children with DCD had elevated ADHD scores but were included in the analysis as per the Leeds Consensus Statement. Cognitive ability: 26 of 30 children (87%) fell at or above intellectually average for their age.	To investigate the relationship between DCD and pedestrian behaviour, specifically focusing on the ability to judge relative approach rates of vehicles and select appropriate crossing gaps. The study aimed to identify whether children with DCD have deficits in these skills and to explore the underlying mechanisms contributing to these difficulties.
Purcell and Romijn, 2017	UK	Repeated measures design (within-subjects) with case-control matching between groups	42 children (21 **DCD**, 21 TD). Age: 6-12 years old. Gender: Matched for age and gender between groups.	To investigate the appropriateness of different pedagogical approaches to road safety education for children with DCD. Specifically, the study aimed to compare the effectiveness of allocentric (aerial viewpoint) and egocentric (first-person viewpoint) virtual reality tasks in teaching road safety skills to children with DCD and TD children.
Purcell et al., 2017	UK	Repeated measures design (within-subjects) with case-control matching between groups	50 children. This included 25 children with **DCD** and 25 TD children, matched for age (6-11 years old) and gender.	To investigate the use of visually guided behaviour in children with DCD when crossing a virtual road. Specifically, the study aimed to examine how children with DCD make decisions about crossing gaps in traffic and whether their decisions are influenced by their motor skills and visual perception
Parr, 2023	US	Cross sectional	Total: 103 children. Age: 9-11 years old. Gender: 53% male. 36 children (35%) met criteria for suspected **ADHD**. 6 children (5.9%) met the cutoff for DCD (5th percentile and below), 18 children	To investigate the relationship between motor coordination, executive functioning, processing speed, and road crossing behaviour in children. Specifically, the

			(17.6%) met the cutoff for at-risk for DCD (9th and 16th percentiles). 17 children completed a 24- or 48-hour medication washout prior to participation.	study aimed to examine how these factors contribute to children's ability to make safe decisions when crossing roads.
Toye, 2016	UK	Matched case-control	122 children (61 **ADHD**, 61 controls). Age range 5 - 12 years. 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. 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).	Three studies focusing on: 1.to investigate differences in safe place finding ability between children with ADHD and TD children. The study also aimed to examine the relationship between conceptual understanding and perceived difficulty of the task in both groups. 2.to investigate differences in visual gap timing ability between children with ADHD and TD children. The study also aims to examine the perceived difficulty of the visual gap timing task in both groups. 3.to investigate whether children with ADHD have difficulties in predicting the intentions of road users, and if so, to understand how this relates to their cognitive functions and social skills.

US: United States; UK: United Kingdom; TD; Typically Developing

5.3.3 Quality assessment results

To assess the quality of the included studies, the CASP quantitative Checklists (CASP, 2023) and the JBI critical appraisal tool were used (Moola et al., 2017). These tools guided the evaluation of the studies' methodological rigour, including factors such as clear research questions, appropriate study design, adequate sampling, valid and reliable data collection methods, appropriate data analysis, and consideration of potential biases. Based on the CASP and JBI assessments, all included studies were of high quality. However, the precision of the treatment effect estimates varied across studies meaning the level of certainty about the findings varied. All studies reported significant p-values and four studies reported moderate to large effect sizes, suggesting a strong association between ADHD or DCD and road crossing behaviour (Stavrinos et al., 2011; Purcell and Romijn, 2017; Tabibi et al., 2022; Tabibi et al., 2023). However, the absence of confidence intervals and the potential for unmeasured confounders limit the ability to quantify the precision of the estimates more definitively. While the quality assessments indicated high-quality studies, the lack of confidence intervals makes it difficult to quantify the magnitude of the effects and the degree of uncertainty surrounding the findings. Additionally, unmeasured confounders may have influenced the observed relationships between neurodevelopmental disorders and road crossing behaviour. Therefore, further research is needed to address these limitations and provide more precise estimates of the effects. No study was excluded based on its quality assessment. The detailed assessment of quality is provided in Tables 5.4 and 5.5.

Table 5.4 CASP appraisal results of the case control studies

Appraisal questions: 1. Did the study address a clearly focused issue?; 2. Did the authors use an appropriate method to answer their question?; 3. Were the cases recruited in an acceptable way?; 4. Were the controls selected in an acceptable way?; 5. Was the exposure accurately measured to minimise bias?; 6. (a) were the groups treated equally?; 6. (b) Have the authors taken account of the potential confounding factors in the design and/or in their analysis?; 7. How large was the treatment effect?; 8. How precise was the estimate of the treatment effect?; 9. Do you believe the results?; 10. Can the results be applied to the local population; 11. Do the results of this study fit with other available evidence?; Y: Yes; C: Can't tell; N: No

Citation	A. Study Validity							B. The results			C. Local implication	
	1	2	3	4	5	6 (a)	6 (b)	7	8	9	10	11
Clancy et al., 2006	Y	Y	Y	Y	Y	Y	Y	The study found significant differences between the ADHD and control groups in several key outcomes, including margin of safety, collisions, and walking speed. However, the magnitude of the effect sizes was relatively small. This suggests that while there may be some differences in road crossing behaviour between children with ADHD and controls, the effect is likely to be modest.	The study did not explicitly report confidence intervals for the key outcomes, which can provide a more precise estimate of the treatment effect and its variability. However, the reported p-values for the significant differences between the ADHD and control groups were generally small, suggesting that the effects are unlikely to be due to chance.	Y	C	Y
Tabibi et al., 2022	Y	Y	Y	Y	Y	Y	Y	The study revealed significant differences in road crossing behaviour between children with ADHD and TD peers, particularly in complex traffic environments. The study employed appropriate statistical methods and controlled for potential confounding factors, strengthening the causal inference between ADHD and road crossing behaviour in complex traffic environments. While the specific effect sizes were not explicitly reported, the	The study provides strong evidence for a significant association between ADHD and road crossing behaviour, particularly in complex traffic environments. The reported p-values and effect sizes suggest that the estimates are precise, but the absence of confidence intervals and not mentioning the selection bias limit the ability to quantify the precision more precisely.	Y	C	Y

							significant findings suggest a moderate to large association.				
Tabibi et al., 2023	Y	Y	Y	Y	Y	Y	Y	The study revealed significant differences between children with ADHD and TD peers in both road crossing behaviour and executive function. Children with ADHD exhibited riskier road crossing behaviours and demonstrated lower executive functioning skills. The study employed appropriate statistical methods and controlled for age, but the specific effect sizes were not reported, limiting our understanding of the strength of the associations.	The study provides strong evidence for a significant association between ADHD and road crossing behaviour. The reported p-values and effect sizes suggest that the estimates are precise, but the absence of confidence intervals limits our ability to quantify the precision more definitively.	Y	C	Y
Stavrinos et al., 2011	Y	Y	Y	Y	Y	Y	Y	The study reported significant differences between the groups, suggesting a moderate to strong association between ADHD and road crossing behaviour. However, the specific effect sizes (e.g., standardised coefficients) were not provided, making it difficult to quantify the strength of the associations.	while the study provides evidence for a significant association between ADHD and risky crossing behaviours, the precision of the treatment effect estimate is difficult to assess without additional information on the confidence intervals, and sensitivity analyses.	Y	C	Y
Purcell et al., 2012	Y	Y	Y	Y	Y	Y	Y	The study found significant differences between children with DCD and TD children in terms of looming sensitivity. Children with DCD had lower looming detection thresholds, suggesting they were less able to detect approaching objects. The study used appropriate statistical methods to analyse the data. While the study did report significant p-values, this measure do not provide a direct measure of effect size. Standardised coefficients offer a more comparable and interpretable way to quantify the strength of the association between variables.	The study provides evidence for a significant association between DCD and reduced looming sensitivity. The study reported significant p-values for the observed effects, suggesting that the findings are statistically significant. This means there is a significant association between DCD and reduced looming sensitivity. However, the precision of the treatment effect estimate is difficult to assess without additional information on the confidence intervals, and sensitivity analyses.	Y	Y	Y

Purcell et al., 2011	Y	Y	Y	Y	Y	Y	Y	The study found significant differences between children with DCD and TD children in terms of roadside judgments. Children with DCD had difficulty judging relative approach rates and tended to choose larger crossing gaps. The study provides evidence for a significant association between DCD and roadside judgments. However, the specific magnitude of the treatment effect (effect size) would be clearer if the exact values of standardized coefficients or other effect size measures were provided.	The study reported significant p-values for the observed effects, suggesting that the findings are statistically significant. However, confidence intervals would provide more accurate quantitative measure of the precision of the estimates.	Y	Y	Y
Purcell and Romijn, 2017	Y	Y	Y	Y	Y	Y	Y	The study found a significant difference in accuracy between children with DCD and TD children on the egocentric condition, but not on the allocentric condition. This suggests that the egocentric viewpoint may be more effective for teaching road safety to children with DCD. the study provides evidence for a moderate effect of the egocentric viewpoint on road safety accuracy in children with DCD (r = 0.31).	There is a significant p-values for the observed effects, suggesting that the findings are statistically significant. The study did not explicitly mention confidence intervals, which are a measure of the precision of an estimate.	Y	Y	Y
Purcell et al., 2017	Y	Y	Y	Y	Y	Y	Y	The study found significant differences between children with DCD and TD children in terms of road crossing judgments. Children with DCD consistently selected insufficient temporal crossing gaps for all vehicle speeds, suggesting a potential risk of collisions.	While the study provides evidence for a significant association between DCD and roadside judgments, the precision of the treatment effect estimate is difficult to assess without additional information on the confidence intervals.	Y	Y	Y

Table 5.5 JBI appraisal results for the cross-sectional studies

Appraisal question: 1. Were the criteria for inclusion in the sample clearly defined?; 2. Were the study subjects and the setting described in detail?; 3. Was the exposure measured in a valid and reliable way?; 4. Were objective, standard criteria used for measurement of the condition?; 5. Were confounding factors identified?; 6. Were strategies to deal with confounding factors stated?; 7. Were the outcomes measured in a valid and reliable way?; 8. Was appropriate statistical analysis used?

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Parr et al., 2021	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
Parr, 2023	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Toye, 2016	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

5.3.4 Themes

Three main themes emerged based on a narrative analysis approach recommended by the Cochrane Consumers and Communication Review Group (Ryan, 2019). To identify these themes, data from each study were examined to uncover recurring patterns and concepts related to road crossing behaviours in children with ADHD or DCD. Patterns within the included data were explored. This led to the use of the included studies in multiple themes.

5.3.4.1 ADHD and Riskier Road-Crossing behaviour

The theme of ADHD and riskier road crossing behaviour was a central focus of the included studies (Clancy et al., 2006; Stavrinos et al., 2011; Toye, 2016; Parr et al., 2021; Tabibi et al., 2022; Tabibi et al., 2023). It showed that children with ADHD aged 5 – 17 years consistently demonstrated riskier road crossing behaviour compared to TD children (Clancy et al., 2006; Stavrinos et al., 2011; Toye, 2016; Parr et al., 2021; Tabibi et al., 2022; Tabibi et al., 2023). This included more unsafe crossings, longer wait times, selecting unsafe routes, poor ability for predicting road user intentions and a tendency to initiate crossings with less time to spare, often leading to shorter reaction times and increased risk of collisions with oncoming vehicles (Stavrinos et al., 2011; Toye, 2016; Parr et al., 2021; Tabibi et al., 2022). For example, Toye (2016) found that, children with ADHD aged 5-12 years (n=61) when finding safe crossing sites, often opted for less favourable crossing sites compared to their TD peers, such as narrow streets or busy intersections, demonstrating a lack of spatial awareness and risk assessment skills. Toye (2016) also found that children with ADHD had limited conceptual understanding of road safety principles and traffic dynamics, which hindered their ability to make informed decisions and navigate the road environment effectively. Furthermore, children with ADHD struggled to accurately predict the intentions of other road users, often misinterpreting vehicle signals or failing to anticipate the actions of pedestrians (Toye, 2016). This suggests difficulties with social perception and information processing, which are essential for safe road crossing (Toye, 2016). Moreover, the inability of children with ADHD to identify relevant environmental cues, such as traffic lights, crosswalk markings, and pedestrian signals, further compromised their ability to navigate the road safely

(Toye, 2016). When crossing roads, Tabibi et al. (2022) and Clancy et al. (2006) using matched case control methods, reported that children with ADHD aged 7 – 12 years (N=17) and 13 – 17 years (N=24) respectively were more likely to have collisions, walked slower, had a lower margins of safety, and exhibited more variable behaviour when crossing the road. Furthermore, children with ADHD aged 5 – 12 years were more likely to choose riskier crossing environments, such as crossing in situations with less time to spare and smaller gaps between vehicles (Stavrinos et al., 2011; Toye, 2016). Parr et al. (2021) also highlighted the importance of motor timing in road crossing safety for children with ADHD aged 9 – 11 years. They found that children with ADHD who exhibited poorer motor timing performance, as measured by tasks requiring duration discrimination and synchronisation-continuation, were also more likely to have difficulties in road crossing tasks (Parr et al., 2021). This suggests that motor timing deficits, rather than inattention/hyperactivity alone, may be a key factor in predicting road crossing performance.

Overall, the included studies consistently demonstrated that children with ADHD could be at increased risk of road crossing accidents due to a combination of factors. ADHD may impair risk assessments, leading to impulsive decisions and less cautious behaviour. Additionally, attentional difficulties may hinder the ability to scan the environment for potential hazards, while motor coordination issues can impact the ability to adjust movements to safely navigate traffic. These findings underscore the importance of further exploring pedestrian behaviours of children with ADHD to address these specific areas through targeted interventions to improve their road safety. Many studies relied on virtual reality (VR) or desktop tasks (Clancy et al., 2006; Stavrinos et al., 2011; Toye, 2016; Parr et al., 2021; Tabibi et al., 2022; Tabibi et al., 2023), these controlled environments offer several advantages. They allow for the precise manipulation of variables and the collection of objective data under standardised conditions, minimising the influence of extraneous factors that may be present in naturalistic settings (Vezzadini, 2004). This controlled environment can facilitate the isolation and investigation of underlying mental processes that contribute to road crossing difficulties in children with ADHD. However, it is crucial to acknowledge the limitations of these methods in terms of ecological validity and generalisability to real-world situations (Vezzadini, 2004). Given the potential safety and ethical concerns associated with naturalistic observations of road crossing behaviour in children with NDDs including ADHD and also DCD, future research should continue to focus on controlled laboratory experiments to rigorously investigate specific underlying reasons that contribute to road crossing difficulties. Once a thorough understanding of these mechanisms is established, research can then progress towards more naturalistic observations to validate and refine these findings in real-world contexts.

Overall, the included studies consistently demonstrated that children with ADHD could be at increased risk of road crossing accidents due to a combination of factors. ADHD may impair risk assessments, leading to impulsive decisions and less cautious behaviour. Additionally, attentional difficulties can hinder the ability to scan the environment for potential hazards, while motor coordination issues can impact the ability to adjust movements to safely navigate traffic. These findings underscore the importance of further exploring pedestrian behaviours of children with ADHD to address these specific areas through targeted interventions to improve their road safety.

5.3.4.2 DCD and Road-Crossing Difficulties

The studies included in this theme explored the challenges faced by children with DCD in navigating road crossing situations (Purcell et al., 2011; Purcell et al., 2012; Purcell et al., 2017; Purcell and Romijn, 2017; Parr, 2023). Children with DCD demonstrated deficits in perceptual skills, including visual processing, depth perception, and motion detection (Purcell et al., 2017; Purcell and Romijn, 2017; Purcell et al., 2011; Purcell et al., 2012). When considering visual processing, children with DCD aged 6 – 11 years demonstrated lower looming detection sensitivity compared to their TD peers, particularly in perifoveal (peripheral) viewing conditions (Purcell et al., 2012). This suggests that they may have difficulties detecting vehicles approaching at standard urban speeds (30 mph in the UK) in the periphery of the visual field (Purcell et al., 2012). This may lead to increased risk of pedestrian accidents due to an inability to detect approaching vehicles travelling at speed. Additionally, children with DCD aged 6 – 11 years were less able to judge which vehicle was travelling faster in a discrimination task, especially when the vehicles were relatively similar in size (Purcell et al., 2011). Purcell et al. (2017) further found that children with DCD aged 6 – 11 years consistently selected insufficient temporal crossing gaps across different vehicle approach speeds (20, 30, and 40 mph), indicating a potential risk of accidents. In contrast, age matched TD children demonstrated appropriate gap selection for lower speeds but struggled at higher speeds (Purcell et al., 2017). These findings suggest that children with DCD may rely more on distance cues and have less ability to compensate for speed when making crossing decisions. There were also differences between children with DCD and TD children aged 6 – 12 years in the accuracy of identifying the safest crossing sites (Purcell and Romijn, 2017). TD children showed higher accuracy in identifying safe crossing sites compared to the DCD group, particularly in egocentric viewpoints (Purcell and Romijn, 2017). Parr (2023) further contributes to this understanding by emphasising the role of motor coordination and timing in road crossing behaviour. Parr's findings suggest that movement coordination difficulties and slower processing speed were associated with greater motor timing variability in children aged 9 – 11 years (Parr, 2023). These factors collectively influenced road crossing behaviour, with deficits in motor coordination and timing leading to riskier gap selection and poorer road crossing timing (Parr, 2023).

The combined evidence from these studies highlights the multifaceted nature of the challenges faced by children with DCD in road crossing situations. These challenges include deficits in perceptual skills, such as visual processing and motion detection, as well as difficulties in motor coordination and timing (Purcell et al., 2011; Purcell et al., 2017; Purcell and Romijn, 2017). Additionally, children with DCD may struggle to accurately judge relative approach rates and select appropriate crossing gaps, further increasing their risk of accidents. Addressing these complex issues requires a comprehensive approach that targets both perceptual-motor deficits and decision-making skills to improve road safety for children with DCD.

5.3.4.3 Key Factors in Pedestrian Safety for Children with DCD and ADHD

Understanding the factors that influence pedestrian safety for children with neurodevelopmental disorders, such as DCD and ADHD, is crucial for developing effective solutions (Toye, 2016). While previous themes discussed DCD or ADHD separately, it is important to investigate the similarities and differences between DCD and ADHD. Although only one study (Parr, 2023) investigated both DCD and ADHD and the relation to poor pedestrian performance, the included studies identified several key factors that influence pedestrian safety and performance for children with DCD and ADHD. One of the factors impacting children's ability to navigate the road safely is motor coordination. Several studies highlighted the importance of motor coordination in pedestrian safety for children with DCD and ADHD (Clancy et al., 2006; Purcell et al., 2012; Parr et al., 2021; Tabibi et al., 2022; Parr, 2023). Poor pedestrian skills including slower walking speeds, variable performance, and difficulties in adjusting their own speed were all highlighted to be an indicative of potential motor coordination deficits in children with DCD or ADHD (Clancy et al., 2006; Purcell et al., 2017; Tabibi et al., 2022; Parr, 2023). While these methods can provide valuable insights into the challenges faced by children with DCD and ADHD, they may not directly quantify underlying motor components. These deficits were associated with poorer road crossing timing, including riskier gap selection and less efficient use of available crossing times (Purcell et al., 2017; Parr et al., 2021; Parr, 2023). Furthermore, motor coordination was found to be interconnected with executive functioning and processing speed, suggesting that addressing these factors comprehensively may be necessary for improving road safety for children with DCD or ADHD (Purcell et al., 2012; Tabibi et al., 2022; Parr, 2023). While inattention/hyperactivity may not directly affect road crossing performance in some studies, it can indirectly influence it through its impact on motor timing (Parr et al., 2021). Motor timing refers to the ability to coordinate the timing of movements (Parr, 2023). In the context of road crossing, it involves the ability to initiate a road crossing at the appropriate moment, adjust the pace of walking to match the traffic flow, and coordinate movements to avoid obstacles (Parr et al., 2021).

Executive dysfunction emerged as another factor influencing pedestrian safety for children with ADHD. However, no study investigated the relationship between DCD and executive dysfunction with regards to road crossing. Although multiple studies have demonstrated a possible link between deficits in executive function, such as attention, decision-making, and working memory, and increased risk of unsafe crossings (Stavrinos et al., 2011; Parr, 2023; Tabibi et al., 2023). While Starvinos et al. (2011) found that executive dysfunction in children with ADHD aged 7 – 10 years mediated poor pedestrian performance, Parr (2023) further reported that poor visual processing mediated the relationship between poorer executive functioning and motor timing in children with ADHD aged 9 – 11 years. Parr (2023) also showed that difficulties in coordinating movements and processing visual information in children with ADHD can lead to variability in timing, which may predict riskier temporal crossing gap selection. This suggests that executive functioning plays a crucial role in mediating the relationship between these neurodevelopmental disorders and pedestrian behaviour (Stavrinos et al., 2011; Parr, 2023; Tabibi et al., 2023). Moreover, executive functioning deficits in children with ADHD were found to be associated with riskier crossing behaviours, including choosing unsafe crossing sites, having longer starting delays, and making more tight fits (Parr, 2023; Tabibi et al., 2023). These findings highlight the importance of executive function challenges in road safety for children with ADHD.

Some of the included studies highlighted the significant role of complex traffic in influencing the road crossing behaviour of children with ADHD. Complex traffic environments, characterised by higher traffic volumes, faster speeds, and more intersections, can pose greater challenges for these children aged 9 – 11 years, increasing their risk of accidents (Parr et al., 2021; Tabibi et al., 2022). This has been shown particularly true for children with ADHD, who may have difficulties in processing information, making decisions, and coordinating their movements in such environments (Clancy et al., 2006; Parr et al., 2021; Tabibi et al., 2022; Parr, 2023). However, one study directly investigated the impact of complex traffic, crossing one-lane and two-lane traffic with multiple car speeds, with children with DCD. Therefore, navigating complex traffic situations may be important for improving pedestrian safety for children with ADHD but this is yet to be confirmed in children with DCD.

While DCD and ADHD are both neurodevelopmental disorders with some commonalities (Goulardins et al., 2024), the included studies primarily focused on different pedestrian skills for each group, limiting direct comparison between the two. Table 5.6 provides a summary of the pedestrian skills included in the studies. Additionally, one of the primary characteristics of the included studies is their reliance on virtual reality (VR) or desktop tasks to assess road crossing behaviour. While these methods may not fully capture the complexities of real-world road crossing situations, they offer controlled environments for better focus and investigation of pedestrian safety. Previous studies found that lab-based studies often have higher internal validity but lower generalisability, while real-world studies offer higher external validity but face challenges with data quality and consistency (Holleman et al., 2020; Yang & Nguyen, 2022). Additionally, investigating the impact of traffic complexity on road crossing behaviour in children with DCD or ADHD would provide valuable insights, as this area has not been extensively explored in previous studies. Therefore, future research should include direct comparisons between children with DCD and ADHD to identify unique challenges faced by each group in road crossing situations.

Table 5.6 Definitions and summary of pedestrian skills considered in the included papers and the investigated population.

Pedestrian Skill	Definition	Group(s)
Safe Route Selection	The ability to choose appropriate crossing route	ADHD
Crossing Gap Selection	The ability to choose appropriate crossing gap	DCD, ADHD
Look Ratio	The amount of time spent looking at traffic	ADHD
Start-Delay	The time taken to initiate crossing	ADHD
Time to Contact	The time between the pedestrian's decision to cross and the vehicle's arrival	DCD, ADHD
Wait Time	The duration spent waiting before crossing	ADHD
Predicting Road User Intentions	The ability to anticipate the actions of other road users, such as drivers and cyclists	ADHD
Looming Detection Sensitivity	The ability to perceive approaching objects and assess their speed and distance	DCD
Depth Perception/ Relative Approach Rate Judgment	The ability to judge the distance between objects and their relative positions	DCD

5.4 Discussion

A comprehensive literature search identified 4,084 potential studies. After removing duplicates and applying strict inclusion criteria, 14 relevant studies were selected for this review. These studies focused on pedestrian skills in children with DCD or ADHD, using quantitative research methods, 11 studies were included and reviewed. The first theme explored the road crossing behaviour of children with ADHD. Children with ADHD consistently exhibited riskier road crossing behaviours than TD children, including more unsafe crossings, shorter start-delays, longer wait times, and difficulties in selecting safe routes and predicting road user intentions (Clancy et al., 2006; Stavrinos et al., 2011; Toye, 2016; Parr et al., 2021; Tabibi et al.,2022; Tabibi et al., 2023).

Conversely, the second theme included studies which explored pedestrian behaviours of children with DCD. The studies in this theme underscore the multifaceted challenges faced by children with DCD in road crossing situations. These challenges included deficits in perceptual skills, motor coordination, decision-making, and visual processing difficulties (Purcell et al., 2011; Purcell et al., 2012; Purcell et al., 2017). Specifically, children with DCD may struggle with visual processing and motion detection, which may impact their ability to perceive approaching vehicles and navigate traffic safely (Purcell et al., 2012; Purcell et al., 2017). From an ecological perspective, these perceptual difficulties may be exacerbated by the dynamic and complex nature of the traffic environment. For example, children with DCD may have difficulties judging different relative approach rates and selecting appropriate temporal crossing gaps in one-lane or tow-lane conditions, demonstrating deficits in perceptual-motor skill and risk assessment (Purcell et al., 2017). Additionally, motor coordination difficulties, such as slower walking speeds, can hinder their ability to execute safe crossings (Parr, 2023; Purcell et al., 2017). These combined challenges contribute to the increased risk of accidents for children with DCD.

Furthermore, the third theme focused on the factors impacting the pedestrian behaviours of children with DCD and with ADHD. Motor coordination, executive function, and complex traffic are all critical factors mentioned in the included studies as influencing pedestrian safety for children with ADHD and with DCD (Parr et al., 2021; Tabibi et al., 2022; Purcell et al., 2012; Tabibi et al., 2022; Parr, 2023). However, while the current literature highlights the role of executive dysfunction in mediating the relationship between ADHD and riskier road crossing behaviour, it primarily focuses on internal cognitive processes such as attention and decision-making. The ecological perspective suggests that perception is not merely a passive process of receiving and interpreting sensory information (Gibson, 1979). Instead, it is an active, dynamic process that is shaped by the interaction between the organism and its environment (Gibson, 1979). This perspective emphasises the importance of considering how children with ADHD or children with DCD perceive and interact with the dynamic and ever-changing traffic environment. For example, how do attentional difficulties impact their ability to perceive and respond to changes in traffic flow or the behaviour of other road users? Furthermore, the impact of complex traffic was limited with one study focus on children with ADHD (Tabibi et al., 2022) and another on children with DCD (Purcell et al., 2017). The characteristic of DCD and ADHD including poor visuo-motor coordination, inattention and hyperactivity (Purcell et al., 2012; Purcell et al., 2017; Tabibi et al., 2022; Parr, 2023), all of which can be exacerbated in complex traffic situations. These children may struggle to process information quickly, assess risks accurately, and coordinate their movements in environments with higher traffic volumes, faster speeds, and more intersections. Therefore, it is reasonable to infer that complex traffic may pose additional challenges for children with DCD and children with ADHD, potentially increasing their risk of accidents. Further research is needed to confirm this. Future research should explore how ecological factors, such as different approaching vehicles sizes and speeds, influence the perception and interpretation of information by children with DCD or children with ADHD, and how this, in turn, impacts their road crossing behaviour.

5.5 Conclusion

The aim of this review was to investigate the pedestrian behaviours of children with DCD or ADHD. The included studies reported consistently that children with DCD or ADHD exhibited more riskier pedestrian behaviours when compared to their TD peers. The included studies further identified several key factors influencing pedestrian safety for children with DCD and with ADHD. Future research should focus on directly comparing these groups to identify if there are unique challenges faced by each group.

The following Chapters (6, 7, & 8) describe a series of quasi-experiments that were conducted to further investigate pedestrian skills in children with DCD and with ADHD. Common methods used in the quasi-experiments are provided in Chapter 2 (Common methodology). These quasi-experiments focused on:

- **Identifying safe crossing sites:** This skill is crucial as it reflects the child's ability to assess the environment and make informed decisions about where to cross, emphasising the interaction between the individual and their environment (different crossing sites).
- **Looming detection:** This skill is critical for perceiving and responding to approaching vehicles, a crucial aspect of road crossing safety. It aligns with an ecological perspective by examining how children perceive and respond to dynamic events in their environment.
- **Gap acceptance:** This skill requires the integration of perceptual information with motor actions (timing of crossing). This aligns with an ecological perspective by emphasising the dynamic interplay between perception and action in a real-world context.

Examining these key skills, this research aimed to gain a deeper understanding of the underlying mechanisms that contribute to the challenges faced by these populations in navigating road crossing situations.

6 Chapter Six: Identification of Safe Crossing Sites

6.1 Introduction to quasi-experiments

Previous research has documented the increased vulnerability of children with DCD and ADHD as pedestrians (Wilmut and Purcell, 2021). In Chapter 4 findings from Phase one were presented that used a qualitative approach to understand parental perspectives. Parents reported anxieties about their children's safety at different crossing sites, particularly regarding behaviours potentially linked to the core characteristics of DCD and ADHD. Parents of children with DCD reported how they often rely on others for crossing decisions. This might stem from diminished confidence or limitations in spatial awareness and perceptual abilities, which are commonly associated with DCD (Purcell et al., 2017; Falemban et al., 2024). These challenges could hinder their ability to independently assess traffic flow and make safe crossing judgments. Parents of children with ADHD expressed concerns about impulsivity and inattention near road crossings. This suggests a possible link between these core ADHD characteristics and risky behaviours at the roadside, such as crossing without looking properly or darting into traffic. Parents of children with ADHD reported that mood fluctuations could further influence decision-making and risk assessment. According to parental reports, children with both ADHD and DCD face a combination of limitations related to concentration, attention difficulties, motor skills and spatial awareness, leading to significant parental concerns about their road safety. While parental observations gained in Phase one are insightful, they lack objective measurement. To gain a more comprehensive understanding of the potential vulnerability of children with DCD or ADHD, this chapter employed a quantitative approach. This approach allowed the examination of specific components of road crossing behaviour highlighted by parents in Chapter 4. By quantifying these behaviours, parental concerns can be objectively measured.

However, some of the road crossing components highlighted in the literature review in Chapter 5 (Table 5.6), have previously been investigated in children with ADHD and DCD. For example, pedestrians are initially required to assess the situation by looking right and left (in a UK context) to identify approaching vehicles in order to determine when to cross. Stavrinos et al. (2011) found that children with ADHD aged 7-10 years move their heads right and left but do not process the visual information in a way that makes it possible for them to cross safely. Although there is no study investigating the ability to detect an approaching vehicle (looming sensitivity) in children with ADHD, children with DCD aged 6 – 11 years were found to be unable to detect approaching vehicles at speeds more than 14 mph in some viewing situations (Purcell et al., 2012), whereas typically developing peers aged 6 – 11 years can detect approaching vehicles at speeds of 20 mph (Wann et al., 2011). After assessing the environment, making a decision about when to cross is required. Purcell et al. (2011) observed that children with DCD aged 6 -11 years, choose shorter temporal crossing gaps in a perceptual task compared to their typically developing peers, suggesting insufficient crossing gaps are left by children with DCD. Similarly, Tabibi et al. (2022) investigated the effect of complex traffic and found shorter crossing gaps and unsafe crossings in children with ADHD aged 8 – 12 years compared to typically developing children (Tabibi et al., 2022). In addition to the selection of the shorter temporal crossing gaps, children with DCD typically walk more slowly (Purcell et al., 2017) and adolescents with ADHD aged 13 – 17 years were found to walk more slowly in a simulated road crossing task compared to their typically developing peers (Clancy et al., 2006). Moreover, where children with DCD or ADHD choose to cross remains unexplored. Therefore, studies to date have investigated some components of road crossing (see Chapter 5 for in-depth exploration of the current road crossing components). However, there are other components that need to be explored in order to better understand parents' concerns which can be explored using quantitative methods regarding their children's roadside behaviours. Phase two of this thesis therefore aimed to quantitively explore components of road crossing such as selecting safe crossing sites, looming detection thresholds and gap acceptance thresholds, amongst children with DCD or ADHD. Table 6.1 presents the demographic characteristics of the participants in each group.

Characteristic	TD (n=12)	DCD (n=10)	ADHD (n=9)	Total (n=31)
Age Mean (SD)	13.58 (1.78)	13.20 (1.69)	12.78 (1.86)	13.23 (1.75)
Male	9	7	6	22 (71%)
Female	3	3	3	9 (29%)

6.1.1 Quasi-experiments research question and hypotheses

Phase two aimed to quantitatively investigate components of road crossing among children with ADHD or DCD who are reportedly more at risk at the roadside. This included the components of: (1) where to cross (see Chapter 6) when to cross (see Chapter 7 and 8). To achieve this, the following questions were formulated and further investigated in each relevant chapter.

- Where to cross:
  - Do children with ADHD or DCD select safe crossing sites compared to their TD peers?
- When to cross:
  - Do children with DCD or ADHD have sufficient looming thresholds in a virtual environment to detect vehicles approaching at the speeds typically encountered in residential areas compared to their TD peers?
  - Do children with DCD or ADHD select sufficient temporal crossing gaps in a virtual environment compared to their TD peer?
  - Do children with ADHD or DCD select sufficient temporal crossing gaps in a virtual environment when a perceptual and perceptual-motor response is needed, compared to their TD peers?

The hypotheses were (Ha = alternative hypothesis):

- Where to cross:
  - (Ha): Children in the TD group will demonstrate a significantly higher ability to identify safe crossing sites compared to children with DCD and children with ADHD.

  It is important to note that this study does not hypothesise a significant difference in safe crossing site identification ability between the DCD and ADHD groups. This is due to the lack of strong evidence in the existing literature to suggest a directional difference between these two neurodevelopmental groups in this specific task.

- When to cross
    - Children with DCD and children with ADHD would exhibit significantly lower looming detection speed thresholds compared to TD children, indicating reduced sensitivity to approaching vehicles. Due to the lack of direct comparative studies, the direction of differences between DCD and ADHD was exploratory.
    - (Ha): participants will have lower looming detection thresholds for larger stimuli (cars) compared to smaller stimuli (motorbikes).
    - (Ha): there would be a difference in the proportion of correct saccades towards the stimulus between the diagnostic groups (DCD and ADHD) and the TD group. The comparison of saccadic differences between the DCD and ADHD groups will be explored.
    - (Ha): there will be a significant difference in temporal gap acceptance thresholds between TD children and children with DCD or ADHD. The comparison of temporal gap acceptance thresholds between the DCD and ADHD groups will be explored.
    - (Ha): there will be a significant difference in perceptual and perceptual-motor temporal gap acceptance thresholds between TD children and children with DCD or ADHD.

6.2 Identification of safe crossing sites quasi-experiment

Road safety is a critical concern, especially for young children. Despite knowledge of road safety rules, such as the Green Cross Code, young children, particularly those aged 9 years and under, often struggle to accurately identify safe and dangerous road crossing scenarios (Ampofo-Boateng & Thomson, 1991). This limited ability to recognise potential hazards puts them at a heightened risk of not identifying safe crossing sites. Previous research has highlighted the importance of visual attention, selective processing, and quick decision-making for safe pedestrian navigation (Tabibi & Pfeffer, 2003). In their computer-based task, Tabibi and Pfeffer (2003) found that older TD children (10-11 years old) and adults were more accurate than younger children (6-9 years old) in identifying safe crossing sites, although reaction times were slower for all age groups when distractions were present. Notably, the speed of identification did not strongly correlate with accuracy, suggesting that these factors are relatively independent (Tabibi & Pfeffer, 2003). These findings highlight the importance of investigating each group of pedestrians separately for tailored road safety intervention. Tabibi & Pfeffer (2003), therefore, indicated that attention is crucial for the rapid and accurate identification of safe road crossing sites, particularly for younger children. Tabibi, & Pfeffer (2007) further investigated the effect of distractors in the identification of safe crossing sites. They stated that the ability to correctly identify safe and dangerous road crossing sites was found to be associated with selective attention and divided attention skills, particularly for children.

Furthermore, children's ability to identify safe crossing sites could improve with age (Tabibi, & Pfeffer, 2007). Ampofo-Boateng & Thomson (1991) initially stated young children, particularly those aged 9 years and under, are at heightened risk of road accidents due to their limited ability to recognise dangerous road crossing situations, even when they are familiar with road safety rules like the Green Cross Code. They further elaborated that younger children often rely on obvious features like crosswalks and may struggle to recognise complex hazards (Boateng & Thomson, 1991). However, a deeper understanding of the specific challenges faced by older children, particularly those with NDDs such as DCD and ADHD, remains limited.

As also highlighted in Chapter 4 (Falemban et al., 2024), parents of children with DCD and/or ADHD reported a range of challenges faced by children in these groups, including difficulties with visual attention, decision-making, and spatial awareness. They also identified a variety of challenges faced by their children with DCD and/or ADHD in navigating road infrastructures (Falemban et al., 2024). While zebra crossings and signalised crossings were generally perceived as safer, parents of children with ADHD expressed particular concerns about driveways, suggesting potential attentional deficits associated with this condition (Falemban et al., 2024). However, less is known about how children with DCD and/or ADHD perform when identifying safe crossing sites. To further explore this and provide objective evidence, a series of quasi-experimental tasks were conducted to assess specific components of road crossing behaviour. This chapter presents the results of the first quasi-experiment, which focused on identifying safe crossing sites.

6.3 Methods

To investigate the identification of safe crossing sites in children with DCD, ADHD, and TD peers, a computer-based eye-tracking task was conducted. This quasi-experiment utilised a series of static images depicting various road crossing scenarios to assess participants' ability to identify safe and unsafe crossing sites. This approach, while replicating previous research (e.g., Tabibi & Pfeffer, 2003), combined the strengths of static image presentation with eye-tracking technology to gain deeper insights into visual attention and decision-making processes.

6.3.1 Research Question

This quasi-experiment aimed to address the following research question:

- Do children with DCD or ADHD exhibit differences in the identification of safe crossing sites compared to their TD peers?

Secondary Question:

- What are the visual strategies of children with DCD, ADHD and TD in relation to their children's ability to identify safe crossing sites?

6.3.2 Null Hypothesis (H_0):

- There will be no significant difference in the ability to identify safe crossing sites between children with DCD, ADHD, and TD peers.

6.3.3 Alternative Hypothesis (Ha):

- Children in the TD group will demonstrate a significantly higher ability to identify safe crossing sites compared to children with DCD and children with ADHD.

This study does not anticipate a significant difference in safe crossing site identification ability between the DCD and ADHD groups due to the lack of strong evidence in the existing literature to suggest a directional difference between these two NDDs groups in this specific task.

6.3.4 Stimulus Presentation

The study utilised a series of static images depicting various road crossing scenarios. Each image featured a ‘child’ standing at the edge of a road, facing towards the traffic. The images included a variety of visual distractions, such as houses, shops, bus stations, and lamp posts, to simulate real-world pedestrian environments. A total of 11 crossing sites, representative of UK road scenarios, were presented sequentially in a random order. The scenarios included a straight road, zebra crossing, blind bend, pelican crossing, roundabout, traffic island, signalised crossing, parked cars, brow of a hill, junction, and road crossing patrol (similar to those used in Tabibi & Pfeffer, 2003), adapted to reflect local UK road conditions. The road crossing patrol scenario served as a practice trial, while the remaining 10 scenarios were used for data collection. Five of the scenarios featured safe crossing sites, and five featured unsafe crossing sites. Participants were asked to identify each crossing site as safe or unsafe by verbally stating their response and clicking the corresponding button on the screen with a mouse. The identification accuracy was scored based on the number of correct responses, with a maximum score of 10. For visual examples of the stimuli used, please refer to Appendix 6.1. Figure 6.1 provides an example of a safe and unsafe crossing site.

Blind Bend (Unsafe) Zebra crossing (Safe)

Figure 6.1 Example of a safe and unsafe crossing site

6.3.5 Procedure

After obtaining written consent from children and parents, the children were seated comfortably in front of a Tobii Pro Spectrum eye-tracking system. Before beginning, the eye-tracking system was calibrated for each participant using a standard procedure in Tobii Pro Lab. To ensure the accuracy and precision of the eye-tracking data, a nine-point calibration procedure was conducted prior to each task using the Tobii Pro Spectrum eye tracker. The calibration was accepted if the mean error was below 0.5 degrees of visual angle, and the standard deviation was below 0.3 degrees of visual angle (Tobii Connect, 2022). The lower values for mean error and standard deviation indicate higher accuracy and precision (Tobii Connect, 2022). Figure 6.2 illustrates an example of the calibration screen used in Tobii Pro Lab. Participants were then instructed to identify safe and unsafe road crossing sites presented on the Tobii Pro Lab screen. A total of 11 crossing sites were presented sequentially in a random order. The first road crossing patrol scenario served as a practice trial, while the remaining 10 trials were used for data collection. While participants were not given a specific time limit to respond, they were aware that their responses would be timed for analysis purposes. Using a computer mouse, participants selected their answers of safe and unsafe option and were also instructed to verbalise their responses. Participants indicated their responses by clicking on the appropriate button on the screen using a computer mouse and were also instructed to verbally state their choice.

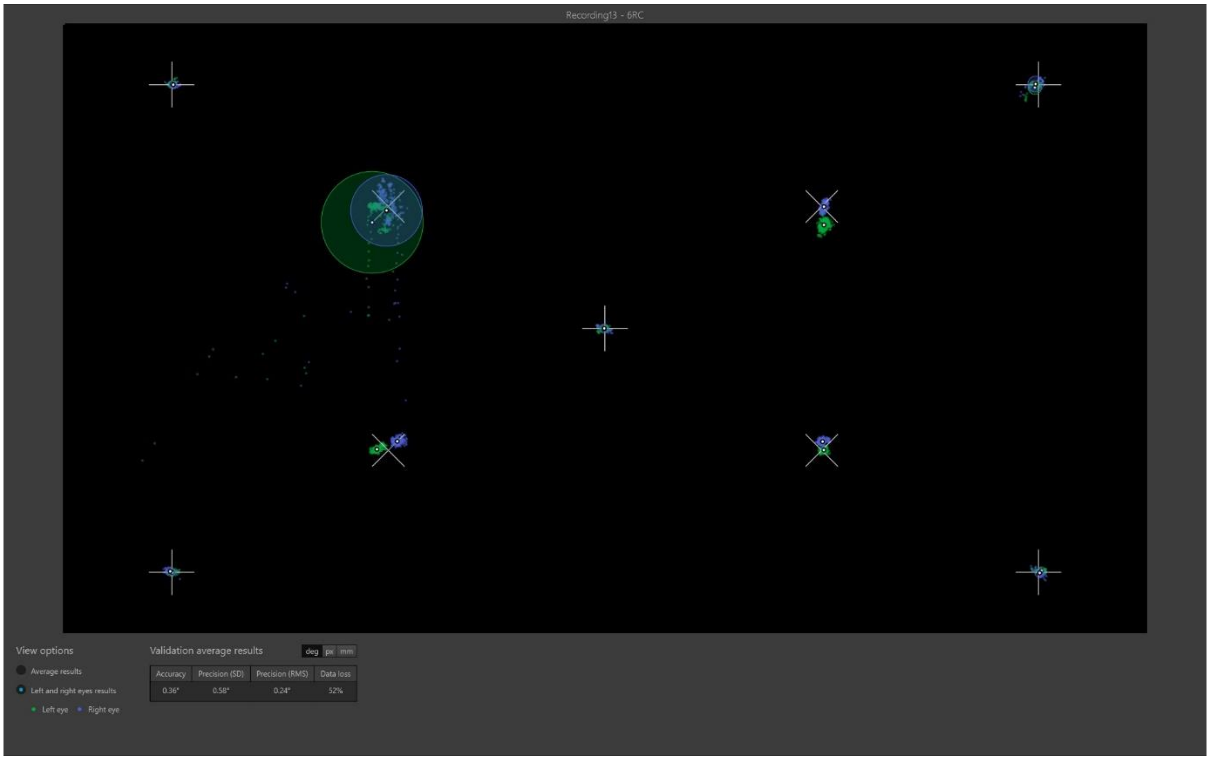


Figure 6.2: Calibration and validation of the eye tracking system in Tobii Pro Lab, accuracy and precision degrees are indicated on down left corner.

6.3.6 Data Analysis

6.3.6.1 Accuracy

Participants' responses were compared to the correct answers for each scenario. To assess overall identification accuracy, the average number of correct responses for each group (TD, DCD, ADHD) was calculated and divided by the total number of trials. To further explore patterns in accuracy, the average accuracy scores were calculated separately for safe and unsafe scenarios. This allowed for a more detailed analysis of the groups' performance on different types of crossing sites. Inferential tests were conducted to compare the mean accuracy scores between the groups for overall accuracy, safe scenarios, and unsafe scenarios. These analyses helped determine if there were significant differences in identification accuracy between the groups and whether specific types of scenarios posed greater challenges for certain groups.

6.3.6.2 Identification Time

The time taken for each participant to identify the crossing site as safe or unsafe was recorded. The mean identification time for each group (TD, DCD, ADHD) was calculated. The results were compared between groups. Inferential tests were conducted to compare the mean identification times between the groups.

6.3.6.3 Eye-Tracking Metrics (Visual Strategy)

Quantitative eye-tracking data were extracted for the following metrics to provide a statistical analysis of the visual strategy used during the tasks:

- **Mean Fixation Duration (MFD):** Defined as the average time (in milliseconds) the eye remains fixed on a single location (Negi & Mitra, 2020). MFD is used as a quantitative measure of cognitive processing, attention, and information extraction during visual tasks, and is calculated by dividing the total fixation duration by the number of fixations during a task (Shi et al., 2025).
- **Total Saccade Count:** A saccade is a rapid, high-velocity eye movement used to shift the gaze from one location to another (Leigh & Kennard, 2004). The total number of saccades provides a measure of oculomotor performance, cognitive function, and attention (Jonikaitis et al., 2013; Gibaldi & Sabatini, 2020).
- **Mean Pupil Diameter (MPD**): Defined as the average pupil diameter (in millimetres) during the trial (Petersch & Dierkes, 2021). MPD was included as a physiological indicator of cognitive effort and mental load (Cuve et al., 2021). The reliable analysis of MPD requires a critical methodological step, baseline correction to isolate cognitive changes from variations in ambient light (Mathôt et al., 2018). As the data extraction did not include this baseline correction, the MPD metric was deemed scientifically invalid for measuring cognitive effort and was therefore excluded due to concerns regarding data validity and reliability.

To test the hypotheses and to determine whether significant differences existed across or within participant groups, a Group [TDC, DCD, ADHD] x Condition [Safe Sites, Unsafe

Sites] Mixed Analysis of Variance (ANOVA) was conducted separately for each of the eye-tracking metrics. Group served as the between-subjects factor, and Condition served as the within-subjects factor.

- **Heatmap Visualisations**

Heatmaps generated by the eye-tracking system provide valuable qualitative insights into visual attention patterns and information processing strategies. Visual representations show where participants focused their attention on a stimulus (Jiang et al., 2021). Colour intensity is used to indicate the frequency of fixations with warmer colours representing areas that received more attention (Jiang et al., 2021). Figure 6.3 is an example of a heatmap. Using the eye-tracking system including Tobii Pro Lab, heatmaps from all participants within each group (TD, DCD, ADHD) for each scenario were averaged to create a single, representative heatmap for each group and scenario. The heatmap averages were used to subjectively identify the areas where the participants focused their gaze and compare different visual attention patterns of each group, serving as a supportive visualisation to the statistical findings.

Figure 6.3: An example of a heatmap

6.4 Results

This section presents the quantitative analysis of road crossing site selection, focusing on the identification of safe and unsafe crossing sites and attention allocation metrics (MFD and Saccade count) by children with ADHD, DCD, and TD peers. The research questions were to investigate whether children with ADHD or DCD exhibit differences in their ability to identify safe crossing sites compared to their TD peers and how they visually processed the environment.

6.4.1 Identification Accuracy in DCD, ADHD, & TD

The overall accuracy of identifying safe and unsafe crossing sites was high across all groups, with an average score of 8.55 out of 10. The TD group demonstrated slightly higher accuracy 8.57 compared to the DCD group 8.17 and the ADHD group 8.33. When analysing the safe and unsafe scenarios separately, the TD group consistently outperformed the other groups. However, the differences between the groups were relatively small. For the five safe scenarios, the TD group achieved an average score of 4.43 out of 5, compared to 4.17 out of 5 for the DCD group and 4.22 out of 5 for the ADHD group. For the five unsafe scenarios, the TD group scored 4.14, while the DCD and ADHD groups scored 4.00 and 4.11, respectively. Table 6.1 provides a summary of the identification accuracy of the safe crossing sites.

Table 6.1 score averages summary of identification accuracy of the safe and unsafe crossing sites

Group	Total Answers / 10 Mean | Standard Deviation (SD)	Safe Sites Correct answers / 5 Mean | SD	Unsafe Sites Correct answers / 5 Mean | SD
TD	8.92 | 1.68	4.50 | 0.90	4.42 | 1.24
DCD	8.17 | 1.11	4.17 | 0.72	4.0 | 1.13
ADHD	8.33 | 1.94	4.22 | 0.83	4.11 | 1.36

A Kruskal-Wallis test revealed no significant differences in the distribution of total score, unsafe crossing sites scores, or safe crossing site scores across the groups [TD, DCD, ADHD]. This indicates that diagnostic group did not significantly influence identification accuracy. Specifically, the Kruskal-Wallis test for total score revealed no significant differences between groups on the identification accuracy, $\chi^2(2) = 4.146$, $p = 0.126$. Additionally, the test for unsafe crossing site scores showed no significant differences between groups $\chi^2(2) = 1.116$, $p = .572$, and no significant differences between groups for safe crossing site scores $\chi^2(2) = 4.636$, $p = .098$ was found. Thus, in all cases, the *p*-values were greater than 0.05, leading to the retention of the null hypothesis and suggesting no significant differences between groups.

6.4.2 Identification Time

The TD group exhibited the fastest identification times, with a mean of 80.4 seconds and standard deviation of 2.28. The DCD group had slightly longer mean identification time (8.16 seconds, SD=2.26), and the ADHD group demonstrated the longest mean identification time (9.48 seconds) and higher standard deviation (4.39). A Kruskal-Wallis test was conducted to determine if there were significant differences in identification time across the diagnostic groups. The results indicated no significant differences between the groups [TD, DCD, ADHD] on identification time, $\chi^2(2) = 1.011$, $p = 0.603$. This suggests that the diagnostic group did not significantly influence identification time.

While the TD group demonstrated the fastest identification times on average, the differences between groups were relatively small. These findings suggest that all groups were able to identify safe and unsafe crossing sites within a comparable timeframe.

6.4.3 Quantitative Attention Allocation (Eye-Tracking Statistics)

To objectively assess attentional processing and visual strategy, two inferential eye-tracking metrics were analysed using a Mixed ANOVA with Group [TD, DCD, ADHD] as the between-subjects factor and Condition [Safe Sites, Unsafe Sites] as the within-subjects factor.

- **Mean Fixation Duration (MFD)**

The overall MFD, aggregated across all conditions, showed a tendency for the TD group to exhibit the longest mean fixation duration (M = 260.09 ms), while the DCD group (M = 236.70 ms) and ADHD group (M = 233.17 ms) had relatively similar, shorter average mean fixations.

When analysing the safe and unsafe scenarios separately, the TD group consistently demonstrated the longest mean fixations in the Safe site condition (M = 274.08 ms, SD = 87.12) compared to the DCD group (M = 228.18 ms, SD = 46.66) and the ADHD group (M = 242.74 ms, SD = 32.04). Conversely, in the Unsafe site condition, the TD group (M = 246.10 ms, SD = 38.89) and DCD group (M = 245.21 ms, SD = 47.78) exhibited comparable mean fixation durations, with the ADHD group showing the shortest mean fixation duration (M = 223.60 ms, SD = 34.03).

However, the analysis of MFD revealed no significant main effect of Group, indicating that the average length of time spent fixating on specific areas was comparable across children with TD, DCD, and ADHD, $F(2, 28) = 1.409$, $p = 0.261$. Furthermore, the analysis showed no significant interaction between Group and Condition, $F(2, 28) = 1.288$, $p = 0.292$, suggesting that the groups did not modulate their fixation durations differently depending on the condition or safety of the environment.

- **Saccade Count (SC)**

The total number of saccades provides a measure of oculomotor performance, cognitive function, visual exploration and attention. The descriptive statistics showed that the ADHD group exhibited the highest overall average number of saccades (M = 14.29 saccades), followed by the TD group (M = 13.49 saccades), and the DCD group (M = 10.78 saccades) had the lowest saccade count.

When analysing each condition, the ADHD group maintained the highest number of mean saccades in both the Safe condition (M = 15.13, SD = 7.59) and Unsafe condition (M = 13.44, SD = 7.53). The TD group exhibited a difference between conditions (Safe: M = 14.78, SD = 7.26; Unsafe: M = 12.20, SD = 5.86), while the DCD group showed very consistent (and lowest) mean saccade counts regardless of condition (Safe: M = 10.84, SD = 5.90; Unsafe: M = 10.72, SD = 6.49).

Despite these raw differences, the Mixed ANOVA revealed no significant main effect of Group, F (2, 28) = 1.000, p = 0.381. This suggests that the total number of visual shifts while searching for safe crossing sites did not differ significantly across children with TD, DCD, and ADHD. Similarly, the analysis found no significant interaction between Group and Condition, F (2, 28) = 0.332, p = 0.720.

The Pupil Dilation (MPD) metric was excluded from all inferential statistical analysis due to concerns regarding data validity resulting from the lack of baseline correction, as detailed in Section 6.3.6.3 of the Methods.

6.4.4 Qualitative Attention Allocation (Heatmap Visualisation)

To complement the non-significant statistical findings, heatmaps were used to subjectively visualise the areas where participants focused their gaze, allowing for qualitative observations of potential differences in visual scanning patterns. All participants consistently focused on traffic flow and pedestrians, indicating their recognition of these elements as important for safe road crossings. By analysing the intensity of the heatmaps, the level of attention to relevant visual cues for each group was determined. As described before, warmer colours indicate areas of more eye fixation and greater attentional focus. For the TD group, children primarily focused on traffic flow, pedestrians crossing the street and on pavements. On the other hand, the DCD group demonstrated a limited level of attention on relevant visual cues as indicated by less warm colours, ADHD children showed the least focus on these elements. Across all scenarios and groups, there was a notable concentration of attention on the related structures such as traffic islands, traffic lights, pedestrians and cars, indicating that participants were aware of their presence and considered these structures as potential obstacles or reference points. However, each group showed specific level of attention as indicated by the colour intensity. Conversely, the overhead structures including buildings, poles and other distractors received relatively less attention by TD children when compared to DCD group based on the intensity of colours in the heatmaps. However, the ADHD group exhibited a higher level of focus on these elements in comparison to DCD and TD groups. Therefore, this may suggest that children with ADHD can be easily distracted by these less relevant structures during this crossing site identification task. Figure 6.4 illustrates the group average attention intensity as heatmaps for the participants of TD, DCD, and ADHD groups in one scenario (the straight road crossing). Another example of group-averaged heatmaps is showed in Figure 6.5 for road crossing between parked cars scenario.

(a) TD

(b) ADHD

(C) DCD

Figure 6.4: group-averaged heatmaps showing the averages of the 3 groups including (a) TD, (b) ADHD and (c) DCD (Straight Road Scenario)

(a) TD (b) ADHD

(C) DCD

Figure 6.5: group-averaged heatmaps showing the averages of the 3 groups including (a) TD, (b) ADHD and (c) DCD in the Parked Car scenario

6.5 Discussion

The aim of this quasi-experiment was to investigate the ability of children with DCD or ADHD to identify safe crossing sites compared to their TD peers. The findings provide valuable insights into the visual attention strategies employed by these groups. The TD group demonstrated slightly higher overall accuracy and faster identification times, which were not statistically significant compared to the DCD or ADHD groups. This could suggest that the characteristics of DCD or ADHD have limited impact on identification accuracy and time to identify safe and unsafe crossing sites. The accuracy score for all groups was around 8 out of 10. Reasons which can be attributed to this high score is the age of the current study population (11-16 years). While Tabibi & Pfeffer (2007) stated that children's ability to identify safe and unsafe road crossing sites improves with age and experience, older children, particularly those above the age of 9 years, tend to have a stronger ability to recognise dangerous road crossing situations compared to younger children (Ampofo-Boateng & Thomson, 1991). Thus, while older children may be able to identify safe crossing sites, this skill in children with DCD or ADHD, particularly under 9 years old, remained unexplored.

The quantitative eye-tracking metrics consistently supported the null findings observed in the identification accuracy and time results. The analysis of MFD, a proxy for cognitive processing, revealed no significant main effect of Group or significant Group x Condition Interaction. Similarly, the Saccade Count was also not statistically significant. This pattern of non-significant findings suggests that, in this specific identification task, the groups did not statistically differ in their cognitive processing or their rate of visual scanning. Consequently, the research proceeded to a qualitative analysis of the heatmap visualisations to better understand the visual strategy and attention distribution that may exist despite the non-significant quantitative measures.

When looking at the averaged heatmaps of all groups and the presented colour intensity, they showed that all groups appeared to consider traffic related structures including pedestrians and cars as crucial factors for assessing site crossing safety. However, the ADHD group demonstrated a more diffuse attention pattern and tended to also look at overhead structures as indicated by the diffused lighter colours on the ADHD averaged heatmaps. Despite the non-significant of MFD and SC results, this may relate to the higher SC in ADHD group when compared with DCD or TD. The DCD group, on the other hand, exhibited a less scattered approach on the averaged heatmaps indicating less attention to overhead structures when compared to ADHD group. This aligns with numerically longer MFD, suggesting deeper processing per point in comparison to the ADHD group, even though not statistically significant. The averaged heatmaps of the TD group showed a more focused and strategic approach as indicated by the warmer colours around the traffic related structures and less light colours on the overhead structures when compared to the DCD and ADHD groups, also aligning with their MFD trend. These differences in visual attention strategies, even though subjective, have important implications for road safety. It is possible that children with ADHD may be more likely to be distracted, make impulsive decisions, and overlook potential hazards. Previous research highlighted attention deficits in ADHD, which can lead to impulsive decision-making and increased risk-taking behaviours (Clancy et al., 2006). On the other hand, the DCD group showed less attention to overhead structures. Overall, all groups demonstrated an awareness of traffic related factors, such as the presence and movement of pedestrians and vehicles, when assessing crossing site safety, although they were using different visual strategies.

While the findings from this task suggest that children with DCD or ADHD showed subjectively different visual explorations with less focus on traffic related structures in crossing site identification when compared to TD children, the differences in identification accuracy between TD, DCD and ADHD group were not statistically significant. These findings were supported by previous studies (Ampofo-Boateng & Thomson, 1991; Tabibi & Pfeffer, 2003; Tabibi, & Pfeffer, 2007). Ampofo-Boateng & Thomson (1991) Tabibi & Pfeffer (2003) found that older TD children (10-11 years old) were more accurate than younger children (6-9 years old) in identifying safe crossing sites. Similarly, the finding from this study suggests that there was no statistically significant difference in terms of identification of safe crossing sites and time to identify safe crossing sites among children with DCD, ADHD and TD peers (aged 11 – 16 years). Tabibi & Pfeffer (2003) & (2007) emphasised the importance of attention for the rapid and accurate identification of safe road crossing sites, particularly for younger children, highlighting the role of selective and divided attention. Therefore, it can be inferred that older children may have more developed attentional skills, allowing them to focus on relevant information more effectively than younger children regardless of the characteristics of DCD or ADHD. Overall, while previous research showed that older TD children can identify safe crossing sites, this research supports this notion and extends these findings by demonstrating that the characteristics of DCD or ADHD may have limited impact on safe crossing site identification task.

It is important to note that this task had limitations. The sample size was relatively small, and the findings may not be generalisable to all TD children or children with ADHD or

DCD. Future research with larger sample sizes is needed to confirm and extend these findings. Additionally, there were differences in the identification time between Tabibi & Pfeffer (2003) and the same task in the current study. The observed discrepancy in identification times can be partially attributed to the differing response modalities employed. In the current task, participants used a mouse to indicate their responses along with a verbal response, while Tabibi & Pfeffer's participants used a response box, a physical device with buttons or keys that participants can press with dominant hand to indicate their responses (Tabibi & Pfeffer, 2003). This difference possibly led to longer identification times in the current task in comparison to Tabibi & Pfeffer (2003) study. This might be due to the additional motor demands and cognitive load associated with using a mouse. Mouse-tracking data has shown that participants exhibit slower response times and less precise cursor movements when performing secondary tasks with higher cognitive demands (Rheem et al., 2018). This suggests that the use of a mouse might have contributed to the longer identification times observed in the current study. Future studies comparing different response modalities could help clarify the impact of this factor on identification times in road crossing tasks.

6.6 Conclusion

This study investigated the ability of children with DCD or ADHD to identify safe crossing sites compared to their TD peers. The findings revealed that all groups were capable of identifying safe and unsafe crossing sites with comparable accuracy and speed. While older children generally exhibit improved abilities in identifying safe crossing sites, the current findings suggest that the presence of DCD or ADHD may not significantly impact this ability in older age groups. While this chapter provides insights into the skill of safe and unsafe crossing site identification and visual attention strategy, it is important to acknowledge that successful road crossing relies on perceptual-motor skills such as identifying approaching vehicles and selecting safe crossing gaps. Thus, the next chapters will investigate looming detection and gap acceptance in children with DCD and ADHD compared to their TD peers.

7 Chapter Seven: Looming Detection in Children with DCD, ADHD, and TD Children

7.1 Introduction

In the preceding chapter, the abilities of children with DCD and ADHD to identify safe crossing sites were examined. The findings revealed that while all groups demonstrated good accuracy and speed in their judgments, they exhibited distinct visual attention strategies. Specifically, children with ADHD displayed a more diffuse and exploratory visual exploration pattern, whereas children with DCD adopted a more focused and strategic approach.

Building upon these insights, this chapter presents the next quasi experiment to explore another crucial aspect of road safety: looming detection. Looming detection refers to the ability of a visual system to perceive and respond to objects that are rapidly approaching, which is critical for survival as it helps avoid collisions and detect threats (Lee, 1976; Purcell et al., 2012). The general introduction (Chapter 1) discussed how the perception of time-to-contact (TTC) is crucial for pedestrians to avoid accidents (Lee, 1976; Wann et al., 2011; Purcell et al., 2012). TTC can be estimated based on the ratio of an object's distance and velocity, which is perceptually specified by the ratio of its optical size to its rate of looming (Lee, 1976). According to Lee (1976), this relationship is known as tau and can be expressed mathematically as follows:

Equation 1 :

$$TTP = \frac{z(t)}{v(t)} = \frac{\theta(t)}{\dot{\theta}(t)} = tau$$

z(t) = distance of the approaching object

v(t) = velocity of the approaching object

θ(t) = optical size of the approaching object

θ'(t) = rate of looming of the approaching object

Purcell et al. (2011) and Wann et al. (2011) further explained that for an observer to make an accurate TTC judgment based on tau, the rate of optical looming θ'(t) must exceed an observer's perceptual threshold. This means if the object's image expands at a rate below the observer's threshold, they may not be able to detect that it is approaching, leading to an inaccurate TTC judgment (Purcell et al., 2017). This can be particularly dangerous in situations like crossing a road, where misjudging the optical expansion of an approaching vehicle can have serious consequences (Purcell et al., 2017). In fact, a low rate of expansion can create a dangerous illusion where faster vehicles may be perceived as not approaching because they loom less, leading to a false sense of safety. The rate of optical looming during approach is a function of the object's size (D), approach velocity *v(t)*, and distance *z(t)*, as shown in Equation 2:

$$\theta'(t) = \frac{D\ v(t)}{z^2}$$

D = size of the approaching object

Equation 2 demonstrates that faster vehicles appear to loom more quickly than slower vehicles when they are at the same distance from the observer. However, if the observer requires a specific amount of time to cross the road (tc), substituting z^2 (the distance of the object) for $(v \times tc)^2$ (where v is the velocity of the object) into Equation 2 reveals a different relationship (Wann et al., 2011). This is shown in equation 3 as follows:

$$\dot{\theta}(t) = \frac{D}{t_c^2 \times v(t)}$$

This transformation in Equation 2 is significant because it inverts the relationship between speed and the rate of looming. While faster vehicles typically loom more rapidly at a given distance, when there is a fixed crossing time, a faster vehicle must be further away to allow for the same crossing duration. Consequently, the vehicle appears smaller and looms at a lower rate. This result suggests that faster vehicles may be less noticeable to pedestrians and might not "pop out" as readily in the visual scene. Finally, if the perceptual threshold for looming (θ'th) is known, Equation 3 can be rearranged to calculate the maximum approach speed (Vmax) that allows the observer to make a reliable decision given their required crossing time (tc) (Purcell, 2011; Wann et al., 2011):

Equation 4:

$$v_{\max} = \frac{D}{t_c^2 \, \dot{\theta}_{th}}$$

vmax: Maximum detectable approach speed

tc: Crossing time

As a result, Equation 4 highlights two key features influencing an observer's ability to detect approaching vehicles (Purcell, 2011). The first is higher perceptual thresholds for looming are an indication of a poorer ability to detect looming objects. Individuals with a poorer ability to detect a looming object (higher perceptual thresholds) can only reliably detect slower approaching vehicles and are not able to detect faster approaching vehicles, if crossing time (tc) is assumed to be fixed (Purcell, 2011). This is because they require a greater rate of expansion / rate of looming θ'(t) for an object to appear to be approaching (Purcell, 2011). Secondly, if the required crossing time (tc) increases, vehicle speeds would need to decrease in order to be detectable (Purcell, 2011). This means that slower traffic speeds are necessary for longer crossing times to ensure that pedestrians can accurately perceive and respond to approaching vehicles. Consequently, individuals with limited visual perception or who require more time to cross the road may face a heightened risk of accidents if they are unable to accurately perceive and react to approaching vehicles (Purcell et al., 2017). These underscore the complex interplay between visual perception, object characteristics, and ultimately the observer's decision-making process in road crossing situations.

Previous research on looming detection has consistently demonstrated a developmental trajectory, with children exhibiting higher thresholds for detecting looming stimuli compared to adults (Lee, 1976; Hoffmann, 1994; Wann et al., 2011). Hoffmann (1994) discovered that children aged 5 to 8 years exhibited significantly higher (poorer) thresholds for looming detection compared to adults, with estimates twenty times higher (0.04 radians/second vs. 0.002 radians/second). Additionally, Wann et al. (2011) directly measured visual looming detection thresholds and found a prolonged developmental process. This means that children's ability to perceive and respond to approaching objects improves gradually as they get older (Wann et al., 2011). They observed that thresholds for a central looming object were 2.5 times higher in 6- to 7-year-olds compared to adults and 1.6 times higher in 10- to 11-year-olds compared to adults. Purcell et al. (2012) further compared the looming detection thresholds of children with DCD and age-matched control children aged 6 – 11 years. They found that there was no significant difference between the two groups in their ability to detect looming objects when presented in the centre of vision (foveal). However, children with DCD tended to have slightly higher thresholds, indicating some difficulty in detecting looming objects. Furthermore, both groups of children had higher looming detection thresholds in the perifoveal conditions (peripheral vision) compared to the foveal conditions (Purcell et al., 2012). However, children with DCD had significantly higher looming detection thresholds in perifoveal conditions when compared to their TD peers, indicating that children with DCD may encounter difficulties in detecting approaching vehicles, particularly when they are not directly in the line of sight (perifoveal vision) (Purcell et al., 2012). Therefore, the results of previous studies set the stage for further investigation by highlighting the potential challenges younger children with DCD, aged 6-11 years, face in detecting looming objects. The difficulties in relation to looming detection are likely due to the poor visual perception (Purcell et al., 2012). While this is known in younger children, no research has investigated the ability to detect looming objects in older children, for example, aged 11 – 16 years. It is crucial to investigate this in older children to explore whether looming detection difficulties persist, or whether a clear developmental trajectory is also observed in children with DCD, as per Wann et al.'s findings with typically developing children (Wann et al., 2011). Continued difficulties with looming detection can have significant implications for older children's safety, particularly in road crossing situations which can limit their independence at an age when they are more likely to be walking to school, for example. While previous studies (Wann et al., 2011; Purcell et al., 2012; Purcell et al., 2011) have primarily focused on car stimuli, it is also important to investigate looming detection thresholds in older children using a variety of stimuli, including motorbikes, which are also frequently encountered on the UK roads. The size of the object, as reflected in Equation 4, can significantly influence the perceived rate of looming. By exploring the impact of object size on looming detection, we can gain a deeper understanding of the specific challenges faced by children with DCD and ADHD in real-world situations, such as road crossing, where object size can vary widely.

Additionally, children with ADHD may also face challenges in road crossing. Studies suggest that children with ADHD have impairments in visual perception, particularly in effortful visual attention and visual-motor integration (Mullane & Klein, 2008; Jung et al., 2014; Fuermaier et al., 2018). These impairments may also hinder looming detection to accurately perceive and respond to approaching vehicles to execute safe road crossing (Purcell et al., 2012). While previous research has primarily focused on the role of visual perception in general road crossing behaviours, such as detecting safe crossing gaps and decision-making (Clancy et al., 2006; Stavrinos et al., 2011), less is known about its specific impact on looming detection in children with ADHD. Furthermore, while previous studies have investigated looming detection in children with DCD using computer-based tasks (Wann et al., 2011; Purcell et al., 2012), children with ADHD often exhibit attentional difficulties (Mullane & Klein, 2008) that may also interfere with their ability to perceive and respond to looming stimuli, especially in complex, real-world scenarios. Therefore, to ensure accurate measurement of looming detection, the use of eye-tracking technology can be utilised to monitor participants' attention and gaze behaviour during the task.

Therefore, to further explore the looming detection abilities of children with DCD or ADHD, the following research question was posed:

- Do children with DCD or ADHD have sufficient looming thresholds in a virtual environment to detect vehicles approaching at the speeds typically encountered in residential areas compared to their typically developing peers?

Null Hypothesis (H_0):

- There will be no significant differences in looming detection thresholds between children with DCD or ADHD and TD children.
- There will be no differences in looming detection thresholds between cars and motorbike stimuli.
- There will be no difference in the proportion of correct saccades towards the stimulus between the diagnostic groups (DCD and ADHD) and the TD group.

Alternative Hypothesis (H_A):

- Children with DCD and children with ADHD would exhibit significantly lower looming detection speed thresholds compared to TD children, indicating reduced sensitivity to approaching vehicles. Without previous comparative data, a specific directional difference between DCD and ADHD was not predicted.
- All participants will have lower looming detection thresholds for car stimuli compared to motorbike stimuli.
- There would be a difference in the proportion of correct saccades towards the stimulus between the diagnostic groups (DCD and ADHD) and the TD group. Due to limited prior research, the saccadic differences between DCD and ADHD will be explored

7.2 Method

7.2.1 Stimulus Presentation

The stimuli used in this task were identical to those employed in Purcell et al. (2012). However, a motorbike was also used in this task. Participants were presented with photographic images of a car or motorbike on a road scene backdrop. The road scene was a 400-tile mosaic designed to replicate the visual attributes of a real road scene while eliminating any static cues to relative distance. The car image was 1.725 meters in size, representing the average of a typical car's width (1.80 meters) and height (1.65 meters) (Purcell et al., 2012). The motorbike images were 1.05 meters in size representing the average motorbike's width (0.8 meters) and height (1.3 meters) (Hussain et al., 2005). These dimensions were used to create realistic 3D images. Furthermore, participants were asked to walk a distance equivalent to the width of a typical UK urban road (approximately 5 meters) at their preferred walking pace. This was repeated three times, and the average walking speed was calculated as an estimate of crossing time. The mean walking speed for the DCD group was 4.79 seconds (SD = 0.42), and for the ADHD group was 4.32 seconds (SD = 0.34). Therefore, children with DCD or ADHD typically require at least 4.56 seconds (average time) to safely cross a standard UK road. To simulate this, the TTC was initially set at 4.56 seconds. However, to maintain a consistent visual angle, the TTC was slightly extended to 5 seconds at the end of the stimulus presentation.

The car and motorbike images were presented at various virtual distances and speeds for 200 ms, simulating different approach scenarios. The size of the vehicle images were adjusted to maintain a constant rate of change of the visual angle, ensuring that the perceived speed remained consistent across different distances. Figure 7.1 provides an example of a sample stimulus for testing looming detection thresholds in foveal vision.

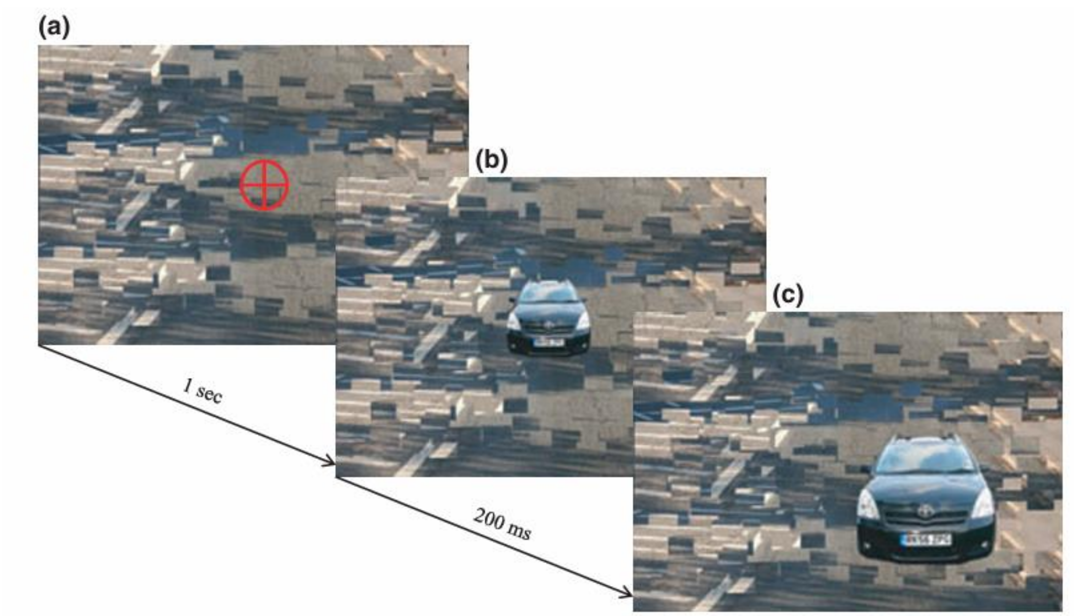


Figure 7.1: A sample stimulus for testing looming detection thresholds in foveal vision, taken from Purcell et al. (2012). The stimulus depicts a car moving laterally across the screen while

approaching the observer (a) initial fixation cross, (b) starting position of the car, and (c) final position of the car after 200ms of looming and 1 degree of lateral motion.

Three tasks were randomly presented:

1. **Foveal isotropic expansion with simulated viewpoint motion (condition 1):** The vehicle appeared directly in the centre of the screen and expanded uniformly in all directions, while the participant's simulated viewpoint moved laterally by 1 degree.
2. **Perifoveal isotropic expansion (condition 2):** The vehicle appeared slightly off-centre, appearing at an angle of 4.25 degrees from the centre of the screen (3 degree in the vertical and horizontal planes) and expanded uniformly in all directions.
3. **Perifoveal isotropic expansion with simulated viewpoint motion (condition 3):** The vehicle appeared slightly off-centre and expanded uniformly in all directions, while the participant's simulated viewpoint moved laterally.

The perifoveal images were randomly placed in one of four quadrants of the screen to simulate real-world conditions where pedestrians may not always fixate directly on an approaching vehicle when visually scanning a cluttered road scene. The simulated movement of the vehicle was adjusted based on its distance from the observer. When the vehicle was closer (44 meters away), it appeared to move more across the screen (0.7 degrees). When the vehicle was further away (88 meters), it appeared to move across the screen less (0.35 degrees). This simulated movement was designed to accurately reflect how the vehicle would appear to an observer if they were moving forward. Stationary vehicles were presented in 50% of trials to ensure that participants were attending to the task and not simply responding randomly.

While foveal expansion can provide valuable insights into basic looming detection (Purcell at al., 2012), perifoveal detection is more representative of real-world situations where pedestrians may not always have direct fixation on approaching vehicles. Therefore, unlike Purcell et al. (2011) this study only included foveal isotropic expansion with simulated viewpoint motion and the perifoveal conditions.

7.2.2 Procedure

The initial sample consisted of 31 participants: 10 with DCD, 9 with ADHD, and 12 TD children. The children were seated comfortably in front of a Tobii Pro Spectrum eye-tracking system. Before beginning, the eye-tracking system was calibrated for each participant using a standard procedure in Tobii Pro Lab. More information about eye tracking calibration is provided in Chapter 2. The system recorded eye movements and calculated calibration parameters to ensure accurate measurement of gaze data (Tobii Connect, 2022). Figure 6.2 illustrates an example of the calibration screen used in Tobii Pro Lab. Participants were then randomly presented with the three conditions for each stimuli car or motorbike, a total of six conditions. Participants used a computer mouse to indicate whether the car/motorbike 'got bigger'. A break was provided whenever needed. To converge on each child's looming detection threshold, a Best Parameter Estimation by Sequential Testing (Best-PEST; Lieberman & Pentland, 1982) staircase procedure was employed (as described in Chapter 2). This adaptive method utilised a downward descent sequence across 1000 intervals, with each interval representing a different stimulus speed. To ensure initial stimuli were easily detectable, the first presentation began with a low speed (high rate of expansion) at the highest interval value (999). Following a correct response, the procedure progressed by presenting a lower rate of expansion (higher speed). The initial speed for each child was manually set at 20 mph. When image expansion was not detected, the algorithm selected an easier stimulus level (lower speed) and recorded a reversal. Stationary car images were presented at the virtual distance of the previously presented moving car. The algorithm terminated after six reversals, and the maximum likelihood threshold value was obtained for each participant. Two participants (one from the DCD and one from the ADHD group) requested a break during the session after which the calibration procedure was repeated. To ensure data reliability, false positive rates were recorded. High false positive rates could indicate potential inattentiveness, task difficulty, or even random guessing, potentially leading to inaccurate results. To minimise the impact of these potential confounds, conditions with false positive rates at or exceeding 50% or where the last stimulus level was 1 or 1000 were excluded. This resulted in data loss, which is further explained in the Results section.

7.2.3 Analysing Eye Tracking Data

Eye saccade data can provide valuable insights into how participants interact with stimuli. A saccade is a rapid, ballistic eye movement that shifts the gaze from one point of fixation to another (Leigh & Kennard, 2004). By analysing saccades, it is possible to determine whether participants actively looked at the stimuli or simply guessed (Lévêque, 2020). After collecting saccade data, a manual coding approach was adopted. While automated analysis tools like Tobii Pro Lab are powerful, they may not always be the most useful method, especially when dealing with complex stimuli and rapid event sequences such as looming detection powered by Best-PEST requiring coding each second the stimuli appeared. Therefore, manually coding the eye tracking data was a pragmatic solution. By manually reviewing each participant's eye-tracking data, identification of participants' initial saccade towards each stimuli was obtained to provide insights into their attentional response. Additionally, quick eye movements towards the stimulus can indicate the underlying mechanisms such as active attention and motor control (Jonikaitis et al., 2013). Thus, this analysis aimed to assess the efficiency of orienting attention to the stimuli (vehicle). A proportion score was calculated for each participant by dividing the number of trials with a correct saccade towards the stimulus by the total number of trials. A correct saccade was defined as the first saccade directed towards the stimulus (vehicle) and landed on it after its appearance. A higher proportion score indicated a greater likelihood of directing initial attention towards the stimulus (Jonikaitis et al., 2013). It is important to note that this analysis was conducted for conditions 2 and 3, but not condition 1. Condition 1 involved foveal isotropic expansion with simulated viewpoint motion, where the vehicle appeared directly in the centre of the screen. As the stimulus was centrally presented, there was no need for a saccade to orient attention, making saccade analysis irrelevant for this condition. By verifying participants initial saccade in conditions 2 and 3, this allowed analysis of their responses to the looming stimuli.

7.3 Results

As previously mentioned, the initial sample consisted of 31 participants: 10 with DCD, 9 with ADHD, and 12 TD children. However, to minimise the impact of potential confounds, conditions were excluded if the false positive rate exceeded 50% or if the Best-PEST staircase procedure failed to converge on a reliable looming detection threshold (indicated by termination at stimulus levels 1 or 1000).

As a result of these exclusion criteria, a substantial amount of data was excluded across the six conditions, leading to varying sample sizes (n) for each group (TD, DCD, ADHD) as presented in Table 7.1. The significant data loss can be primarily attributed to the complexity of the task and the overall experiment design, which likely led to increased fatigue and a higher likelihood of guessing. Participants were required to complete the test component of the MABC-2 (Henderson et al., 2007) and identify safe crossing sites before undertaking the looming detection task, which involved six conditions with rapid presentations of subtle looming stimuli. This demanding sequence and the length of the looming detection six conditions task likely led to increased fatigue and reduced attention, particularly for children with NDDs who may have greater susceptibility to fatigue and attentional difficulties (Rogers et al., 2017; Bonthrone et al., 2023). Although participants were offered breaks, only two requested them, suggesting that fatigue may have been underestimated and not adequately addressed. The task itself was inherently challenging, requiring participants to detect subtle changes in looming stimuli and make quick decisions repeatedly. This complexity, compounded by fatigue, may have led to increased guessing, contributing to the high false positive rates.

Table 7.1. Sample Sizes (n) for Each Group and Condition

Condition	TD	DCD	ADHD
Car Condition 1	10	2	8
Car Condition 2	9	8	7
Car Condition 3	8	7	3
Bike Condition 1	6	5	7
Bike Condition 2	10	5	5
Bike Condition 3	11	6	6

As shown in Table 7.1, the remaining sample sizes varied considerably across conditions. Notably, the DCD group in Car Condition 1 had a sample size of only 2, while the TD group had a sample size of 10 participants in Car Condition 1, 9 in Car Condition 2, and

8 Car Condition 3. The ADHD group also experienced substantial data loss, such as in Car Condition 3, where the sample size was reduced to 3. This level of data loss, particularly the substantial reduction in sample sizes for specific conditions and groups, may limit the generalisability of the findings and needs to be considered when interpreting the results. Due to the data loss and the resulting small and uneven sample sizes across conditions, inferential statistical analysis were not conducted. The reduced statistical power and potential violation of assumptions would have made any inferential findings unreliable. Therefore, descriptive statistics for each group and condition are presented.

The descriptive analysis revealed some key patterns in looming detection across the groups. For car conditions, children with DCD showed the highest mean thresholds, potentially less refined detection compared to TD and ADHD children. the TD group who had the lowest thresholds, demonstrated the best performance. Children with ADHD displayed intermediate performance. Children with ADHD displayed a unique pattern of looming detection, performing at a level between the TD and DCD groups. Motorbike conditions showed more variable results, with ADHD children exhibiting the lowest thresholds in Conditions 2 and 3, and no other group showing consistently superior or inferior performance. Mean looming detection thresholds for the car and motorbike conditions by group are presented in Figures 7.2 and 7.3.

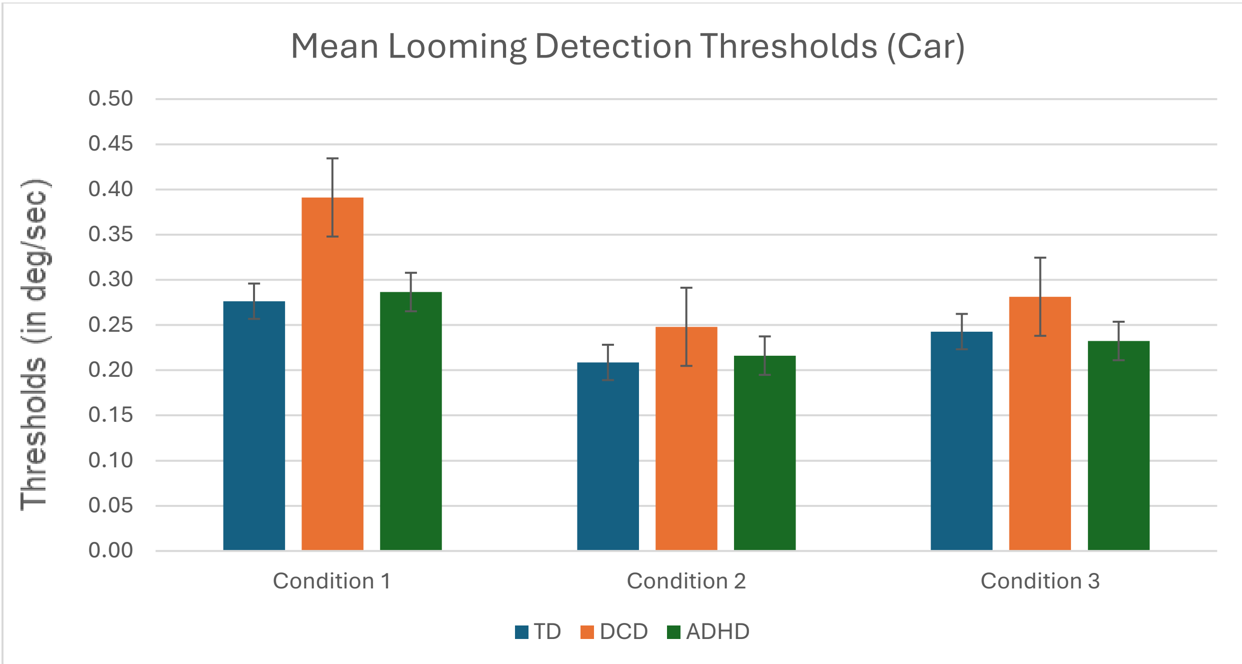


Figure 7.2 Mean looming detection thresholds and standard error for condition 1 (Foveal isotropic expansion with simulated viewpoint motion), 2 (Perifoveal isotropic expansion), and 3 (Perifoveal isotropic expansion with simulated viewpoint motion), for the DCD, ADHD and TD group

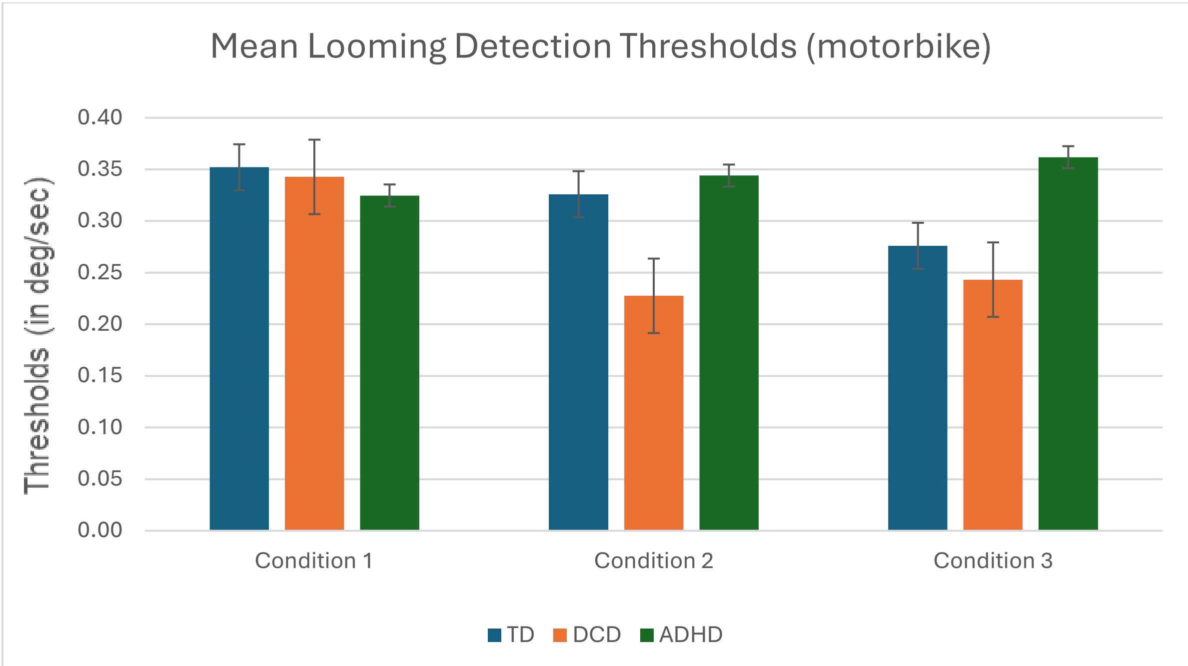


Figure 7.3 Mean looming detection thresholds and standard error for condition 1 (Foveal isotropic expansion with simulated viewpoint motion), 2 (Perifoveal isotropic expansion), and 3 (Perifoveal isotropic expansion with simulated viewpoint motion), for the DCD, ADHD and TD group.

The observed looming detection thresholds were converted into equivalent vehicle speeds using Equation 4. The calculations for *D* were based on a standard average car size of 1.725 meters, and on a standard average motorbike size of 1.05 meters, the TTC for both was 5 seconds. The mean threshold speeds for TD, DCD and ADHD across all conditions (car and motorbike) are provided in Figures 7.4 and 7.5 respectively.

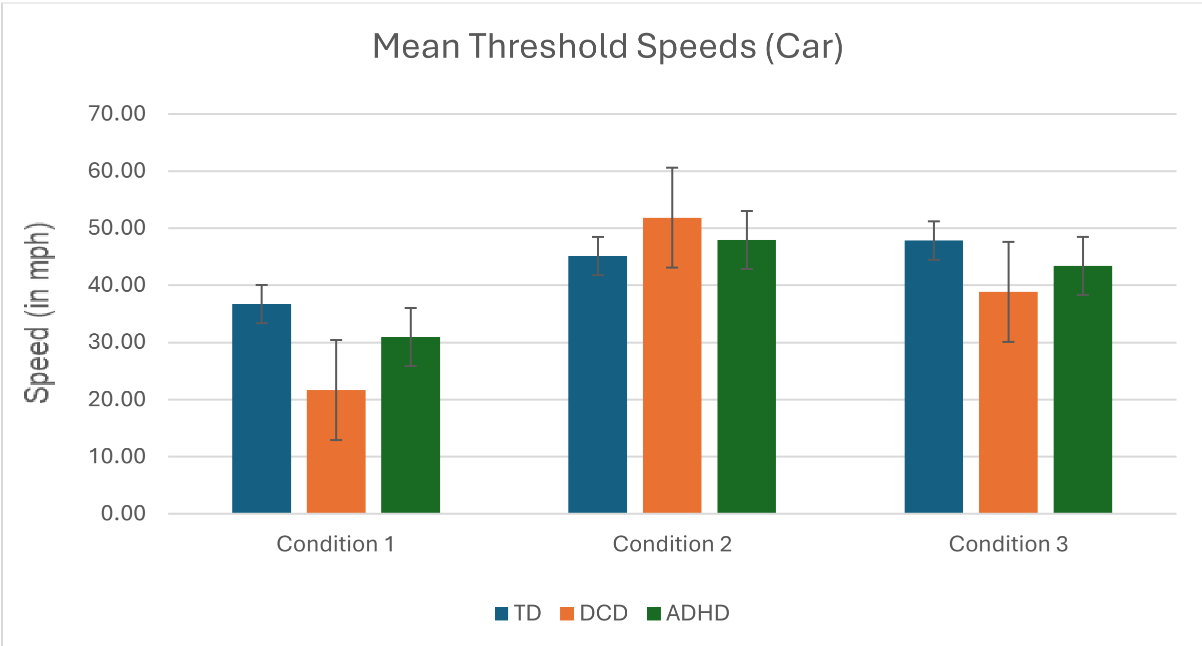


Figure 7.4 Mean speed thresholds (mph) and standard error for car stimuli in condition 1 (Foveal isotropic expansion with simulated viewpoint motion), 2 (Perifoveal isotropic expansion), and 3 (Perifoveal isotropic expansion with simulated viewpoint motion), for the DCD, ADHD and TD group.

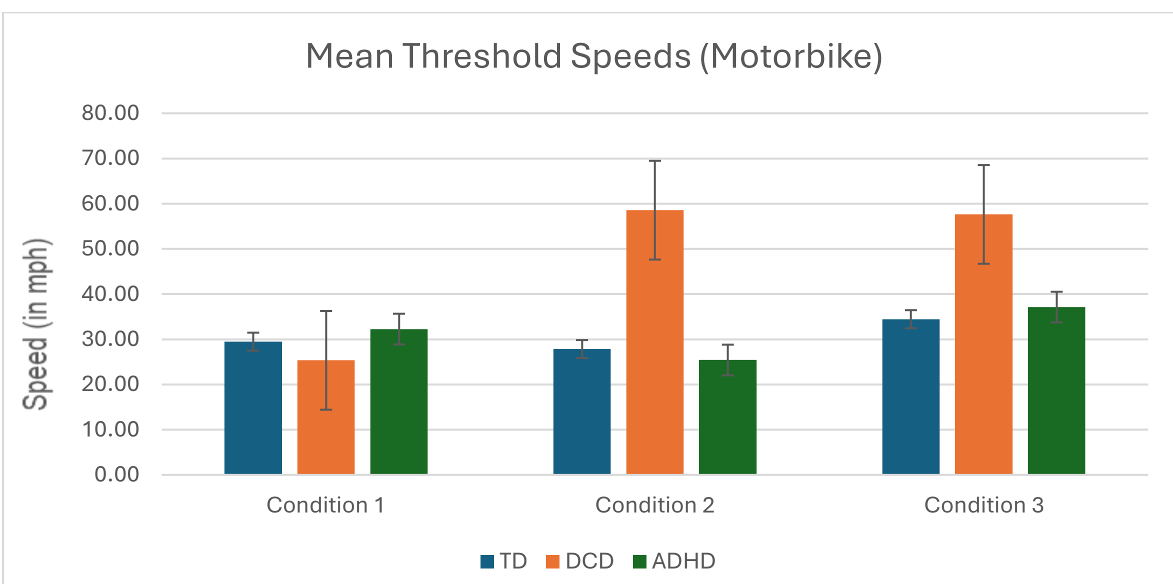


Figure 7.5 Mean speed thresholds (mph) and standard error for motorbike stimuli in condition 1 (Foveal isotropic expansion with simulated viewpoint motion), 2 (Perifoveal isotropic expansion), and 3 (Perifoveal isotropic expansion with simulated viewpoint motion), for the DCD, ADHD and TD group.

Eye saccade

To assess the efficiency of initial visual attention, the correct saccadic eye movements were analysed for all groups [DCD, ADHD, TD] in perifoveal conditions [perifoveal isotropic expansion condition (condition 2), perifoveal isotropic expansion with simulated viewpoint motion (condition 3)] using both vehicle stimuli [car and motorbike]. Therefore, the analysis of saccade metrics was limited to perifoveal conditions. In foveal conditions, where the stimulus appeared directly in the centre of the visual field, it was not meaningful to measure saccade initiation due to the initial fixation on the central point.

Table 7.1 shows mean percentages of correct saccades in condition 2 (Perifoveal isotropic expansion) and condition 3 (Perifoveal isotropic expansion with simulated viewpoint motion), for DCD, ADHD and TD group (please note this is not calculated for condition 1 as no eye movement would be expected in a foveal presentation). Participants demonstrated high levels of initial attention efficiency in the two car conditions, with mean correct saccade rates for TD and ADHD at or exceeding 90%. While children with DCD had 88% correct saccades in car condition 2, they had 84% correct saccades in car condition 3. For the motorbike, both conditions showed relatively high mean correct saccade scores across all groups. The TD group consistently demonstrated the highest mean correct saccade rate (96% in condition 2 and 94% in condition 3), indicating an appropriate level of shifting their initial attention. The ADHD group had lower mean correct saccade scores compared to the TD group, 79% correct saccades in condition 2 and 80% correct saccades in condition 3. Furthermore, while children with DCD had 84% correct saccades in condition 2, they achieved 87% correct saccades in condition 3.

Table 7.1 Proportion of Correct Saccades Towards Looming Stimuli [Car & Motorbike] in Perifoveal Conditions [condition 2 (Perifoveal isotropic expansion) and condition 3 (Perifoveal isotropic expansion with simulated viewpoint motion)] for Diagnostic Groups [DCD, ADHD, TD].

	DCD	ADHD	TD
Perifoveal isotropic expansion (condition 2)			
Car	88%	93%	97%
Motorbike	84%	79%	96%
Perifoveal isotropic expansion with simulated viewpoint motion (condition 3)			
Car	87%	90%	95%
Motorbike	87%	80%	94%

A Three-way mixed ANOVA Group, [TD, DCD and ADHD], Vehicle [car, motorbike] and Condition [Condition 2 (Perifoveal isotropic expansion), Condition 3 (Perifoveal isotropic expansion with simulated viewpoint motion)] was used to compare the means of correct saccades towards looming stimuli. The ANOVA test revealed a significant main effect of Vehicle, $F(1, 28) = 5.910$, $p = .022$, partial $\eta^2 = .174$. A greater proportion of correct saccades were found for the car compared to the motorbike condition. However, no significant difference was found for Condition, $F(1, 28) = .072$, $p = .791$, partial $\eta^2 = .003$, and a non-significant Vehicle × Condition interaction was found, $F(1, 28) = .308$, $p = .583$, partial $\eta^2 = .011$.

Furthermore, a significant difference between the three groups was found, $F(2, 28) = 4.619$, $p = .018$, partial $\eta^2 = . .248$. Post-hoc comparisons using Tukey's HSD test revealed significant differences when compared correct saccade between the TD group and DCD group (Mean difference = 0.0892, $p = .050$). Additionally, the TD group had significantly higher correct saccades than the ADHD group (Mean difference = 0. .0991, $p = . 032$). However, there was no significant difference between DCD group and ADHD group (Mean difference = 0.0099, $p = .964$).

7.4 Discussion

The aim was to investigate whether children with DCD or ADHD aged 11 – 16 years exhibit sufficient looming detection thresholds in a virtual environment to detect approaching vehicles at typical residential speeds, and to compare their performance to that of their TD peers. It was hypothesised that significant differences in looming detection thresholds would be observed between children with DCD, ADHD, and TD children. However, due to substantial data loss, inferential statistical analyses were not conducted. Descriptive analysis revealed tentative patterns across the groups. In car conditions, the DCD group had the highest mean looming detection thresholds, potentially indicating less refined looming detection when compared to children with ADHD and TD children. This suggests that children with DCD may have greater difficulty in detecting approaching cars, regardless of whether they are presented in central or peripheral vision or whether there is simulated viewpoint motion. In contrast, the TD group generally demonstrated the lowest looming detection thresholds, indicating better looming detection performance. Additionally, children with ADHD exhibited a unique pattern of looming detection performance, falling between the TD and DCD groups. These findings highlight potential visual-perceptual deficits in children with DCD that may impact their ability to detect approaching vehicles when compared to TD and ADHD groups.

The looming detection thresholds for motorbike conditions revealed a degree of variability across all groups. Notably, no single group consistently demonstrated superior or inferior performance across all three conditions except children with ADHD where they had the lowest looming detection thresholds in Conditions 2 and 3. This inconsistency suggests that the task, particularly with the smaller motorbike stimuli, may have presented unique challenges for all participants. Potential factors contributing to this variability include task complexity, attentional fluctuations, and differences in peripheral visual processing. Further research with larger sample sizes and refined methodology is needed to explore these inconsistencies to elucidate the specific challenges faced by each group in detecting approaching motorbikes. However, considering the looming detection thresholds for all groups for the motorbike foveal condition, the recent reduction in urban speed limits in Wales (Welsh Government, 2024) is a positive step as it may help mitigate some of these challenges in perceiving approaching motorbikes.

Purcell et al. (2012) reported higher looming detection thresholds (poorer looming sensitivity) in children with DCD aged 6 to 11 years compared to the participants who were aged 11-16 years here, this suggests some potential improvements over time, the findings still however highlight potential heightened risk faced by older children with DCD in detecting approaching vehicles, particularly when compared to TD children. Wann et al. (2011) stated that the ability to perceive and respond to approaching vehicles develops in children as they get older. Thus, it is not surprising that the looming detection thresholds of the 11-16-year-old TD children were improved compared to the 6–11-year-old children tested by Wann et al. (2011), possibly due to maturation in the looming detection network. Therefore, while older TD children aged 11 – 16 years seem to have greater sensitivity to looming with age, older children with DCD may still be less refined in identifying vehicles as approaching in some viewing conditions. Additionally, children with ADHD exhibited a unique pattern of looming detection performance, falling between the TD and DCD groups in car conditions. They had lower car looming detection thresholds than DCD children but higher car looming detection thresholds than TD children in conditions 1 and 2. This may, in part, help to explain previous research which has suggested that individuals with ADHD exhibit poor pedestrian performance (Clancy et al., 2006; Stavrinos et al., 2011; Toye, 2016; Tabibi et al., 2021).

Furthermore, the analysis of the translated looming detection thresholds to the speed equivalent in mph suggest the TD group generally demonstrated the best performance (car conditions 1 and 3) and the DCD group showed the lowest speed thresholds across car conditions 1 and 3. The ADHD group had speed thresholds falling between the TD and DCD groups. Overall, the findings suggest that all groups exhibit adequate looming detection for cars based on the types of speeds typically encountered when crossing roads. For the motorbike conditions, a high degree of variability across all groups and conditions was evident, with no clear consistent pattern of performance except children with DCD where they had the lowest speed thresholds in condition 1 but show a marked increase in sensitivity in conditions 2 and 3. This suggests that the DCD group processes the approaching bike stimulus differently compared to the TD and ADHD groups, and this difference is dependent on the specific condition. However, further research is needed to understand the underlying factors contributing to these inconsistencies.

The hypothesis that there would be a difference in the proportion of correct saccades towards the stimulus between the diagnostic groups (DCD, ADHD) and the TD group was supported by the findings. The findings showed that there were significant differences in correct saccades between the ADHD and TD groups and between the DCD and TD groups. These suggested difficulties in efficiently directing their initial attention towards the target stimulus. However, a high false positive rate was observed, indicating potential guessing behaviour and leading to the exclusion of data from those conditions. This exclusion resulted in substantial data loss, which must be considered when interpreting the overall findings. Therefore, while there was a significant difference in directing initial attention towards stimuli between children with ADHD and TD children, this may indicate a different less effective visual scan of the scene, rather than a lack of attention towards the stimuli. Furthermore, DCD participants exhibited significant differences in shifting their attention towards the stimuli when compared to their TD peers. However, they did not exhibit significant differences compared to the ADHD group. The looming detection task revealed that children with DCD consistently exhibited higher looming detection thresholds (indicating poorer looming detection) across all car conditions. This suggests that children with DCD may have difficulties in perceiving and responding to looming stimuli, but the differences in looming detection thresholds between DCD and TD is likely due to initial shifting attention or saccade. However, the underlying mechanisms linking initial attention and looming sensitivity are complex and may involve multiple factors, including visual attention, motor control and perception (Jonikaitis et al., 2013; Sumner et al., 2016; Skaramagkas et al., 2021). Overall, the significant differences in saccadic patterns between DCD and TD, coupled with the looming detection results, suggest less effective visual scan and perception for children with DCD.

Furthermore, it was also hypothesised that all participants would exhibit higher looming detection speed thresholds for car stimuli compared to motorbike stimuli. This hypothesis was supported by the findings, with participants exhibiting higher mean looming detection speed thresholds for car stimuli compared to motorbike stimuli. This suggests that participants may have difficulty detecting smaller approaching vehicles, such as motorbikes, compared to larger approaching vehicles, such as cars. Previous research suggested that smaller objects, especially those presented in peripheral vision, can be more challenging to detect (Gould et al., 2013). The study by Gould et al. (2013) demonstrated that participants (drivers) were less able to detect the approach of motorbikes compared to cars. When considering that the complex road crossing task is a perceptual and visually guided task, these difficulties in relation to looming detection may be due to the poor visual perception (Mullane & Klein, 2008; Purcell et al., 2012; Jung et al., 2014; Fuermaier et al., 2018). These findings highlight the importance of considering the size of vehicle when assessing looming detection abilities, especially in vulnerable populations due to the possibility of reduced perceptual abilities. Eye-tracking data further support this observation. Participants were more likely to make correct saccades towards the car stimuli compared to motorbike stimuli, regardless of the specific condition. This aligns with the findings of Peschel & Orquin (2013), who suggested that larger objects tend to be more salient and attract attention more readily than smaller objects. This highlighted the importance of object size for both of initial attention efficiency and looming detection.

Despite the valuable insights gained from these tasks, it is important to acknowledge certain limitations. The substantial data loss due to high false positive rates for some participants significantly impacted the study. This data loss resulted in small and uneven sample sizes across conditions, limiting the generalisability of the findings and preventing the use of inferential statistics. Future studies should consider implementing strategies to minimise fatigue and task complexity, such as shortening the overall session and incorporating more frequent breaks. This will help to reduce data loss and allow for more robust statistical analysis. The use of a virtual environment, while providing a controlled setting, may not fully capture the complexity of real-world pedestrian scenarios. Factors such as traffic noise, weather conditions, and unexpected obstacles can influence attention and perception, which may not be fully replicated in a virtual environment. Additionally, the task primarily focused on car and motorbike stimuli. Exploring a wider range of vehicle types and sizes could provide further insights into the factors affecting looming detection in children with DCD and ADHD. Future research could explore the underlying neural mechanisms associated with looming detection in children with DCD and ADHD. That said, this contributes to a growing body of literature on looming detection and its implications for road safety.

7.5 Conclusion

This study investigated the looming detection thresholds of children with DCD and ADHD compared to TD children. The results revealed some tentative differences between the groups, particularly in terms of the impact of groups on looming detection thresholds. Additionally, the TD group exhibited the best looming detection thresholds (lowest looming detection thresholds), followed by the ADHD group, with the DCD group showing the highest looming detection thresholds, particularly in car conditions. While previous studies have investigated looming detection in younger children with DCD, this study extends these findings to older children with DCD and also provides the first set of findings about looming detection in children with ADHD. By incorporating eye-tracking measures, this study provides novel insights into the attentional processes underlying looming detection in these populations. By examining the impact of vehicle type, diagnostic group, and eye movements, this has provided a more comprehensive understanding of the factors influencing looming detection in this population. The findings emphasise the challenges faced by children with DCD or ADHD in perceiving approaching vehicles. To further explore the implications of looming detection on road safety, the following chapter investigates the gap acceptance behaviour of children with DCD and ADHD in a simulated road crossing task.

8 Chapter Eight: Gap Acceptance Thresholds in Children with DCD or ADHD

8.1 Introduction

In the previous chapter, looming detection thresholds in children with DCD or ADHD were investigated. Findings revealed the DCD group had the lowest looming detection thresholds, followed by the ADHD group, with the TD group having the highest looming detection thresholds. This suggested difficulties in perceiving approaching vehicles in children with DCD or ADHD in comparison to TD children. Given the importance of looming detection for road crossing safety, these results highlight the potential challenges faced by children with DCD or ADHD in this context. Chapter 7 on looming detection thresholds in children with DCD or ADHD, focused on the perceptual aspects of this task. However, to fully understand road crossing behaviour in children with DCD or ADHD, it is essential to examine road crossing comprehensively. This chapter presents the quasi experiment that investigated gap acceptance thresholds in children with DCD or ADHD, exploring how their perceptual-motor skills and their locomotive abilities, influenced their decision-making during simulated road crossings scenarios. Gap acceptance, a critical component of road crossing safety, refers to the decision-making process pedestrians use to determine whether the available gap in traffic is sufficient for them to cross safely (Theofilatos et al., 2021). It involves the ability to accurately assess the size of a traffic gap and ensure that the gap affords a safe crossing based on an individual's action capabilities (Purcell et al., 2017). This means that error can occur when pedestrians overestimate the size of the gap or underestimate how long it takes to cross leading to unsafe crossing attempts. This concept is crucial for understanding pedestrian safety and behaviour at uncontrolled crossings, midblock crosswalks, and intersections.

Previous studies have investigated the factors impacting on gap acceptance judgments. Lobjois & Cavallo (2007) investigated gap selection when crossing in relation to vehicle speed in older pedestrians aged 60 to 80 years compared to adult pedestrian aged 20-30 years. They found that higher vehicle speeds led to pedestrians accepting smaller and riskier gaps for crossing for all age groups. On the other hand, Theofilatos et al. (2021)

stated that as the speed of oncoming vehicles increases, the likelihood of an adult pedestrian crossing the road decreases. They indicated that pedestrians become more cautious and less likely to attempt a crossing as the perceived risk increases with higher vehicle speeds. Pedestrians were also more likely to accept crossing gaps when the approaching vehicle is smaller or slower (Chandra et al., 2014; Pawar & Patil, 2015). Moreover, waiting time was found to have a non-significant impact on gap acceptance size in adult pedestrians (Zhao et al., 2019; Theofilatos et al., 2021).

However, studies show that children often make riskier decisions than adults and rely more on parental guidance (Plumert et al., 2004; O'Neal et al., 2018a; O'Neal et al., 2018b). For example, children tend to accept smaller crossing gaps as vehicle speed increases, often making potentially dangerous decisions at higher vehicle speeds (Connelly & Isler, 1996; O'Neal et al., 2018b). Research also shows that children primarily use distance in their TTC judgments (Connelly et al., 1998). This reliance on distance and speed may contribute to riskier behaviour at uncontrolled crossings, especially when there are multiple lanes to cross (Kadali & Vedagiri, 2020). This over-reliance on distance and speed neglects the concept of tau or TTC, the ratio of an object's distance and velocity, perceptually represented by the ratio of its optical size to its rate of looming (more details provided in Chapter 7) (Lee, 1976). By focusing solely on distance and speed, pedestrians may fail to adequately perceive and respond to the looming of approaching vehicles leading to accepting riskier crossing gap and underestimation of the overall risk (Purcell et al., 2017). Thus, at such crossings, pedestrians must accurately base their decision of road crossing considering TTC or tau. Reduced sensitivity to looming in children when compared to adults can further exacerbate this issue, making it more difficult for children to detect the approaching vehicles and make timely decisions (Wann et al., 2011). Looming detection including looming rate is a key factor providing critical information about the vehicle’s TTC and its potential threat (more details provided in Chapter 7) (Wann et al., 2011). However, further studies suggest children's ability to judge safe gaps for road crossing improves with age (Plumert et al., 2004; O'Neal et al., 2018a). Developmentally, pedestrians become more conservative in their gap choices and better at coordinating their movements with traffic at age 12 years (O'Neal et al., 2018b).

Younger TD children (6-10 years) however are less discriminating in their gap selection, accepting riskier gaps compared to older TD children (12 years and above) (O'Neal et al., 2018ba; O'Neal et al., 2018b). Furthermore, the coordination and timing of entry behind the lead vehicle in a gap when crossing can improve steadily with age, reaching adult-like levels by 14 years of age (O'Neal et al., 2018b).

Additional challenges impacting TTC judgments have been identified in children with NDDs such as DCD and ADHD. While previous studies have examined gap acceptance in TD children, limited attention has been given to this in children with DCD or ADHD. Children with ADHD often exhibit poor temporal gap choices when crossing roads, opting for smaller and unsafe crossing gaps that increase their risk of collisions (Clancy et al., 2006). This tendency also exists in older children, as studies have shown that individuals with ADHD aged 13 to 17 years demonstrate more unsafe road crossing behaviours, such as a narrower margin of safety and inconsistent crossing actions (Clancy et al., 2006). Furthermore, poor visual perception in children with DCD or ADHD could impact road crossing safety leading to a higher number of unsafe road crossings (Purcell et al., 2012; Jung et al., 2014; Fuermaier et al., 2018). When combined with poor motor coordination and judging appropriate TTC, accepting sufficient road crossing gaps can become even more challenging (Purcell et al 2017; Meyer & Sagvolden, 2006). Meyer & Sagvolden (2006) found that children with ADHD aged 6-9 years showed poorer motor coordination in complex tasks. On the other hand, children with DCD aged 6 to 11 years face significant motor challenges that may hinder their ability to execute visually guided actions essential for safe road crossing (Purcell et al., 2017). Therefore, children with DCD may select insufficient temporal gaps when crossing virtual roads, which could lead to collisions if applied to real-world situations (Purcell et al., 2017). Given the heightened risk of collisions for children with DCD or ADHD, it is crucial to understand their gap acceptance behaviour in more detail. This task aimed to investigate gap acceptance in 11 – 16-year-old children with these conditions. Children with DCD or ADHD were compared to their TD peers within the same age range. By examining their performance in a controlled virtual environment, the following questions were addressed:

- Do children with DCD or ADHD perceptually select sufficient temporal crossing gaps in a virtual environment compared to their TD peers?
- Do children with ADHD or DCD select sufficient temporal crossing gaps in a virtual environment when a perceptual and perceptual-motor response is needed, compared to their TD peers?

Null Hypothesis (H_0):

- (H_0): there will be no significant difference in gap acceptance thresholds as vehicle speed increases among children with DCD, ADHD, and typically developing children.
- (H_0): there will be no significant differences in gap acceptance thresholds between TD children and children with DCD or ADHD.
- (H_0): there will be no significant differences in perceptual and perceptual-motor gap acceptance thresholds between TD children and children with DCD or ADHD.

Alternative Hypothesis (Ha):

- (Ha): gap acceptance thresholds among children with DCD, ADHD, and TD children will decrease as vehicle speed increases.
- (Ha): there will be a significant difference in temporal gap acceptance thresholds between TD children and children with DCD or ADHD. The comparison of temporal gap acceptance thresholds between the DCD and ADHD groups will be explored.
- (Ha): there will be a significant difference in perceptual and perceptual-motor temporal gap acceptance thresholds between TD children and children with DCD or ADHD. The comparison of temporal gap acceptance thresholds between the DCD and ADHD groups will be explored.

8.2 Methods

8.2.1 Apparatus

The study utilised a Dell Alienware X16 laptop, equipped with an Intel Core i9-12900H processor, NVIDIA GeForce RTX 4090 graphics, 32GB of RAM, and a 16-inch display, to power the virtual environment. Three projector screens were arranged to provide a heading viewpoint, left viewpoint, and right viewpoint, with the left and right screens angled at 113° (Purcell et al., 2017). The projector was equipped with Texas Instruments DLP® technology, offering a WXGA native resolution, 16:10 aspect ratio, and a brightness of 5000 lumens. The image projection specifications included a 0.65" panel size, 400000:1 contrast ratio, and a maximum supported resolution of 1920 x 1200.

8.2.2 Stimuli and Procedure

The virtual road scene used in this study replicated the stimuli employed by Purcell et al. (2017), providing a realistic environment for assessing gap acceptance behaviour (shown in Figure 8.1). As shown in Figure 8.2, participants stood at a designated distance of 90 cm from the edge of the heading projector screen, replicating a more natural road crossing posture compared to the seated position employed in Purcell et al.'s study. The three projector screens provided a heading viewpoint, a right viewpoint and a left viewpoint to give a 3D impression when looking right and left at the approaching vehicles in the virtual road scene. Participants stood in front of the heading viewpoint and were presented with a continuous stream of simulated traffic. In the static condition, participants were required to verbally respond 'yes' or 'no' to indicate whether they would cross the road at a selected presented gap. In the dynamic condition, participants were required to step forward to indicate their intention to cross or remain stationary if they rejected the crossing gap. The researcher observed and recorded participant responses using a keyboard press.

The virtual road consisted of a straight flat section of road within a virtual city, which was consistent in all conditions. The road was divided into two lanes (3.5 m for each lane) by dashed white lines, and a pavement was visible furthest from the viewpoint. Near to the viewpoint, there was a continuous white line to mark the road from the standing point. Figure 8.1 illustrates the virtual road environment from various perspectives, adapted from Purcell et al. (2017). To enhance the realism of the environment, the virtual city included additional visual cues, such as shops, and buildings. All trials started with a demonstration in which the heading viewpoint simulated a road crossing at a normal walking pace of 0.93 m/s (7.5 s) of a child crossing a road (Purcell, 2011).

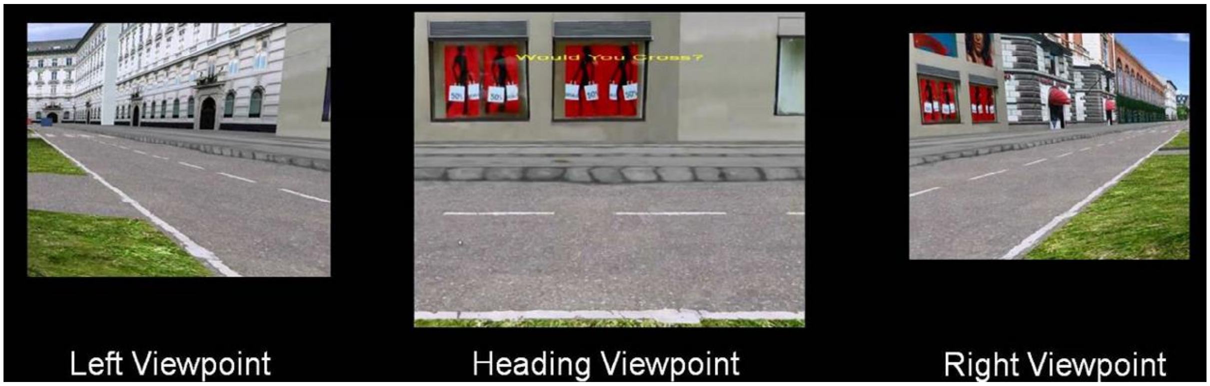


Figure 8.1 virtual road environment to test gap acceptance thresholds in one-lane and two-lane crossings taken from Purcell et al. (2017).

Vehicles, represented as a stream alternated coloured blocks, approached from either the near-side lane or both near-and-far-side lanes. The vehicles alternated in colour between red and blue, making each approaching vehicle easily distinguishable from the previous one. The vehicles were sized to be equivalent to typical cars found on UK roads, ensuring a realistic representation of vehicle dimensions (Renault Logan length: 4.25 m, width: 1.74 m; height: 1.53 m) (Purcell et al., 2017). The vehicles were travelling at either 20 mph or 30 mph mirroring the range of speeds observed in real-world urban traffic environments and there was no zebra crossing or traffic lights (mid-block road crossings). Vehicle speeds were randomly presented and interleaved. This setup allowed for a standardised and controlled assessment of gap acceptance thresholds. The virtual environment provided a safe and repeatable setting for studying road crossing decisions, allowing for the precise control of variables such as vehicle speed, gap size, and traffic conditions. The use of a standing posture contributed to the overall realism and effectiveness of the stimuli.

Before starting the trials, participants were asked to walk a distance equivalent to the one lane width, 3.5 m. They were asked to walk three times at their preferred walking speed. The average walking speed of participants was then calculated to be compared with accepted temporal crossing gap thresholds in the virtual road task. Children then completed the gap acceptance tasks. The task replicated Purcell et al. (2017), presenting participants with an initial simulated crossing at a walking speed of 7.5 seconds. In the first four conditions, participants were asked to verbalise their answers during the tasks. Participants encountered one lane (near-side conditions) and two lanes (near and far-side conditions) at 20 mph and 30 mph. In the next four conditions, participants were asked to step forward whenever they felt it was safe to cross indicating that they accepted the temporal crossing gap. Similarly, they encountered one lane and two-lane conditions at either 20 mph or 30 mph. In the one lane stimuli, participants encountered vehicles approaching from the near-side lane. In the two-lane conditions, vehicles approached from near and far-side lanes. Children indicated whether they would 'cross' or 'not cross' between approaching vehicles. A Best-PEST procedure (Lieberman & Pentland, 1982) with 1000 intervals was used to determine each child's gap acceptance threshold (more details provided in Chapter 2). The TTC range was 2-20 seconds, resulting in varying inter-vehicle distances based on speed (142m at 20 mph, and 213m at 30 mph). The first presentation had a fixed TTC of 2 seconds to discourage immediate crossing. The algorithm terminated after nine reversals, and the maximum likelihood value was taken as the child's gap acceptance threshold.

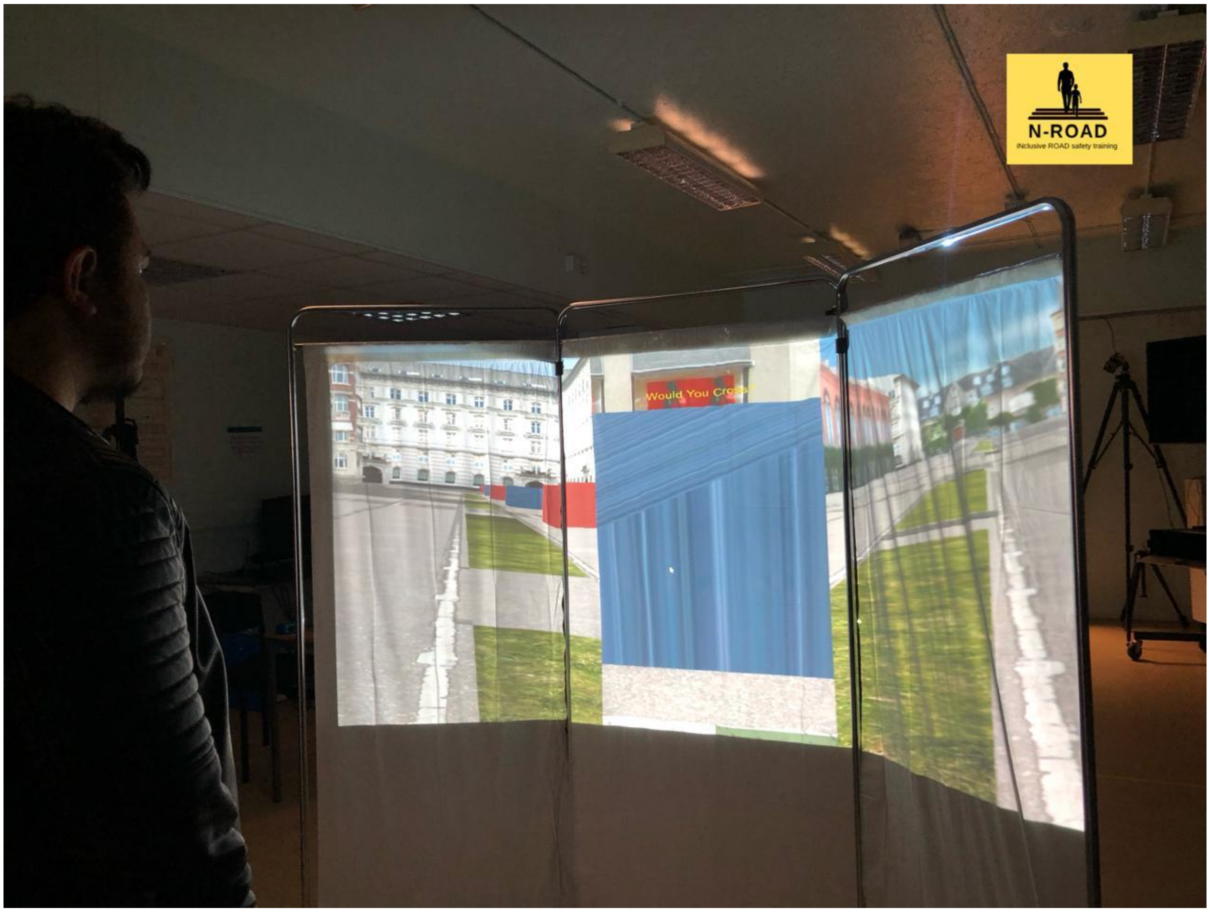


Figure 8.2: Virtual road crossing scene used in the study. Participants stood in front of the road, facing oncoming traffic.

8.3 Results

To investigate the effect of group, number of lanes, conditions, and vehicle approach speed on gap acceptance thresholds, the mean scores for each group were calculated. Figure 8.3 presents the mean gap acceptance thresholds for each combination of group and condition. A three-way mixed ANOVA for Group, [TD, DCD, ADHD], number of Lanes [one-lane, two-lane], Condition [Static, Dynamic], and vehicle Speed [20 mph, 30 mph] was used to compare mean gap acceptance thresholds. The ANOVA revealed a significant main effect of vehicle Speed, $F(1, 28) = 42.741$, $p < .001$, partial $\eta^2 = .604$, and significant Condition x Speed interaction, $F(1, 28) = 5.234$, $p = .030$, partial $\eta^2 = .157$. There were no significant differences between Conditions, $F(1, 28) = 2.157$, $p = .153$, partial $\eta^2 = .072$. Additionally, no significant difference was found for number of Lanes,

$F(1, 28) = .884$, $p = .355$, partial $\eta^2 = .031$. This indicates that vehicle Speed (20 mph, 30 mph) had a significant effect on crossing gap acceptance thresholds, with participants accepting larger temporal gaps for slower-moving vehicles (20 mph) compared to faster-moving vehicles (30 mph). Furthermore, the significant interaction between Speed and Condition suggests that this effect of Speed on gap acceptance thresholds was not uniform across different conditions (static vs. dynamic). However, there was no statistically significant effect of Group on gap acceptance thresholds, $F(2, 28) = .974$, $p = .390$, partial $\eta^2 = .065$, suggesting that overall average gap acceptance behaviour did not differ significantly between the groups (TDC, DCD, and ADHD).

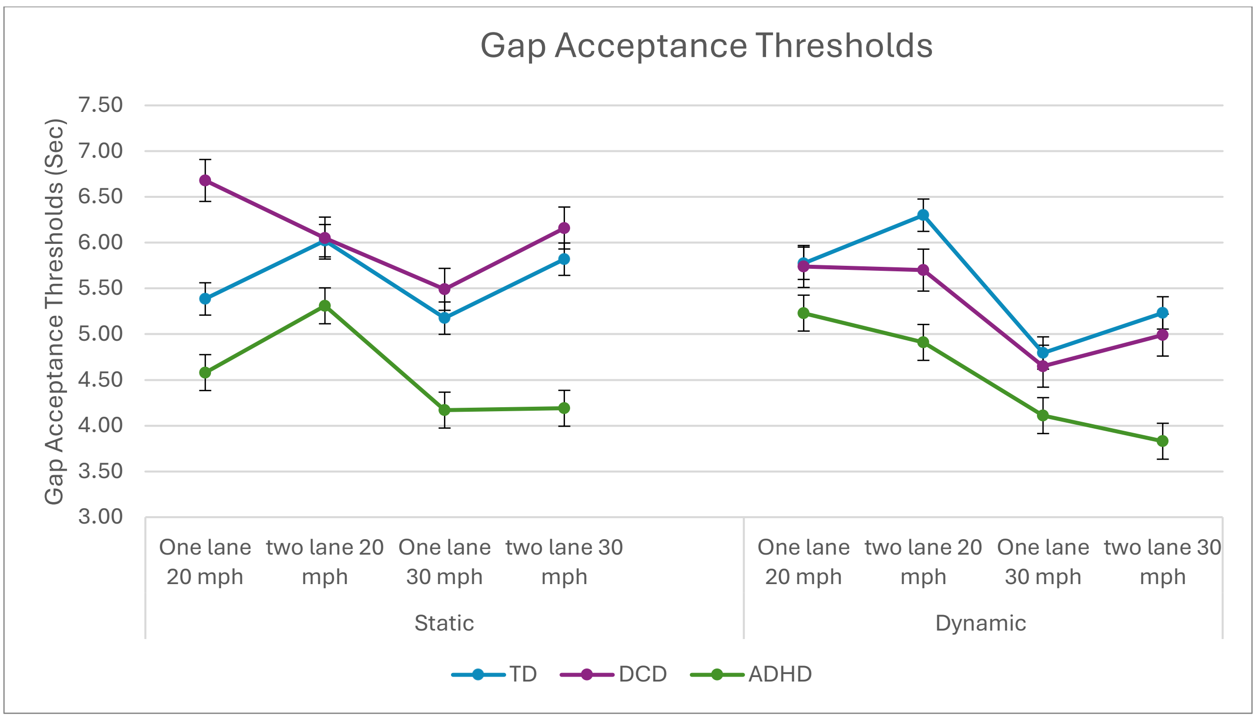


Figure 8.3: Mean gap acceptance thresholds (sec) and Standard Error of Mean (SE) for each combination of group and condition

8.3.1 Adequacy of Crossing Times

A one-way ANOVA was used to examine differences in walking speeds between the three groups. The mean walking time for the TD group was 4.33 sec l (SD = 0.37), for the DCD group was 4.79 seconds (SD = 0.42), and for the ADHD group was 4.32 seconds (SD = 0.34). The results revealed significant differences in walking times between the three groups, $F(2, 32) = 6.243$, $p = 0.005$. The results of the Tukey HSD post-hoc test revealed DCD participants took significantly longer than both TD and ADHD participants (TD vs. DCD: mean difference = -0.44, $p = 0.011$; DCD vs. ADHD: mean difference = 0.47, $p = 0.015$). There was no significant difference between the walking times of TD and ADHD participants (mean difference = -0.03, $p = 0.979$).

To further assess whether the temporal gap thresholds for each group would have been sufficient in the context of real road crossings, the difference between their mean gap acceptance thresholds and their mean walking times were calculated to provide safety margins. Each mean safety margin was also categorised as follows: 'Safe' if the lower 95% Confidence Interval (CI) exceeded 1.5 seconds, 'Near Miss' if the lower CI was above 0 but the upper CI fell below 1.5 seconds, and 'Unsafe' if the upper 95% CI fell below 0.

Figure 8.4 illustrates the differences between gap acceptance thresholds and walking times for the three groups (TD, DCD, ADHD) across the different conditions. Table 8.1 presents the safety margins of road crossings and their corresponding 95% confidence intervals for each group and condition. The table shows that the TD group consistently showed safety margins just above 0, indicating that they generally would have near misses. However, the safety margins of the DCD group and ADHD group would lead to near-misses and more unsafe crossings than TD group in all but one condition for the DCD group where the safety margin suggested safe road crossing. Additionally, the table highlights the differential impact of vehicle speed on the three groups. While all groups exhibited a decrease in safety margins with increasing speed, the impact of this decrease varied. DCD and ADHD participants, in particular, showed a reduction in safety margins, which would lead to unsafe crossings. On the other hand, the one-lane and two-lane conditions, or static and dynamic conditions had less impact on the safety margins of the participants.

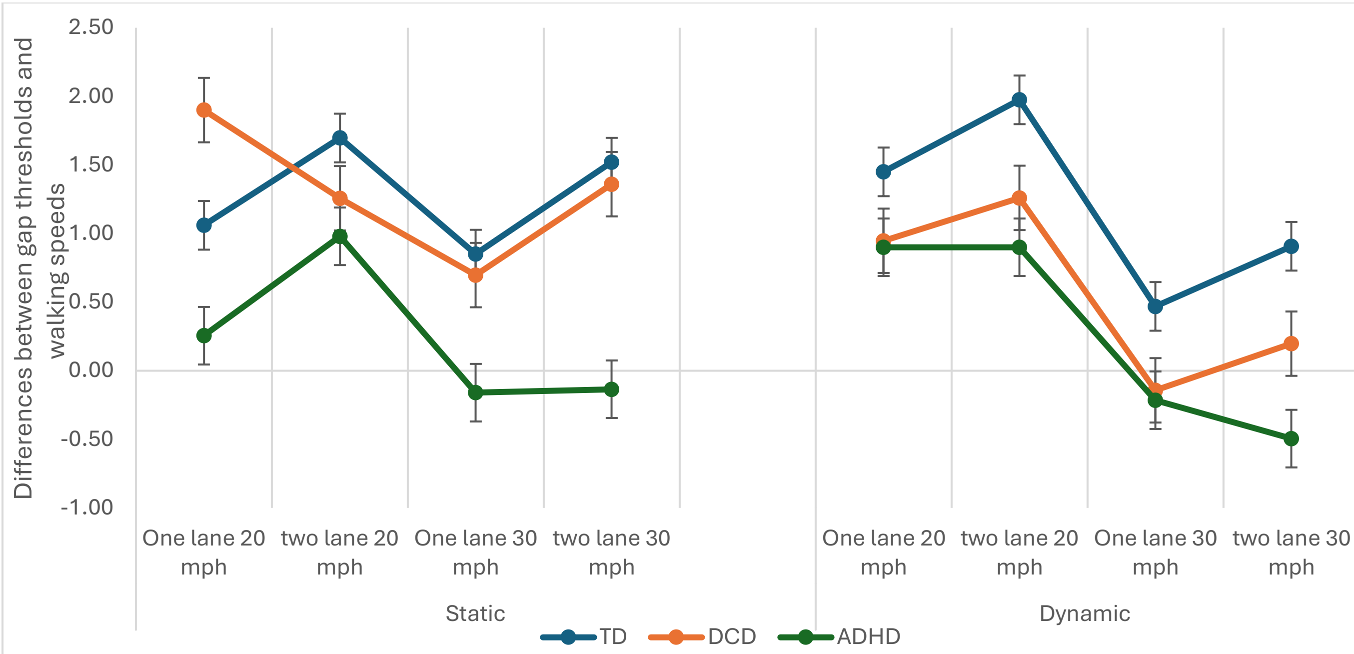


Figure 8.4: Differences between mean gap acceptance thresholds and mean walking times to show the sufficiency for all groups.

Table 8.1 Safety margin and their corresponding 95% Confidence Intervals (CI) with lower and upper bound for each group and condition. Each mean was classified as 'safe' (lower CI fell above 1.5 seconds), 'near miss; (upper CI fell below 1.5 second, but lower CI fell above 0) or 'unsafe' (upper CI fell below 0).

Diagnosis	Static				Dynamic			
	20 mph		30 mph		20 mph		30 mph	
TD (N = 12)	1 lane	2 lanes	1 lane	2 lanes	1 lane	2 lanes	1 lane	2 lanes
Mean	1.06	1.70	0.85	1.52	1.45	1.97	0.47	0.91
CI	0.83 / 1.30	1.5/ 1.93	0.62 / 1.09	1.28/ 1.76	1.22/ 1.69	1.74/ 2.21	0.24/ 0.70	0.68/ 1.14
Un/safe Gap	Near miss	Safe	Near miss	Near miss	Near miss	Safe	Near miss	Near miss
DCD (N = 10)								
Mean	1.90	1.26	0.70	1.36	0.95	1.26	-0.14	0.20
CI	1.56 /	0.92/	0.36 /	1.03/	0.61/	1.06/	-0.50/	-0.14/

	2.10	1.47	0.91	1.58	1.16	1.48	0.07	-0.41
Un/safe Gap	Safe	Near miss	Near miss	Near miss	Near miss	Near miss	Unsafe	Unsafe
ADHD (N = 9)								
Mean	0.26	0.98	-0.16	-0.13	0.90	0.90	-0.21	-0.49
CI	- 0.008/ 0.52	0.72/ 1.25	-0.42/ 0.10	-0.40/ 0.13	0.64/ 1.17	0.32/ 0.85	-0.48/ 0.05	-0.76/ -0.23
Un/safe Gap	Unsafe	Near miss	Unsafe	Unsafe	Near miss	Near miss	Unsafe	Unsafe

8.4 Discussion

The ability to safely cross a road is a complex skill that requires both perceptual and motor integration. Pedestrians must accurately assess approaching vehicles and execute the crossing action with appropriate timing and coordination (Purcell et al., 2017). This task aimed to investigate gap acceptance thresholds amongst children with DCD or ADHD compared to TD peers in a virtual environment. It was hypothesised that gap acceptance thresholds among children with DCD, ADHD, and TD children would decrease as vehicle speed increases. The results revealed that vehicle speed significantly influenced gap acceptance behaviour across all groups, with participants demonstrating higher gap acceptance thresholds for slower-moving vehicles (20 mph) when compared to the gap acceptance thresholds for faster approaching vehicles (30 mph). This finding aligns with previous research suggesting that younger children with DCD and TD children aged 6 – 11 years, adjust their crossing gaps based on vehicle speed instead of TTC, opting for longer gaps when vehicles approached at slower speeds (e.g. 20 mph vs 30 mph and 30 mph vs 40 mph) (Purcell et al., 2017). Previous studies have consistently showed that increases in vehicle speed leads to higher risks of pedestrian accidents, fatalities, and severe injuries (Rosén et al., 2011; Tefft, 2013; Hussain et al., 2019), whilst lowering speed limits, especially in high pedestrian areas, can contribute to reduced incidence and severity of pedestrian accidents (Fridman et al., 2020). However, it is important to note that this does not necessarily imply an understanding of safe road crossing as a dynamic, perceptual-motor task in older children with DCD or ADHD. Simply accepting larger gaps at slower speeds may reflect a simple rule-based strategy rather than an accurate ability of detecting the changing risk associated with approaching traffic, particularly the TTC or tau. This is crucial, as perception of TTC influenced by factors such as rate of expansion, is essential for accurately detecting approaching traffic and safe road crossing. Therefore, children with DCD or ADHD can be at higher risk of RTA due to difficulties in accurately perceiving and responding to the dynamic cues of traffic, leading to more pronounced risk-taking behaviour. This study extends previous research by demonstrating that while the acceptance of temporal crossing gaps among older children with DCD may still be primarily influenced by vehicle speed, relatively similar to younger children with DCD, older children with ADHD also exhibited reliance on the same strategy when accepting crossing gaps. Thus, both groups may experience significant difficulties in accurately perceiving and responding to approaching vehicles leading to increased risk of RTA.

To further explore the gap acceptance thresholds among these populations, it was hypothesised that there will be a significant difference in temporal gap acceptance thresholds between children with DCD, ADHD and TD children. Contrary to the initial hypothesis, the results indicated no significant difference in temporal gap acceptance thresholds between children with DCD, ADHD, and TD children. This finding suggests that, despite the potential challenges associated with DCD and ADHD, these groups did not exhibit significantly different temporal crossing gaps compared to TD children. While previous research has shown shorter gap acceptance thresholds in younger children with DCD aged 6 - 11 years (Purcell et al., 2017) and children with ADHD aged 8 -12 years (Tabibi et al., 2021), this study with older children did not replicate these findings. This discrepancy may be due to developmental factors. However, it is important to acknowledge that the lack of significant differences between groups does not necessarily imply that all children possess a comprehensive understanding of safe road crossing as a dynamic, perceptual-motor task. Further research is needed to explore the factors contributing to this result and to investigate potential differences in gap acceptance with a larger sample.

It was also hypothesised that there would be a significant difference in perceptual and perceptual-motor gap acceptance thresholds between children with DCD, ADHD and TD children. The results showed that there were no significant differences in gap acceptance thresholds between static (verbal responses) and dynamic (stepping forward). Therefore, the findings did not support this hypothesis. To further assess the potential safety implications of these gap acceptance thresholds, the difference between each participant's gap acceptance time and their walking time was calculated, providing an estimate of safety margins. The findings revealed that TD group consistently demonstrated near miss crossing margins, with safety margins just above 0 except in two conditions suggesting safe crossing. In contrast, children with DCD or ADHD exhibited a higher frequency of near-misses and unsafe crossings, particularly at higher vehicle speeds (30 mph). These findings suggested that children with DCD or ADHD may have difficulties in accurately perceiving and judging approaching vehicles during road crossings when compared to TD leading to reduced safety margins and an increased probability of collisions. Previous studies indicated that children with DCD or ADHD showed riskier behaviours and more unsafe crossings when compared to TD peers (Clancey et al., 2006; Purcell et al., 2017; Tabibi et al., 2023). Overall, this study highlights the uniqueness of older children with DCD or ADHD regarding gap acceptance threshold in comparison to their TD peers.

One potential limitation of the study is the influence of the initial simulated crossing on subsequent gap acceptance decisions. While the initial simulated crossing presented a walking speed of 7.5 seconds to familiarise participants with the task, it could potentially have influenced participants' perception of appropriate traffic gaps. However, given that participants were instructed to walk at their own pace to cross a simulated street width before the main task, and the initial simulated crossing was explicitly framed as an introductory exercise to familiarise participants with the task and virtual environment, it is unlikely that this had a significant impact on their subsequent gap acceptance decisions. Additionally, the fact that participants consistently accepted smaller gaps, especially in the DCD and ADHD groups, suggests that the initial simulation did not lead to overly conservative decision-making. Another potential limitation of the study relates to the lack of significant differences between static (verbal responses) and dynamic (stepping forward) conditions in gap acceptance thresholds. While the inclusion of a dynamic condition was intended to assess the impact of perceptual-motor integration on road crossing decisions, the observed lack of difference may suggest that the current task did not adequately challenge the motor demands of the participants. For example, the stepping forward response may not have sufficiently challenged the motor skills of the participants, or the distance required to step forward may not have been sufficiently demanding to differentiate between groups. Future studies could explore the impact of different motor demands (e.g., varying distances to step) on gap acceptance decisions in children with DCD or ADHD.

8.5 Conclusion

This study extends previous research by investigating the gap acceptance thresholds of children with DCD and children with ADHD aged 11 – 16 years. Contrary to the hypothesis, the findings revealed no significant differences in gap acceptance thresholds between children with DCD, children with ADHD, and TD children. This suggests that, in the context of a virtual reality task, older children with DCD and ADHD did not exhibit significantly different temporal gap acceptance compared to their TD peers. While previous studies have highlighted difficulties associated with gap acceptance in children with DCD younger than 11 years old, the results indicate that these difficulties might not persist in older children. However, an analysis of safety margins revealed a different pattern. While the TD group consistently demonstrated near-miss and safe crossing margins, children with DCD or ADHD exhibited a higher frequency of near-misses and unsafe crossings, particularly at higher vehicle speeds (30 mph). This suggests that although the groups did not differ significantly in their overall gap acceptance thresholds, children with DCD or ADHD may still be at greater risk in real-world road crossing scenarios due to their reduced safety margins. These findings highlight the importance of considering safety margins in addition to gap acceptance thresholds when assessing road crossing competence. Further research is needed to explore the generalisability of these findings to real-world scenarios and to investigate the impact of more challenging perceptual-motor demands on gap acceptance decisions and safety margins in children with DCD or ADHD.

9 Chapter Nine: Overall Discussion

Navigating roads as pedestrians requires quick decision-making and accurate perceptual-motor skills. Children with DCD or with ADHD face additional challenges in this regard, making their road safety a significant concern. While growing attention is focused on the pedestrian safety risks associated with DCD and/or ADHD, there is a lack of clarity regarding parental concerns and a critical gap remains in our understanding of the perceptual-motor abilities of older children (11- 17 years old) with these conditions. This thesis aimed to explore these unique challenges faced by children with DCD or ADHD in relation to road safety. In order to achieve that, an exploration of parents' perspectives of children with DCD and/or ADHD regarding their daily roadside challenges was initially investigated (Chapter 4). This was further investigated with three quasi experiments through exploring the identification of safe crossing sites (Chapter 6), looming detection thresholds (Chapter 7), and gap acceptance thresholds (Chapter 8). These investigated aspects of road crossing will be discussed further in this chapter.

9.1 Parents Perspectives of Their Child Pedestrian Safety

The qualitative phase of the study (Chapter 4) explored parental experiences, revealing parents' influence, concerns, attitudes and strategies towards their children's pedestrian safety. While there is growing recognition of the challenges faced by children with DCD and/or ADHD in relation to road safety, research exploring parental perspectives on this issue remains limited. Therefore, this phase employed a qualitative approach, utilising semi-structured interviews, to overcome the limitations of previous quantitative research, which often relied on structured questionnaires (Boynton & Greenhalgh, 2004; Bowling, 2005; Brook & Boaz, 2006; DeJonckheere & Vaughn, 2019; Wilmut & Purcell, 2020) that may not fully capture the nuanced perspectives and experiences of parents of children with DCD and/or ADHD.

Subsequently, the qualitative findings from Chapter 4 revealed distinct and unique differences in the experiences of parents of children with DCD and/or ADHD compared to the broader literature on parental perspectives of TD child pedestrian safety in Chapter 3. While the literature review (Chapter 3) highlighted that parents of TD children are primarily concerned with environmental factors such as traffic congestion, speeding drivers, and the absence of safe crossing locations (Atrooshi, 2017; Teller, 2018; Al-Najjar et al., 2022; Swain et al., 2024), this thesis uniquely emphasises the additional and significant role of child-specific challenges in shaping parental decisions for children with DCD and/or ADHD at the roadside. Parents reported children with ADHD tend to exhibit impulsive behaviour, while those with DCD may struggle with spatial awareness and motor coordination. The co-occurrence of both conditions can further exacerbate these challenges. Parents further related these challenges to visual-motor and attentional challenges and described its impact on road safety of children with DCD and/or ADHD. For example, parents of children with ADHD reported a reduction in attending to traffic situations when crossing, often described as “tunnel vision”, whilst children with DCD were described as having difficulties processing visual cues. Parents of children with co-occurring DCD and ADHD reported to have a combination of these factors. Overall, parents of children with DCD and/or ADHD emphasised the additional challenges faced by their children including visual-motor and attentional challenges that significantly impact the road safety.

These unique challenges revealed in the qualitative phase (Chapter 4) directly inform the core factors of the proposed Parental Road Crossing Decision-Making Model (PRCDM), which was introduced in Chapter Three. The PRCDM posits that parental perceptions of child vulnerability and safety concerns are the central drivers of the Decision Output (e.g., restricted independent mobility). The utility of the PRCDM in this thesis is that it successfully allowed for a structured comparison between the concerns of parents of TD children, as highlighted in the Chapter 3 review, and the parents of children with DCD and/or ADHD (Chapter 4). This comparison demonstrated that while the parents of TD children focus primarily on external, environmental risks (Environmental and Moderating Factors), the decisions of DCD/ADHD parents are overwhelmingly driven by internal, child-specific factors (Core Factors), such as impulsivity and visual-motor challenges, which override other considerations. This differential emphasis explains why the decision output for parents of children with DCD/ADHD frequently results in increased restrictions or accompanied travel, thus validating the model's effectiveness in interpreting the distinct determinants of parental decision-making.

These findings appear to highlight the importance of providing tailored support and guidance to parents of children with DCD and/or ADHD, addressing their specific concerns and empowering them to make informed decisions about their children's pedestrian safety. While research on specific parent-focused interventions for these conditions is limited, existing literature on parent training programs for road safety in TD children (e.g., Van der Molen et al., 1983; Lam, 2001; Zare et al., 2019) suggests that equipping parents with knowledge and strategies to address their children's specific needs is crucial for promoting safe pedestrian behaviours. For example, Zare et al. (2018, 2019) developed an 8-session pedestrian safety intervention for 7-8-year-old children. The intervention, which included both classroom-based and practical sessions, aimed to improve looking for cars, attention to danger, and safe crossing site selection. Significant improvements were observed in all three skills after training, with sustained benefits 6 months later. Zare et al. (2019) further investigated the impact of parental involvement, demonstrating that active parental engagement significantly enhanced long-term outcomes. While performance declined slightly across all groups over time, likely due to observational learning of unsafe crossing behaviours, the intervention group with parental involvement maintained a significant advantage (Zare et al., 2019). Thus, these findings highlight the importance of developing and evaluating parent-focused interventions tailored to the specific needs of children with DCD and/or ADHD, building upon the existing evidence base of effective road safety programs.

9.2 Pedestrian Skills in Children with DCD or ADHD

It becomes evident from the findings of Phase one that parents are concerned about their children safety as pedestrians. However, the importance of investigating pedestrian skills in children with DCD or ADHD does not only relate to the increase of their safety at the roadside, it is also related to safe independent community mobility, which is considered an integral occupational enabler, as it plays a vital role in supporting individuals' participation in meaningful occupations such as education, social participation, and leisure activities (AOTA, 2017; Stav, 2014). This significantly contributes to overall health, wellbeing, and quality of life (AOTA, 2017). Therefore, enhancing community mobility skills in children with DCD or ADHD is essential for their overall development and wellbeing. To achieve that, Luu et al. (2022) emphasised the importance of a sequential understanding of pedestrian behaviours, highlighting the need to consider both pre-crossing and the execution of the crossing itself. Therefore, the first quasi-experimental task focused on pre-crossing, specifically investigating the ability of children with DCD or ADHD to identify safe crossing sites. While prior research has demonstrated that older TD children can identify safe crossing sites (Tabibi & Pfeffer, 2007; Ampofo-Boateng & Thomson, 1991), this study found that children with DCD or ADHD, despite their neurodevelopmental conditions, were also able to accurately identify safe crossing sites. Furthermore, the eye-tracking data, specifically Mean Fixation Duration (MFD) and Total Saccade Count revealed no statistically significant differences in visual attention patterns or search strategies between the groups. This suggests that while all groups possess the necessary explicit knowledge and visual-search capacity to distinguish safe from unsafe locations in a static, the primary challenge may lie not in identification, but in the execution of the crossing decision under dynamic conditions, which was explored in the following quasi-experimental tasks.

Building upon this understanding of pre-crossing aspect, the subsequent quasi-experimental tasks focused on the execution of road crossing. As explained before road crossing is a complex perceptual-motor task requiring the integration of perception and motor execution, the subsequent tasks focused on examining critical perceptual-motor aspects - looming detection and gap acceptance. The second task investigated looming detection in 11-16-year-old children with DCD or ADHD compared to TD peers. Previous research has shown that looming detection develops with age and is impaired in younger children with DCD (Wann et al., 2011). While ADHD's impact on looming detection remains largely unexplored, it is associated with increased road crossing risks. Results showed that in the car conditions, the TD group demonstrated the best looming detection, followed by the ADHD group, while the DCD group exhibited the most difficulty in perceiving looming stimuli. Vehicle type influenced performance, with lower speed thresholds observed for motorbikes in Condition 2 and Condition 3. Eye-tracking data revealed lower correct saccades in the ADHD group, suggesting less effective visual scan for the scene. While DCD children also demonstrated lower looming detection thresholds, they did not exhibit significant differences in shifting their attention to the stimuli when compared to TD. Therefore, their difficulties may stem from underlying visual perceptual deficits, such as difficulties in processing visual information quickly and accurately, which can be further impacted by the dynamic and unpredictable nature of real-world traffic environments.

The third task extended previous research by investigating the gap acceptance thresholds of children with DCD and children with ADHD aged 11 – 16 years. While previous studies have highlighted the difficulties associated with gap acceptance in children with DCD or ADHD younger than 11 years old (Purcell et al., 2017; Tabibi et al, 2021), this study demonstrates that even older children with DCD or ADHD may exhibit relatively similar difficulties in selecting safe temporal crossing gaps. Additionally, vehicle speed significantly influenced gap acceptance thresholds, with participants accepting shorter temporal crossing gaps for faster-moving vehicles leading to increased risk of RTA. This may be due to children with DCD or ADHD over-relying on vehicle distance in their crossing decisions, instead of TTC and the ability of detecting different rates of approaching vehicles. Therefore, DCD and ADHD groups may still exhibit difficulties to accurately perceive approaching vehicles and make timely decisions, leading to decreased safety margins and increased risk of accident among these populations. These findings emphasise the importance of considering the dynamic nature of road traffic and understanding road safety holistically considering the interplay between individual characteristics and environmental affordances/factors.

This thesis explored pedestrian safety in children with DCD and/or ADHD from both parental and child perspectives. The qualitative findings revealed that parents of children with DCD and/or ADHD face unique challenges related to their children's road safety, primarily stemming from visual-motor and attentional difficulties. These parental concerns were echoed in the quantitative findings, which showed distinct visual attention patterns in children with DCD or ADHD during the safe crossing site identification task. While these children were able to accurately identify safe crossing sites, their visual attention strategies differed from their TD peers, with children with ADHD exhibiting more diffuse exploration and children with DCD demonstrating a more focused search.

Additionally, the looming detection task revealed that generally children with DCD or ADHD tended to exhibit higher looming detection thresholds compared to their TD peers, especially in car conditions. While this suggests potential difficulties in perceiving and reacting to approaching vehicles, it is essential to interpret these findings cautiously due to the substantial data loss experienced in this task. Future research should further investigate the looming detection abilities of children with DCD or ADHD, with larger samples and refined methodologies, to confirm these trends and explore the underlying mechanisms.

Furthermore, the quantitative findings revealed that, despite the parental concerns and the observed differences in visual attention patterns, children with DCD or ADHD did not exhibit significantly different gap acceptance thresholds compared to TD children. However, the analysis of safety margins revealed a higher frequency of near-misses and unsafe crossings in the DCD and ADHD groups, particularly at higher vehicle speeds. This suggests that while these children may be able to make appropriate gap acceptance judgments in controlled settings, they might still be at greater risk in real-world scenarios due to slower walking speeds in the case of DCD and shorter temporal gap acceptance thresholds in the case of ADHD resulting in reduced safety margins.

These findings highlight the complex interplay between individual characteristics, such as visual-motor and attentional abilities, and environmental factors in shaping pedestrian safety outcomes. The qualitative data provides valuable insights into the parental perspectives and concerns, which can inform the development of targeted interventions. The quantitative data, on the other hand, offers a more objective assessment of children's pedestrian skills, revealing both their strengths and vulnerabilities. By integrating these two perspectives, this thesis provides a more comprehensive understanding of pedestrian safety in children with DCD and/or ADHD, paving the way for more effective interventions that address both individual and environmental factors.

9.3 Future directions

Collectively, the three quasi-experimental tasks provide a nuanced picture of the challenges faced by children with DCD and children ADHD at the roadside. Despite potential differences in the specific visual scanning patterns observed between children with DCD or ADHD (as detailed in Chapters 6 and 7), both groups may face challenges in accurately perceiving approaching vehicles and making timely decisions when crossing the road as indicated by gap acceptance threshold and safety margins (Chapter 8) results. This shared vulnerability highlights the need for interventions that address common perceptual-motor deficits in both populations. Interventions should incorporate real-world scenarios and dynamic traffic environments to help children develop the skills and strategies necessary to navigate complex and unpredictable road situations. This can be achieved through pedestrian training programs that incorporate real-world traffic conditions, such as pedestrian crossing simulations or virtual reality training programs, in conjunction with existing knowledge-based pedestrian safety courses.

For example, Schwebel et al. (2018) tested a smartphone-based intervention in a within participant design using the Viewmaster Virtual Reality (VR) headset to hold the smartphone. The data was obtained from 56 children (mean age of 9 years) in order to measure change in self-efficacy, road crossing behaviour in VR and real-road crossing behaviour (Schwebel et al., 2018). Following the training, children perceived themselves as skilled pedestrians and felt safer compared to baseline, based on a valid self-efficacy survey consisting of seven questions (Schwebel et al., 2018). Pedestrian skills were assessed in VR and improved as indicated by the significant decrease in the probability of collisions, unsafe crossings, stopping midway crossing the road and start/delay to enter the road, all of which reflect safer decision-making. However, there was a decrease in TTC, indicating the selection of shorter traffic gaps leading to an increase in the risk of pedestrian injury, potentially due to self-confidence improvement (Schwebel et al., 2018). Through observing the actual road crossing behaviours of 25 children (also with a mean age of 9 years), the authors found that they tended to look more frequently at the upcoming cars and were less likely to rely on crossing instruction from the crossing guard, presumably due to the improvement of self-confidence and becoming safer pedestrians (Schwebel et al., 2018).

Another example is using simulator environments for pedestrian training. Schwebel et al. (2016) used 3 projector screens to build a simulator environment aiming to improve unsafe crossings, start/delay time, attention to traffic and TTC. The intervention was investigated among 44 children aged 7 to 8 years old (Schwebel et al., 2016). The authors found that there were no significant improvements in unsafe crossings and a possible increase in the risk of pedestrian injury after training, reflected by a decrease in attention to traffic and TTC (Schwebel et al., 2016). The results were not in line with the intervention aim which was to improve pedestrian safety and the authors suggest that the increase in confidence among children could be one of the explanations for these results (Schwebel et al., 2016). The start/delay time to enter the road declined after the intervention indicating children were less hesitant in initiating a crossing once they decided to cross (Schwebel et al., 2016). This further supported the possibility of improved confidence and efficient decision making (Schwebel et al., 2016). Explanations as to why unsafe crossings did not significantly decrease post simulation training could relate to boredom, also children may perceive their behaviours in an simulation environment as without risk compared to real-world road crossing situations (Schwebel et al., 2016).

Generally, these studies aimed to improve different child pedestrian skills and many of the targeted pedestrian skills were improved when VR or simulator was used to deliver child pedestrian interventions (Schwebel et al., 2018; Schwebel et al., 2016). Nonetheless, there were inconsistent results in the simulator study conducted by Schwebel et al. (2016) with an increase in confidence provided as a possible explanation for these results. Self-efficacy was further tested by Schwebel et al. (2018) and despite the increase in confidence amongst children after training, the relationship between confidence and child pedestrian safety requires further investigation. Furthermore, other limitations of the Schwebel et al. (2016) study include difficulties with implementing simulator outside of a laboratory setting, the cost of developing the simulator environment and the human resources required to operate the system and train/instruct children. These issues apply less to fully immersive VR, which provided the opportunity for repetitive practice leading to improvement in child pedestrian skills both within the VR environment and in real-world road crossing (Schwebel et al., 2018). Therefore, it seems that VR can help to improve some aspects of child pedestrian safety, it is encouraging that the number of studies utilising VR for road safety interventions is increasing, especially when considering that it provides a safe environment for repetitive practice.

In contrast, knowledge based pedestrian courses could be beneficial but for short-term effect. For example, Jiang et al. (2021) created a PowerPoint training course to individually teach children pedestrian skills focusing on improving road crossing behaviours and pedestrian visual attention. Jiang et al. (2021) recruited 20 children aged between 8- and 12-years old (Jiang et al., 2021). The authors found that there were significant changes in pedestrian behaviours and visual attention after the training (Jiang et al., 2021). Using an eye tracker, for example, children in the experimental group focused on small areas of the visual scene when using zebra crossings before training however after the training they focused on larger traffic areas including the right and left sides of the zebra crossing, reflecting an increase in their pedestrian visual attention (Jiang et al., 2021). Unsafe crossings also decreased after training in the experimental group based on a frame-by-frame analysis of video recordings of actual road crossings at predetermined un-signalised and signalised intersections (Jiang et al., 2021). However, these improvements in pedestrian safety declined one month after training (Jiang et al., 2021). Hence, there were improvements in pedestrian behaviours, but these were not retained after one month, possibly due to the observational learning of unsafe crossing behaviours from other pedestrians (Jiang et al., 2021). The rapid loss of learned skills strongly suggests that perceptual-motor skills were not adequately developed or reinforced by the knowledge-based approach. This finding directly supports the argument that interventions focusing on cognitive elements alone may not be sufficient for long-term improvement. The quasi-experimental studies demonstrated challenges with specific perceptual-motor skills such as gap acceptance and looming detection, in children with DCD or ADHD when compared to TD. Therefore, it is imperative that interventions integrate perceptual-motor training to address the core deficits impacting road crossing safety.

Overall, while knowledge-based courses had a short-term effect on pedestrian skills, there were inconsistent results from VR and simulated environments. This demonstrates the importance of conducting more research using better training designs to overcome the challenges related to the implementation of new technologies. Moreover, pedestrian safety including road crossing is complex and requires multi-layered skills, using a single method to target these skills may lead to only partial improvement in child pedestrian safety. Thus, using multiple or combining methods may be more effective in improving child pedestrian safety. Furthermore, active parental involvement is crucial for the success of these interventions. Parents can play a vital role in reinforcing safe road crossing behaviours, practicing crossing skills with their children in real-world settings, and providing ongoing support and encouragement (as discussed in the section 9.1 Parents perspectives of their child pedestrian safety). By combining technology-enhanced training with active parental involvement, a more comprehensive and effective approach can be created to improving road safety for children with DCD or ADHD.

10 Concluding Statement

In conclusion, this thesis has provided valuable insights into the challenges faced by children with DCD and/or ADHD in relation to road safety. By combining qualitative and quantitative methodologies, a deeper understanding of the factors influencing their road crossing behaviors was gained. The findings demonstrated that older children with DCD or ADHD have limitations in their ability to accurately perceive and respond to TTC information, particularly in road traffic scenarios as indicated by safety margins. This highlights the importance of addressing the unique needs of these children through tailored interventions and support. Importantly, although parents believe it is mainly their responsibility to ensure the pedestrian safety of their children, it is a shared responsibility of all stakeholders including local authorities and schools. Moreover, other road users such as drivers are required to regulate their speed to ensure their own safety and others as well. Future research should continue to explore the underlying mechanisms and develop evidence-based strategies to improve the road safety of children with DCD and/or ADHD.

References

Abdelnour, E., Jansen, M.O. and Gold, J.A. (2022). ADHD Diagnostic Trends: Increased Recognition or Overdiagnosis?. *Missouri medicine*, *119*(5), p.467.

Aghabayk, K., Esmailpour, J., Jafari, A., & Shiwakoti, N. (2021). Observational-based study to explore pedestrian crossing behaviors at signalized and unsignalized crosswalks. *Accident Analysis & Prevention*, *151*, 105990.

Al-Najjar, E., Sukor, N. S., & Shbeeb, L. I. (2022). Addressing safety issues along the way to school: Qualitative findings from Jerash camp, Jordan. *Journal of Transport & Health*, *26*, 101370.

American Occupational Therapy Association. (2017). The Occupational Therapy Role in Driving and Community Mobility Across the Lifespan. Retrieved from https://www.aota.org/About-Occupational-Therapy/Professionals/PA/Facts/Driving-Community-Mobility.aspx

American Psychiatric Association, D.S.M.T.F. and American Psychiatric Association, 2013. *Diagnostic and statistical manual of mental disorders: DSM-5* (Vol. 5, No. 5). Washington, DC: American psychiatric association.

American Psychiatric Association, DSM-5 Task Force. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5™* (5th ed.). American Psychiatric Publishing, Inc.. https://doi.org/10.1176/appi.books.9780890425596

Ampofo-Boateng, K., & Thomson, J. (1991). Children's perception of safety and danger on the road.. *British journal of psychology*, 82 (Pt 4), 487-505 . https://doi.org/10.1111/J.2044-8295.1991.TB02415.X.

Andersson, D., Wahlgren, L., Olsson, K., & Schantz, P. (2023). Pedestrians' Perceptions of Motorized Traffic Variables in Relation to Appraisals of Urban Route Environments. International Journal of Envi*ronmental Research and Public Health*, 20. https://doi.org/10.3390/ijerph20043743.

Aramide, K., Jacob, U., & Pillay, J. (2023). Conceptualisation and Contextualisation of Mixed-Methods Research: A Review. *Research in Social Sciences and Technology*. https://doi.org/10.46303/ressat.2023.31

Arbogast, H., Burke, R. V., Muller, V., Ruiz, P., Knudson, M. M., & Upperman, J. S. (2014). Randomized controlled trial to evaluate the effectiveness of a video game as a child pedestrian educational tool. *The journal of trauma and acute care surgery,* 76(5), 1317–1321. https://doi.org/10.1097/TA.0000000000000217

Arigo, D., Pagoto, S., Carter-Harris, L., Lillie, S. E., & Nebeker, C. (2018). Using social media for health research: Methodological and ethical considerations for recruitment and intervention delivery. Digital Health, 4, 2055207618771757–2055207618771757. https://doi.org/10.1177/2055207618771757

Arnold, L., Hodgkins, P., Hodgkins, P., Kahle, J., Madhoo, M., & Kewley, G. (2020). Long-Term Outcomes of ADHD: Academic Achievement and Performance. *Journal of Attention Disorders*, 24, 73 - 85. https://doi.org/10.1177/1087054714566076

Ashur, S., & Alhassan, M. (2015). Selection of pedestrian crossing treatments at controlled and uncontrolled locations. *Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2015/03. West Lafayette, IN: Purdue University.* https://doi.org/10.5703/1288284315522

Atrooshi, D. (2017). *Exploring Parental Perceptions of a Walking-School-Bus Initiative in Northern Ontario* (Doctoral dissertation).

Ball, W., & Tronick, E. (1971). Infant responses to impending collision: Optical and real. *Science*, *171*(3973), 818-820.

Bart, O., Katz, N., Weiss, P. L., & Josman, N. (2008). Street Crossing by Typically Developed Children in Real and Virtual Environments. OTJR: *Occupation, Participation and Health,* 28(2), 89–96. https://doi.org/10.3928/15394492-20080301-01

Barton, B., & Schwebel, D., 2006. The roles of age, gender, inhibitory control, and parental supervision in children's pedestrian safety.. *Journal of pediatric psychology*, 32 5, pp. 517-26 . https://doi.org/10.1093/JPEPSY/JSM014.

Basile, O., Persia, L., & Usami, D. (2010). A methodology to assess pedestrian crossing safety. *European Transport Research Review*, 2, pp. 129-137. https://doi.org/10.1007/S12544-010-0036-Z

Becker, P., Rask, M., Safipour, J., & Gunnarsson, A. B. (2023). Selfcare Strategies Shown to Be Useful in Daily Life for Adults Diagnosed with Attention Deficit Hyperactivity Disorder–A Systematic Review. *Issues in mental health nursing*, *44*(9), 825-833.

Bender, J. L., Cyr, A. B., Arbuckle, L., & Ferris, L. E. (2017). Ethics and Privacy Implications of Using the Internet and Social Media to Recruit Participants for Health Research: A Privacy-by-Design Framework for Online Recruitment. *Journal of medical Internet research*, *19*(4), e104. https://doi.org/10.2196/jmir.7029

Bernardi, M., Leonard, H. C., Hill, E. L., Henry, L. A. (2015). Brief report: response inhibition and processing speed in children with motor difficulties and developmental coordination disorder. *Child Neuropsychol.* 22, 627–634. doi: 10.1080/09297049.2015.1014898

Bernardi, M., Leonard, H., Hill, E., Botting, N., & Henry, L. (2018). Executive functions in children with developmental coordination disorder: a 2-year follow-up study. *Developmental Medicine & Child Neurology*, 60. https://doi.org/10.1111/dmcn.13640.

BIOPAC (2024). Tobii Pro Spectrum Eye Tracking Bar Systems. Retrieved August 24, 2024, from https://www.biopac.com/product/tobii-spectrum-eye-tracking-bar-systems/

Blank, R., Barnett, AL, Cairney, J., Green, D., Kirby, A., Polatajko, H., Rosenblum, S., Smits-Engelsman, B., Sugden, D., Wilson, P. and Vinçon, S. (2019). International clinical practice recommendations on the definition, diagnosis, assessment, intervention, and psychosocial aspects of developmental coordination disorder. Developmental Medicine & Child Neurology , 61 (3), pp.242-285.

Bo, J., & Lee, C. (2013). Motor skill learning in children with Developmental Coordination Disorder.. *Research in developmental disabilities*, 34 6, 2047-55 . https://doi.org/10.1016/j.ridd.2013.03.012

Boddy, C.R. (2016). Sample size for qualitative research. *Qualitative Market Research: An International Journal*, *19*(4), pp.426-432.

Bonifacci, P. (2004). Children with low motor ability have lower visual-motor integration ability but unaffected perceptual skills. *Human movement science*, *23*(2), 157-168.

Bonthrone, A., Green, D., Morgan, A., Mankad, K., Clark, C., & Liégeois, F. (2023). Attention and motor profiles in children with developmental coordination disorder: A neuropsychological and neuroimaging investigation. *Developmental Medicine and Child Neurology*, 66, 362 - 378. https://doi.org/10.1111/dmcn.15745.

Bowling, A. (2005). Mode of questionnaire administration can have serious effects on data quality.. *Journal of public health*, 27 3, 281-91 . https://doi.org/10.1093/PUBMED/FDI031.

Boynton, P., & Greenhalgh, T. (2004). Selecting, designing, and developing your questionnaire. *BMJ : British Medical Journal*, 328, 1312 - 1315. https://doi.org/10.1136/BMJ.328.7451.1312.

Braun, V., & Clarke, V. (2021). Thematic analysis: A practical guide.

Braun, V. and Clarke, V. (2022). Conceptual and design thinking for thematic analysis. *Qualitative Psychology*, *9*(1), p.3.

Braun, V. and Clarke, V. (2023). Toward good practice in thematic analysis: Avoiding common problems and be (com) ing a knowing researcher*. International Journal of Transgender Health, 24*(1), pp.1-6.

Briggs, G.F., Hole, G.J., Land, M.F. (2016). Imagery-inducing distraction leads to cognitive tunnelling and deteriorated driving performance. *Transportation research part F: traffic psychology and behaviour, 38*, pp.106-117.

Brook, U., and Boaz, M. (2006). Adolescents with attention deficit and hyperactivity disorder/learning disability and their proneness to accidents. *Indian J. Pediatr.* 73, 299–303. doi: 10.1007/BF02825823

Burks, H.F., 1960. The hyperkinetic child. *Exceptional children*, *27*(1), pp.18-26.

Bussing, R., Fernandez, M., Harwood, M., Hou, W., Garvan, C., Eyberg, S., et al. (2008). Parent and teacher SNAP-IV ratings of attention deficit hyperactivity disorder symptoms. *Assessment* 15, 317–328. doi: 10.1177/1073191107313888

Bussing, R., Fernandez, M., Harwood, M., Hou, W., Garvan, C., Eyberg, S., & Swanson, J. (2008). Parent and Teacher SNAP-IV Ratings of Attention Deficit Hyperactivity Disorder Symptoms. *Assessment*, 15, pp. 317 - 328. https://doi.org/10.1177/1073191107313888.

Castro, C., Ventsislavova, P., Garcia-Fernandez, P., & Crundall, D. (2021). Risky Decision-Making and Hazard Prediction are Negatively Related and Could Be Assessed Independently Using Driving Footage. *Psychology research and behavior management,* 14, 857–876. https://doi.org/10.2147/PRBM.S305979

Chandra, S., Rastogi, R., & Das, V. (2014). Descriptive and parametric analysis of pedestrian gap acceptance in mixed traffic conditions. *KSCE Journal of Civil Engineering*, 18, 284-293. https://doi.org/10.1007/S12205-014-0363-Z.

Christmas, J., & Weyer, R. (2019). Developmental coordination disorder (DCD). *Hands on Dyspraxia: Developmental Coordination Disorder*. https://doi.org/10.4324/9780429438998-1

Clancy, T., Rucklidge, J., & Owen, D. (2006). Road crossing Safety in Virtual Reality: A Comparison of Adolescents With and Without ADHD. *Journal of Clinical Child*

& Adolescent Psychology, 35, 203 - 215. https://doi.org/10.1207/s15374424jccp3502_4.

Cœugnet, S., Cahour, B., & Kraïem, S. (2019). Risk-taking, emotions and socio-cognitive dynamics of pedestrian street-crossing decision-making in the city. *Transportation Research Part F: Traffic Psychology and Behaviour*. https://doi.org/10.1016/J.TRF.2019.07.011

Connelly, M. L., Conaglen, H. M., Parsonson, B. S., & Isler, R. B. (1998). Child pedestrians' crossing gap thresholds. *Accident Analysis & Prevention*, *30*(4), 443-453.

Connelly, M., & Isler, R. (1996). Child Pedestrians' Judgments of Safe Crossing Gaps at Three Different Vehicle Approach Speeds: A Preliminary Study.. *Education and Treatment of Children*, 19, 19-29.

Cornelis, E., Gorus, E., Van Schelvergem, N., & De Vriendt, P. (2019). The relationship between basic, instrumental, and advanced activities of daily living and executive functioning in geriatric patients with neurocognitive disorders. *International Journal of Geriatric Psychiatry*, 34, 889 - 899. https://doi.org/10.1002/gps.5087.

Cuve, H., Stojanov, J., Roberts-Gaal, X., Catmur, C., & Bird, G. (2021). Validation of Gazepoint low-cost eye-tracking and psychophysiology bundle. *Behavior Research Methods*, 54, 1027 - 1049. https://doi.org/10.3758/s13428-021-01654-x.

Craig, F., Margari, F., Legrottaglie, A., Palumbi, R., De Giambattista, C., & Margari, L. (2016). A review of executive function deficits in autism spectrum disorder and attention-deficit/hyperactivity disorder. *Neuropsychiatric Disease and Treatment*, 12, 1191 - 1202. https://doi.org/10.2147/NDT.S104620.

Creswell, J., & Tashakkori, A. (2007). Editorial: Differing Perspectives on Mixed Methods Research. *Journal of Mixed Methods Research*, 1, 303 - 308. https://doi.org/10.1177/1558689807306132

Critical Appraisal Skills Programme (2023). CASP (CASP Qualitative Studies Checklist) Checklist. [online] Available at: https://casp-uk.net/casp-tools-checklists/qualitative-studies-checklist/ . Accessed: 25/09/2024.

Critical Appraisal Skills Programme (2023). *CASP (CASP Qualitative Studies Checklist) Checklist.* [online] Available at: *https://casp-uk.net/casp-tools-checklists/qualitative-studies-checklist/ .* Accessed: 25/07/2024.

Darko, E. M., Kleib, M., & Olson, J. (2022). Social media use for research participant recruitment: integrative literature review. *Journal of Medical Internet Research*, *24*(8), e38015.

Dawadi, S., Shrestha, S., & Giri, R. A. (2021). Mixed-methods research: A discussion on its types, challenges, and criticisms. *Journal of Practical Studies in Education*, *2*(2), 25-36.

Deconinck, F., Clercq, D., Savelsbergh, G., Savelsbergh, G., Coster, R., Oostra, A., Dewitte, G., & Lenoir, M. (2006). Visual contribution to walking in children with Developmental Coordination Disorder.. *Child: care, health and development*, 32 6, 711-22. https://doi.org/10.1111/J.1365-2214.2006.00685.X.

DeJonckheere, M., & Vaughn, L. (2019). Semistructured interviewing in primary care research: a balance of relationship and rigour. *Family Medicine and Community Health*, 7. https://doi.org/10.1136/fmch-2018-000057.

Department for Transport. (2019). Reported road casualties in Great Britain: 2018 annual report. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/834585/reported-road-casualties-annual-report-2018.pdf [Accessed JUNE 24, 2023].

Department for Transport. (2020). Reported road casualties in Great Britain: 2019 annual report. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/att achment_data/file/922717/reported-road-casualties-annual-report-2019.pdf [Accessed JUNE 24, 2023].

Department for Transport. (2023). *The Highway Code.* Retrieved from https://www.gov.uk/guidance/the-highway-code/rules-for-pedestrians-1-to-35

Deshmukh, P., & Patel, D. (2019). Driving and Road Rage Associated with Attention Deficit Hyperactivity Disorder (ADHD): a Systematic Review. *Current Developmental Disorders Reports*, 6, 241 - 247. https://doi.org/10.1007/s40474-019-00183-9

Dickerson, A. E. (2020). 10 Driving and Community Mobility as an Instrumental Activity of Daily Living. *Stroke Rehabilitation E-Book: A Function-Based Approach*, 220.

Diamond, A. (2013). Executive functions. *Annual review of psychology*, *64*(1), 135-168.

Dionne, E., Bolduc, M., Majnemer, A., Beauchamp, M., & Brossard-Racine, M. (2022). Academic Challenges in Developmental Coordination Disorder: A Systematic Review and Meta-Analysis. *Physical & Occupational Therapy In Pediatrics*, 43, 34 - 57. https://doi.org/10.1080/01942638.2022.2073801

DiScala, C., Lescohier, I., Barthel, M., & Li, G. (1998). Injuries to Children With Attention Deficit Hyperactivity Disorder. Pediatrics (Evanston), 102(6), 1415–1421. https://doi.org/10.1542/peds.102.6.1415

Duperrex, O., Roberts, I., & Bunn, F. (2002). Safety education of pedestrians for injury prevention. *The Cochrane database of systematic reviews*, 2002(2), CD001531. https://doi.org/10.1002/14651858.CD001531

Durand, G., Arbone, I. S., & Wharton, M. (2020). Reduced organizational skills in adults with ADHD are due to deficits in persistence, not in strategies. *PeerJ*, *8*, e9844.

Dyck, D., Baijot, S., Aeby, A., Tiège, X., & Deconinck, N. (2022). Cognitive, perceptual, and motor profiles of school-aged children with developmental coordination disorder. *Frontiers in Psychology*, 13. https://doi.org/10.3389/fpsyg.2022.860766

Edemekong, P. F., Bomgaars, D. L., Sukumaran, S., & Schoo, C. (2025). *Activities of Daily Living*. In *StatPearls* [Internet]. StatPearls Publishing. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470404/

Edmonds, W., & Kennedy, T. (2017). Exploratory-sequential approach. In An Applied Guide to Research Designs: Quantitative, Qualitative, and Mixed Methods (Second ed., pp. 201-207). SAGE Publications, Inc, https://doi.org/10.4135/9781071802779

Egan, C. D. (2012). *Children's Gaze Behaviour at Real-world and Simulated Road Crossings* (Doctoral dissertation, Edinburgh Napier University).

Etikan, I., Musa, S.A., Alkassim, R.S. (2016). Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics*, *5*(1), pp.1-4.

Evans, K. (1987). Definition of occupation as the core concept of occupational therapy. *The American journal of occupational therapy: official publication of the American Occupational Therapy Association*, 41 10, pp. 627-8.

Ezzati Amini, R., Katrakazas, C., & Antoniou, C. (2019). Negotiation and decision-making for a pedestrian roadway crossing: A literature review. *Sustainability*, *11*(23), 6713.

Falemban, R., Wilmut, K., Hurst, H., & Purcell, C. (2024). Roadside experiences of parents of children with developmental coordination disorder and/or attention deficit hyperactivity disorder. *Frontiers in human neuroscience*, *18*, 1339043. https://doi.org/10.3389/fnhum.2024.1339043

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods*, *39*(2), 175-191

Fenton, W. S. (1996). DSM-IV Training Guide; DSM-IV Guidebook; DSM-IV Handbook of Differential Diagnosis; Diagnostic and Statistical Manual of Mental Disorders: Primary Care Version. *American Journal of Psychiatry*, *153*(7), 960-a.

Fetters, M.D., Curry, L.A. and Creswell, J.W., 2013. Achieving integration in mixed methods designs—principles and practices. *Health services research*, *48*(6pt2), pp.2134-2156.

Fitzpatrick, K., Brewer, M., & Turner, S., 2006. Another Look at Pedestrian Walking Speed. *Transportation Research Record*, 1982, pp. 21 - 29. https://doi.org/10.1177/0361198106198200104

Fliers, E., Franke, B., Lambregts-Rommelse, N., Altink, M., Buschgens, C., Sanden, M., Sergeant, J., Faraone, S., & Buitelaar, J. (2010). Undertreatment of Motor Problems in Children with ADHD.. *Child and adolescent mental health*, 15 2, 85-90 . https://doi.org/10.1111/J.1475-3588.2009.00538.X.

Fridman, L., Ling, R., Rothman, L., Cloutier, M., Macarthur, C., Hagel, B., & Howard, A. (2020). Effect of reducing the posted speed limit to 30 km per hour on pedestrian motor vehicle collisions in Toronto, Canada - a quasi experimental, pre-post study. *BMC Public Health*, 20. https://doi.org/10.1186/s12889-019-8139-5.

Fogel, Y., Stuart, N., Joyce, T., & Barnett, A. (2021). Relationships between motor skills and executive functions in developmental coordination disorder (DCD): A systematic review. *Scandinavian Journal of Occupational Therapy*, 30, 344 - 356. https://doi.org/10.1080/11038128.2021.2019306.

Fuermaier, A., Hüpen, P., Vries, S., Müller, M., Kok, F., Koerts, J., Heutink, J., Tucha, L., Gerlach, M., & Tucha, O. (2018). Perception in attention deficit hyperactivity disorder. *ADHD Attention Deficit and Hyperactivity Disorders*, 10, 21-47. https://doi.org/10.1007/s12402-017-0230-0.

Fugard, A.J. and Potts, H.W. (2015). Supporting thinking on sample sizes for thematic analyses: a quantitative tool. *International journal of social research methodology*, *18*(6), pp.669-684.

Gårder, P., 1989. Pedestrian safety at traffic signals: a study carried out with the help of a traffic conflicts technique. *Accident; analysis and prevention*, 21 5, pp. 435-44. https://doi.org/10.1016/0001-4575(89)90004-3

Gau, S.S.F., Shang, C.Y., Liu, S.K., Lin, C.H., Swanson, J.M., Liu, Y.C. and Tu, C.L. (2008). Psychometric properties of the Chinese version of the Swanson, Nolan, and Pelham, version IV scale–parent form. *International journal of methods in psychiatric research*, *17*(1), pp.35-44

Ghafoor, F., Riaz, M., Deifalla, A., Azab, M., Javaid, O., Sattar, M., & Sadiq, M. (2023). Serviceability Analysis of Pedestrian Overhead Bridges and Underpasses. *Civil Engineering Journal*. https://doi.org/10.28991/cej-2023-09-04-09

Gibaldi, A., & Sabatini, S. (2020). The saccade main sequence revised: A fast and repeatable tool for oculomotor analysis. *Behavior Research Methods*, 53, 167 - 187. https://doi.org/10.3758/s13428-020-01388-2.

Gibson, J. (1979). The ecological approach to visual perception. New Jersey, USA: Lawrence Erlbaum Associates, Inc. Publishers.

Gielen, A., Defrancesco, S., Bishai, D., Mahoney, P., Ho, S., & Guyer, B. (2004). Child pedestrians: The role of parental beliefs and practices in promoting safe walking in urban neighborhoods. *Journal of Urban Health*, 81, 545-555. https://doi.org/10.1093/jurban/jth139.

Gillberg, C., & Kadesjö, B., 2003. Why Bother About Clumsiness? The Implications of Having Developmental Coordination Disorder (DCD). *Neural Plasticity*, 10, pp. 59 - 68. https://doi.org/10.1155/NP.2003.59.

Gomez, A., & Sirigu, A. (2015). Developmental coordination disorder: core sensori-motor deficits, neurobiology and etiology. *Neuropsychologia*, 79, 272-287. https://doi.org/10.1016/j.neuropsychologia.2015.09.032.

Goulardins, J. B., Nascimento, R. O., Casella, E. B., Silva, M. A., Piek, J., Matos, M. A., & de Oliveira, J. A. (2024). Do Children with Co-Occurring ADHD and DCD Differ in Motor Performance?. *Journal of Motor Behavior*, 1-11.

Goulardins, J.B., Rigoli, D., Licari, M., Piek, J.P., Hasue, R.H., Oosterlaan, J. and Oliveira, J.A. (2015). Attention deficit hyperactivity disorder and developmental coordination disorder: Two separate disorders or do they share a common etiology. *Behavioural brain research*, *292*, pp.484-492.

Gould, M., Poulter, D. R., Helman, S., & Wann, J. P. (2013). Detection of vehicle approach in the presence of additional motion and simulated observer motion at road junctions. *Journal of experimental psychology: applied*, *19*(2), 171.

Guo, H., Wang, W., Guo, W., Jiang, X., & Bubb, H. (2012). Reliability Analysis of Pedestrian Safety Crossing in Urban Traffic Environment. *Safety Science*, 50, pp. 968-973. https://doi.org/10.1016/J.SSCI.2011.12.027

Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis Campbell Systematic Reviews, 18, e1230. https://doi.org/10.1002/cl2.1230

Hall, C. L., Guo, B., Valentine, A. Z., Groom, M. J., Daley, D., Sayal, K., & Hollis, C. (2020). The Validity of the SNAP-IV in Children Displaying ADHD Symptoms. Assessment, 27(6), 1258–1271. https://doi.org/10.1177/1073191119842255

Hamann, C., Dulf, D., Baragan-Andrada, E., Price, M., & Peek-Asa, C. (2017). Contributors to pedestrian distraction and risky behaviours during road crossings in Romania. *Injury Prevention*, *23*(6), 370–376. https://doi.org/10.1136/injuryprev-2016-042219

Hannah, C., Spasić, I., & Corcoran, P. (2018). A computational model of pedestrian road safety: the long way round is the safe way home. *Accident Analysis & Prevention*, *121*, 347-357.

Happell, B., Stanton, R., Hoey, W., & Scott, D. (2014). Knowing is not doing: The relationship between health behaviour knowledge and actual health behaviours in people with serious mental illness. *Mental Health and Physical Activity,* 7(3), 198-204.

Harris, S., Purcell, C., Wilmut, K. (2022). Moving with confidence: How does anxiety impede performance in individuals with developmental coordination disorder (DCD)?. *Current Developmental Disorders Reports*, pp.1-7.

Harrowell, I., Hollén, L., Lingam, R., Emond, A. (2018). The impact of developmental coordination disorder on educational achievement in secondary school. *Res. Dev. Disabil.* 72, 13–22. doi: 10.1016/j.ridd.2017.10.014

Hasselkus, B. R., & Dickie, V. (2024). *The meaning of everyday occupation*. Taylor & Francis.

Hatfield, J., Fernandes, R., Job, R.S. and Smith, K. (2007). Misunderstanding of right-of-way rules at various pedestrian crossing types: observational study and survey. *Accident Analysis & Prevention, 39(4)*, pp.833-842

Henderson, S. E, Sugden, D., & Barnett, A. L. (2007). *Movement Assessment Battery for Children-2* [Database record]. APA PsycTests. https://doi.org/10.1037/t55281-000

Henderson, S. E., & Sugden, D. A. (1992). Movement Assessment Battery for Children: Manual. London Psychological Corporation.

Henderson, S. E., & Sugden, D. A. (1992). Movement Assessment Battery for Children: Manual. London Psychological Corporation.

Hoffmann, E. R. (1994). Estimation of time to vehicle arrival—Effects of age on use of available visual information. *Perception*, *23*(8), 947-955.

Holleman, G., Hooge, I., Kemner, C., & Hessels, R. (2020). The 'Real-World Approach' and Its Problems: A Critique of the Term Ecological Validity. *Frontiers in Psychology*, 11. https://doi.org/10.3389/fpsyg.2020.00721.

Holloway, I. and Todres, L. (2003). The status of method: flexibility, consistency and coherence. *Qualitative research*, *3*(3), pp.345-357.

Hong QN, Pluye P, Fàbregues S, Bartlett G, Boardman F, Cargo M, Dagenais P, Gagnon M-P, Griffiths F, Nicolau B, O'Cathain A, Rousseau M-C, Vedel I. Mixed Methods Appraisal Tool (MMAT), version 2018. Registration of Copyright (#1148552), Canadian Intellectual Property Office, Industry Canada.

Huber, A., Lopez, J., & Sipe, E. (2020). Developmental Coordination Disorder. *Definitions*. https://doi.org/10.1016/b978-0-12-385216-8.00007-2.

Hunt, J., Zwicker, J.G., Godecke, E. and Raynor, A. (2021). Awareness and knowledge of developmental coordination disorder: A survey of caregivers, teachers, allied health professionals and medical professionals in Australia. *Child: Care, Health and Development*, *47*(2), pp.174-183.

Hussain, H., Farhan, M. A., Umar, R. R., & Dadang, M. M. (2005). Key components of a motorcycle-traffic system: A study along the motorcycle path in Malaysia. *IATSS research*, *29*(1), 50-56.

Hussain, Q., Feng, H., Grzebieta, R., Brijs, T., & Olivier, J. (2019). The relationship between impact speed and the probability of pedestrian fatality during a vehicle-pedestrian crash: A systematic review and meta-analysis.. *Accident; analysis and prevention*, 129, 241-249 . https://doi.org/10.1016/j.aap.2019.05.033.

Iragorri, N., & Spackman, E. (2018). Assessing the value of screening tools: reviewing the challenges and opportunities of cost-effectiveness analysis. *Public Health Reviews*, 39. https://doi.org/10.1186/s40985-018-0093-8

Jahani, M., Pishyareh, E., Haghgoo, H., Hosseini, S., & Sani, S. (2016). Neurofeedback Effect on Perceptual-Motor Skills of Children with ADHD. *Iranian Rehabilitation Journal*, 14, 43-50. https://doi.org/10.15412/J.IRJ.08140107

Janmohammadi, S., Haghgoo, H., Farahbod, M., Overton, P., & Pishyareh, E. (2020). Effect of a visual tracking intervention on attention and behavior of children with Attention Deficit Hyperactivity Disorder. *Journal of Eye Movement Research*, 12. https://doi.org/10.16910/jemr.12.8.6

Jiang, K., Wang, Y., Feng, Z., Cui, J., Huang, Z., Yu, Z., & Sze, N. . (2021). Research on intervention methods for children's street-crossing behaviour: Application and expansion of the theory of "behaviour spectrums." *Accident Analysis and Prevention,* 152, 105979–105979. https://doi.org/10.1016/j.aap.2021.105979

Jiang, K., Wang, Y., Feng, Z., Sze, N. N., Yu, Z., & Cui, J. (2021). Exploring the crossing behaviours and visual attention allocation of children in primary school in an outdoor road environment. *Cognition, Technology & Work*, *23*, 587-604.

Johnson, R.B., Onwuegbuzie, A.J. and Turner, L.A. (2007). Toward a definition of mixed methods research. *Journal of mixed methods research*, *1*(2), pp.112-133. https://doi.org/10.1177/1558689806298224

Johnston, I. (2012). The Normal Child. *BMJ: British Medical Journal*, 344. https://doi.org/10.1136/BMJ.E2436.

Jonikaitis, D., Szinte, M., Rolfs, M., & Cavanagh, P. (2013). Allocation of attention across saccades.. *Journal of neurophysiology*, 109 5, 1425-34 . https://doi.org/10.1152/jn.00656.2012.

Jung, H., Woo, Y., Kang, J., Choi, Y., & Kim, K. (2014). Visual Perception of ADHD Children with Sensory Processing Disorder. *Psychiatry Investigation*, 11, 119 - 123. https://doi.org/10.4306/pi.2014.11.2.119.

Kadali, B., & Vedagiri, P. (2020). Role of number of traffic lanes on pedestrian gap acceptance and risk taking behaviour at uncontrolled crosswalk locations. *Journal of transport and health*, 19, 100950. https://doi.org/10.1016/J.JTH.2020.100950.

Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a Research Paradigm and Its Implications for Social Work Research. Social Sciences (Basel), 8(9), 255–. https://doi.org/10.3390/socsci8090255

Kayed, N. S., & Van der Meer, A. L. (2009). A longitudinal study of prospective control in catching by full-term and preterm infants. *Experimental brain research*, *194*, 245-258.

Kim, M., & Seo, J. (2021). Impulsivity is related to overhasty risk learning in attention-deficit/hyperactivity disorder: A computational psychiatric approach. *Journal of psychiatric research*, 143, 84-90. https://doi.org/10.1016/j.jpsychires.2021.07.044

Kirby, A. and Sugden, D.A., (2007). Children with developmental coordination disorders. *Journal of the Royal Society of Medicine*, *100*(4), pp.182-186.

Kirby, A., Sugden, D. and Edwards, L. (2011). Driving behaviour in young adults with developmental co-ordination disorder. *Journal of Adult Development*, *18*, pp.122-129.

Kirby, A., Williams, N., Thomas, M., Hill, E.L. (2013). Self-reported mood, general health, wellbeing and employment status in adults with suspected DCD. *Research in developmental disabilities*, *34*(4), pp.1357-1364.

Klein, E., Licari, M., Barbic, S., & Zwicker, J. (2024). Diagnostic services for developmental coordination disorder: Gaps and opportunities identified by parents.. *Child: care, health and development*, 50 1, e13230. https://doi.org/10.1111/cch.13230.

Knoblauch, R., Pietrucha, M., & Nitzburg, M., 1996. Field Studies of Pedestrian Walking Speed and Start-Up Time. *Transportation Research Record*, 1538, pp. 27 - 38. https://doi.org/10.1177/0361198196153800104

Kofler, M., Raiker, J., Sarver, D., Wells, E., & Soto, E. (2016). Is hyperactivity ubiquitous in ADHD or dependent on environmental demands? Evidence from meta-analysis.. *Clinical psychology review*, 46, 12-24 . https://doi.org/10.1016/j.cpr.2016.04.004

Kong, X., Das, S., Zhang, Y. and Xiao, X. (2021). Lessons learned from pedestrian-driver communication and yielding patterns. *Transportation research part F: traffic psychology and behaviour, 79*, pp.35-48.

Kuo, D.Z., Houtrow, A.J., Arango, P., Kuhlthau, K.A., Simmons, J.M., Neff, J.M. (2012). Family-centered care: current applications and future directions in pediatric health care. *Maternal and child health journal*, *16*, pp.297-305.

Kurt, S. (2016). ASSURE: Instructional Design Model. Retrieved from https://educationaltechnology.net/assure-instructional-design-model/

Kvale, S. (2009). *Interviews: Learning the craft of qualitative research interviewing*. Sage.

Lahey, B., & Carlson, C., 1991. Validity of the Diagnostic Category of Attention Deficit Disorder Without Hyperactivity. *Journal of Learning Disabilities*, 24, pp. 110 - 120. https://doi.org/10.1177/002221949102400208.

Lachambre, C., Proteau-Lemieux, M., Lepage, J., Bussières, È., & Lippé, S. (2021). Attentional and executive functions in children and adolescents with developmental coordination disorder and the influence of comorbid disorders: A systematic review of the literature. *PLoS ONE*, 16. https://doi.org/10.1371/journal.pone.0252043.

Lam, L., 2001. Factors associated with parental safe road behaviour as a pedestrian with young children in metropolitan New South Wales, Australia.. *Accident; analysis and prevention*, 33 2, pp. 203-10 . https://doi.org/10.1016/S0001-4575(00)00033-6.

Lawton, M. P., & Brody, E. M. (1969). Assessment of older people: self-maintaining and instrumental activities of daily living. *The gerontologist*.

Lee, D. N. (1976). A theory of visual control of braking based on information about time-to-collision. *Perception*, *5*(4), 437-459.

Leigh, R., & Kennard, C. (2004). Using saccades as a research tool in the clinical neurosciences.. *Brain : a journal of neurology*, 127 Pt 3, 460-77 . https://doi.org/10.1016/J.AJO.2004.04.039.

Lévêque, L., Ranchet, M., Deniel, J., Bornard, J., & Bellet, T. (2020). Where Do Pedestrians Look When Crossing? A State of the Art of the Eye-Tracking Studies. *IEEE Access*, 8, 164833-164843. https://doi.org/10.1109/ACCESS.2020.3021208.

Lieberman, H. R., & Pentland, A. P. (1982). Microcomputer-based estimation of psychophysical thresholds: the best PEST. *Behavior Research Methods & Instrumentation*, *14*(1), 21-25.

Linde, B., Netten, J., Otten, B., Postema, K., Geuze, R., & Schoemaker, M. (2015). Activities of Daily Living in Children With Developmental Coordination Disorder: Performance, Learning, and Participation. *Physical Therapy*, 95, 1496 - 1506. https://doi.org/10.2522/ptj.20140211

Liu, H., Hirayama, T., Saiki, L. Y. M., & Murase, H. (2020). What Timing for an Automated Vehicle to Make Pedestrians Understand Its Driving Intentions for Improving Their Perception of Safety? 2020 IEEE 23rd International Conference on Intelligent Transportation Systems (ITSC), 1–6. Ithaca: IEEE. https://doi.org/10.1109/ITSC45102.2020.9294696

Llorca, D., Montero, V., Parra, I., Gavilán, M., Daza, I., Pérez, J., & Sotelo, M., 2011. Autonomous Pedestrian Collision Avoidance Using a Fuzzy Steering Controller. *IEEE Transactions on Intelligent Transportation Systems*, 12, pp. 390-401. https://doi.org/10.1109/TITS.2010.2091272.

Lobjois, R., & Cavallo, V. (2007). Age-related differences in street-crossing decisions: the effects of vehicle speed and time constraints on gap selection in an estimation task.. *Accident; analysis and prevention*, 39 5, 934-43 . https://doi.org/10.1016/J.AAP.2006.12.013.

Loe, I., & Feldman, H. (2007). Academic and educational outcomes of children with ADHD.. *Journal of pediatric psychology*, 32 6, 643-54 . https://doi.org/10.1093/JPEPSY/JSL054

Leonard, H., Bernardi, M., Hill, E., & Henry, L. (2015). Executive Functioning, Motor Difficulties, and Developmental Coordination Disorder. *Developmental Neuropsychology*, 40, 201 - 215. https://doi.org/10.1080/87565641.2014.997933.

Loh, P.R., Piek, J.P., Barrett, N.C. (2011). Comorbid ADHD and DCD: Examining cognitive functions using the WISC-IV. *Research in developmental disabilities*, *32*(4), pp.1260-1269.

Lupton, K., Colwell, J., & Bayley, M. (2002, June). Aspects of children's road crossing behaviour. In *Proceedings of the Institution of Civil Engineers-Municipal Engineer* (Vol. 151, No. 2, pp. 151-157). Thomas Telford Ltd.

Luu, D.T., Eom, H., Cho, G.H., Kim, S.N., Oh, J. and Kim, J. (2022). Cautious behaviors of pedestrians while crossing narrow streets: Exploration of behaviors using virtual reality experiments. *Transportation research part F: traffic psychology and behaviour, 91*, pp.164-178.

Maleki, S., & Zarei, M. (2016). Correlation Between Executive Function Behaviors and Educational Achievement of Children With Developmental Coordination Disorder. *Middle East Journal of Rehabilitation and Health*, 3. https://doi.org/10.17795/MEJRH-37378.

Marshall, B., Cardon, P., Poddar, A., Fontenot, R. (2013). Does sample size matter in qualitative research?: A review of qualitative interviews in IS research. *Journal of computer information systems*, *54*(1), pp.11-22.

Martin, N., Piek, J., & Hay, D. (2006). DCD and ADHD: a genetic study of their shared aetiology.. *Human movement science*, 25 1, 110-24 . https://doi.org/10.1016/J.HUMOV.2005.10.006

Mathôt, S., Fabius, J., Van Heusden, E., & Van Der Stigchel, S. (2018). Safe and sensible preprocessing and baseline correction of pupil-size data. *Behavior Research Methods*, 50, 94 - 106. https://doi.org/10.3758/s13428-017-1007-2.

Mattes, J.A., 1980. The role of frontal lobe dysfunction in childhood hyperkinesis. *Comprehensive psychiatry*, *21*(5), pp.358-369.

McLaughlin, C. M., Barry, W. E., Barin, E. N., Mert, M., Lowery, C., Upperman, J. S., Jensen, A. R., & Arbogast, H. (2019). Interactive Education is Associated With Lower Incidence of Pedestrian-Related Injury in Children. *The Journal of surgical research,* 244, 57–62. https://doi.org/10.1016/j.jss.2019.06.015

Meachon, E., Zemp, M., & Alpers, G. (2022). Developmental Coordination Disorder (DCD): Relevance for Clinical Psychologists in Europe. *Clinical Psychology in Europe*, 4. https://doi.org/10.32872/cpe.4165

Meachon, E.J., Melching, H. and Alpers, G.W. (2023). The overlooked disorder:(Un) awareness of developmental coordination disorder across clinical professions. *Advances in Neurodevelopmental Disorders*, pp.1-9.

Meachon, E.J., Meyer, M., Wilmut, K., Zemp, M., Alpers, G.W. (2021). Evoked potentials differentiate Developmental Coordination Disorder from Attention-Deficit/Hyperactivity Disorder in a stop-signal task: A pilot study. *Frontiers in Human Neuroscience*, *15*, p.629479.

Meir, A., & Oron-Gilad, T. (2020). Understanding complex traffic road scenes: The case of child-pedestrians' hazard perception.. *Journal of safety research*, 72, 111-126 . https://doi.org/10.1016/j.jsr.2019.12.014

Meir, A., Oron-Gilad, T., & Parmet, Y. (2015). Are child-pedestrians able to identify hazardous traffic situations? Measuring their abilities in a virtual reality environment. *Safety Science,* 80, 33-40. https://doi.org/10.1016/j.ssci.2015.07.007

Meyer, A., & Sagvolden, T. (2006). Fine motor skills in South African children with symptoms of ADHD: influence of subtype, gender, age, and hand dominance. *Behavioral and Brain Functions*, 2, 33 - 33. https://doi.org/10.1186/1744-9081-2-33.

Miller, J., Austin, J., & Rohn, D. (2004). Teaching Pedestrian Safety Skills to Children. *Environment and Behavior*, 36, 368 - 385. https://doi.org/10.1177/0013916503260880.

Monge, S. (2015). PP11.2 – 2533: Deficit of visuospatial perception in a group of children with developmental coordination disorder with or without comorbidity. *European Journal of Paediatric Neurology*, 19. https://doi.org/10.1016/S1090-3798(15)30245-2.

Mon-Williams, M. A., Pascal, E., & Wann, J. P. (1994). Ophthalmic factors in developmental coordination disorder. *Adapted Physical Activity Quarterly*, *11*(2), 170-178.

Moola S, Munn Z, Tufanaru C, Aromataris E, Sears K, Sfetcu R, Currie M, Qureshi R, Mattis P, Lisy K, Mu P-F. Chapter 7: Systematic reviews of etiology and risk . In: Aromataris E, Munn Z (Editors). Joanna Briggs Institute Reviewer's Manual. The Joanna Briggs Institute, 2017. Available from https://reviewersmanual.joannabriggs.org/

Morrongiello, B. A., Corbett, M., Beer, J., & Koutsoulianos, S. (2018). A Pilot Randomized Controlled Trial Testing the Effectiveness of a Pedestrian Training Program That Teaches Children Where and How to Cross the Street Safely. *Journal of pediatric psychology*, 43(10), 1147–1159. https://doi.org/10.1093/jpepsy/jsy056

Morrongiello, B., & Barton, B. (2009). Child pedestrian safety: parental supervision, modeling behaviors, and beliefs about child pedestrian competence.. *Accident;*

analysis and prevention, 41 5, 1040-6 . https://doi.org/10.1016/j.aap.2009.06.017.

Morrongiello, B., Corbett, M., Milanovic, M., & Beer, J. (2016). Using a Virtual Environment to Examine How Children Cross Streets: Advancing Our Understanding of How Injury Risk Arises.. *Journal of pediatric psychology*, 41 2, 265-75 . https://doi.org/10.1093/jpepsy/jsv078.

Morrongiello, B.A. and Corbett, M. (2015). Using a virtual environment to study child pedestrian behaviours: a comparison of parents' expectations and children's street crossing behaviour. *Injury prevention*, *21*(5), pp.291-295.

Mullane, J., & Klein, R. (2008). Literature Review: Visual Search by Children With and Without ADHD. *Journal of Attention Disorders*, 12, 44 - 53. https://doi.org/10.1177/1087054707305116.

Myers, C., Zane, T., Van Houten, R. and Francisco, V.T. (2022). The effects of pedestrian gestures on driver yielding at crosswalks: A systematic replication. *Journal of applied behavior analysis, 55(2)*, pp.572-583.

Nakanishi, H., Dillon, A., & Tranter, P. (2017). Getting more children walking and cycling to school: Insights from parents in three Australian cities. In *Australasian Transport Research Forum 2017 Proceedings* (pp. 1-12). Australasian Transport Research Forum Incorporated. https://www.atrf.info/papers/2017/files/ATRF2017_030.pdf

National Highway Traffic Safety Administration. (2024). *Pedestrian Safety.* Retrieved from https://www.nhtsa.gov/road-safety/pedestrian-safety#:~:text=Unfortunately%2C%20pedestrian%20injuries%20and%20fatalities,67%2C000%20pedestrians%20were%20injured%20nationwide. [Accessed JUNE 24, 2023].

National Institute for Health & Care Excellence. (2018). Attention deficit hyperactivity disorder: diagnosis and management.

https://www.nice.org.uk/guidance/ng87/chapter/Recommendations#service-organisation-and-training [Accessed JUNE 24, 2023].

National Safety Council. (2024). *Road Users; Pedestrian.* Retrieved from https://injuryfacts.nsc.org/motor-vehicle/road-users/pedestrians/data-details/#:~:text=The%20percent%20of%20pedestrian%20deaths,accounting%20for%2017.7%25%20in%202022.

Negi, S., & Mitra, R. (2020). Fixation duration and the learning process: an eye tracking study with subtitled videos. *Journal of Eye Movement Research*, 13. https://doi.org/10.16910/jemr.13.6.1.

Ngu, L.S., Hanafi, Z., Taslikhan, M. (2016). Influence of parental involvement on academic achievement. *International Journal of Advanced Education and Research*, *1*(4), pp.1-4.

Nyström, M., Niehorster, D. C., Andersson, R., & Hooge, I. (2021). The Tobii Pro Spectrum: A useful tool for studying microsaccades?. *Behavior Research Methods*, *53*, 335-353.

O'Dea, Á., Stanley, M., Coote, S., & Robinson, K. (2021). Children and young people's experiences of living with developmental coordination disorder/dyspraxia: A systematic review and meta-ethnography of qualitative research. *PLoS ONE*, 16. https://doi.org/10.1371/journal.pone.0245738

O'Neal, E.E., Rahimian, P., Jiang, Y., Zhou, S., Nikolas, M., Kearney, J.K., Plumert, J.M. (2022). How Do Child ADHD Symptoms and Oppositionality Impact Parent–Child Interactions When Crossing Virtual Roads?. *Journal of pediatric psychology*, *47*(3), pp.337-349.

Öhrström, E. and Skånberg, A. 2004. Sleep disturbances from road traffic and ventilation noise—laboratory and field experiments. *Journal of Sound and Vibration*, 271(1-2), pp.279-296.

Olfert, M., Hagedorn, R., Leary, M., Eck, K., Shelnutt, K., & Byrd-Bredbenner, C. (2019). Parent and School-Age Children's Food Preparation Cognitions and

Behaviors Guide Recommendations for Future Interventions. *Journal of nutrition education and behavior*, 51 6, 684-692. https://doi.org/10.1016/j.jneb.2019.01.022.

Olowosegun, A., Babajide, N., Akintola, A., Fountas, G., & Fonzone, A. (2022). Analysis of pedestrian accident injury-severities at road junctions and crossings using an advanced random parameter modelling framework: The case of Scotland. *Accident Analysis & Prevention, 169,* 106610.

O'Neal, E., & Plumert, J. (2018a). PA 08-3-2283 How do parents teach children to cross roads safely? a study of parent-child road crossing in an immersive pedestrian simulator. *Injury Prevention*, 24, A17 - A18. https://doi.org/10.1136/injuryprevention-2018-safety.48.

O'Neal, E., Jiang, Y., Franzen, L., Rahimian, P., Yon, J., Kearney, J., & Plumert, J. (2018b). Changes in Perception–Action Tuning Over Long Time Scales: How Children and Adults Perceive and Act on Dynamic Affordances When Crossing Roads. *Journal of Experimental Psychology: Human Perception and Performance*, 44, 18–26. https://doi.org/10.1037/xhp0000378.

O'Neal, E., Plumert, J., & Schwebel, D. (2012). How well do children estimate the time it takes to cross a road? A risk factor for pedestrian injury. *Injury Prevention*, 18, A103 - A104. https://doi.org/10.1136/INJURYPREV-2012-040590D.24.

O'Neal, E., Zhao, S., & Plumert, J. (2017). 35 Using an immersive virtual environment to study parent-child safety conversations in vivo. *Injury Prevention*, 23, A13 - A13. https://doi.org/10.1136/injuryprev-2017-042560.35.

Orm, S., Øie, M., Fossum, I., Fjermestad, K., Andersen, P., & Skogli, E. (2023). 1 Executive Functioning and Anxiety/Depressive Symptoms as Mediators Between ADHD and Quality of Life: A 10-year Longitudinal Study. *Journal of the International Neuropsychological Society*, 29, 515 - 515. https://doi.org/10.1017/s1355617723006653.

Owens, D. K., Lohr, K. N., Atkins, D., Treadwell, J. R., Reston, J. T., Bass, E. B., Chang, S., & Helfand, M. (2010). AHRQ series paper 5: grading the strength of a body of evidence when comparing medical interventions--agency for healthcare research and quality and the effective health-care program. *Journal of clinical epidemiology,* 63(5), 513–523. https://doi.org/10.1016/j.jclinepi.2009.03.009

Pacilli, M., Giovannelli, I., Prezza, M., & Augimeri, M. (2013). Children and the public realm: antecedents and consequences of independent mobility in a group of 11–13-year-old Italian children. *Children's Geographies*, 11, pp. 377 - 393. https://doi.org/10.1080/14733285.2013.812277.

Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

Panagiotidi, M., Overton, P., & Stafford, T. (2019). Co-Occurrence of ASD and ADHD Traits in an Adult Population. *Journal of Attention Disorders*, 23, 1407 - 1415. https://doi.org/10.1177/1087054717720720.

Pantangi, S. S., Ahmed, S. S., Fountas, G., Majka, K., & Anastasopoulos, P. C. (2021). Do high visibility crosswalks improve pedestrian safety? A correlated grouped random parameters approach using naturalistic driving study data. *Analytic methods in accident research*, *30*, 100155.

Parenti, I., Rabaneda, L., Schoen, H., & Novarino, G. (2020). Neurodevelopmental Disorders: From Genetics to Functional Pathways. *Trends in Neurosciences*, 43, 608-621. https://doi.org/10.1016/j.tins.2020.05.004.

Parr, M.N., Tang, H., Mallaro, S.R., Kearney, J.K. and Plumert, J.M. (2021). Do Inattention/Hyperactivity and Motor Timing Predict Children’s Virtual Road crossing Performance?. *Journal of pediatric psychology*, *46*(9), pp.1130-1139.

Pastor, P. N., & Reuben, C. A. (2006). Identified Attention-Deficit/Hyperactivity Disorder and Medically Attended, Nonfatal Injuries: US School-Age Children, 1997–2002. Ambulatory Pediatrics : the Official Journal of the Ambulatory Pediatric Association, 6(1), 38–44. https://doi.org/10.1016/j.ambp.2005.07.002

Patros, C., Alderson, R., Kasper, L., Tarle, S., Lea, S., & Hudec, K. (2016). Choice-impulsivity in children and adolescents with attention-deficit/hyperactivity disorder (ADHD): A meta-analytic review. *Clinical psychology review*, 43, 162-74. https://doi.org/10.1016/j.cpr.2015.11.001

Pawar, D., & Patil, G. (2015). Pedestrian temporal and spatial gap acceptance at mid-block street crossing in developing world.. *Journal of safety research*, 52, 39-46 . https://doi.org/10.1016/j.jsr.2014.12.006.

Peasgood, T., Bhardwaj, A., Biggs, K., Brazier, J., Coghill, D., Cooper, C., Daley, D., Silva, C., Harpin, V., Hodgkins, P., Nadkarni, A., Setyawan, J., & Sonuga-Barke, E. (2016). The impact of ADHD on the health and well-being of ADHD children and their siblings. *European Child & Adolescent Psychiatry*, 25, 1217 - 1231. https://doi.org/10.1007/s00787-016-0841-6

Peschel, A., & Orquin, J. (2013). A review of the findings and theories on surface size effects on visual attention. *Frontiers in Psychology*, 4. https://doi.org/10.3389/fpsyg.2013.00902.

Peters MDJ, Godfrey C, McInerney P, Munn Z, Tricco AC, Khalil, H. Scoping Reviews (2020). Aromataris E, Lockwood C, Porritt K, Pilla B, Jordan Z, editors. *JBI Manual for Evidence Synthesis*. JBI; 2024. Available from: https://synthesismanual.jbi.global. https://doi.org/10.46658/JBIMES-24-09

Petersch, B., & Dierkes, K. (2021). Gaze-angle dependency of pupil-size measurements in head-mounted eye tracking. *Behavior Research Methods*, 54, 763 - 779. https://doi.org/10.3758/s13428-021-01657-8.

Petticrew, M., & Roberts, H. (2008). *Systematic reviews in the social sciences: A practical guide*. John Wiley & Sons.

Pitcher, T., Piek, J., & Hay, D. (2003). Fine and gross motor ability in males with ADHD. *Developmental Medicine & Child Neurology*, 45. https://doi.org/10.1111/j.1469-8749.2003.tb00952.x.

Plumert, J., 1995. Relations between children's overestimation of their physical abilities and accident proneness. *Developmental Psychology*, 31, pp. 866-876. https://doi.org/10.1037/0012-1649.31.5.866.

Plumert, J., Kearney, J., & Cremer, J. (2004). Children's perception of gap affordances: bicycling across traffic-filled intersections in an immersive virtual environment.. *Child development*, 75 4, 1243-53 . https://doi.org/10.1111/J.1467-8624.2004.00736.X.

Poku-Boansi, M., Amoako, C., & Atuah, D. O. (2019). Urban travel patterns and safety among school children around Accra, Ghana. *Journal of Transport & Health*, *15*, 100660.

Purcell, C. (2011). *Perceptual errors in predicting vehicle approach in typical and atypical populations* (Doctoral dissertation, University of London).

Purcell, C., & Romijn, A. (2017). Appropriateness of different pedagogical approaches to road safety education for children with Developmental Coordination Disorder (DCD).. *Research in developmental disabilities*, 70, 85-93 . https://doi.org/10.1016/j.ridd.2017.08.010.

Purcell, C., Wann, J. P., Wilmut, K., and Poulter, D. (2011). Roadside judgments in children with developmental co-ordination disorder. *Res. Dev. Disabil.* 32, 1283–1292. doi: 10.1016/j.ridd.2010.12.022

Purcell, C., Wann, J. P., Wilmut, K., and Poulter, D. (2012). Reduced looming sensitivity in primary school children with developmental co-ordination disorder. *Dev. Sci.* 15, 299–306. doi: 10.1111/j.1467-7687.2011.01123.x

Purcell, C., Wilmut, K., & Wann, J. (2017). The use of visually guided behaviour in children with Developmental Coordination Disorder (DCD) when crossing a virtual road.. *Human movement science*, 53, 37-44 . https://doi.org/10.1016/j.humov.2016.11.007.

Qiu, L. and Zhu, X. (2017). Impacts of housing and community environments on children's independent mobility: a systematic literature review. *New ARCH*, *18*, p.43.

Ramos-Quiroga, J.A., Daigre, C., Valero, S., Bosch, R., Gómez-Barros, N., Nogueira, M., Palomar, G., Roncero, C., Casas, M. (2009). Validation of the Spanish version of the attention deficit hyperactivity disorder adult screening scale (ASRS v. 1.1): a novel scoring strategy. *Revista de neurologia*, *48*(9), pp.449-452.

Rankavat, S. and Tiwari, G., 2020. Influence of actual and perceived risks in selecting crossing facilities by pedestrians. Travel behaviour and society, 21, pp.1-9.

Regan, D., & Hamstra, S. J. (1993). Dissociation of discrimination thresholds for time to contact and for rate of angular expansion. *Vision research*, *33*(4), 447-462.

Rheem, H., Verma, V., & Becker, D. (2018). Use of Mouse-tracking Method to Measure Cognitive Load. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 62, 1982 - 1986. https://doi.org/10.1177/1541931218621449.

Ridel, D., Rehder, E., Lauer, M., Stiller, C. and Wolf, D. (2018), November. A literature review on the prediction of pedestrian behavior in urban scenarios. *In 2018 21st International Conference on Intelligent Transportation Systems (ITSC)* (pp. 3105-3112). IEEE.

Rivilis, I., Hay, J., Cairney, J., Klentrou, P., Liu, J., & Faught, B. (2011). Physical activity and fitness in children with developmental coordination disorder: a systematic review. *Research in developmental disabilities*, 32 3, 894-910. https://doi.org/10.1016/j.ridd.2011.01.017

Rogers, D., Dittner, A., Rimes, K., & Chalder, T. (2017). Fatigue in an adult attention deficit hyperactivity disorder population: A trans-diagnostic approach. *British Journal of Clinical Psychology*, 56, 33–52. https://doi.org/10.1111/bjc.12119.

Rosén, E., Stigson, H., & Sander, U. (2011). Literature review of pedestrian fatality risk as a function of car impact speed.. *Accident; analysis and prevention*, 43 1, 25-33 . https://doi.org/10.1016/j.aap.2010.04.003.

Ryan R; Cochrane Consumers and Communication Review Group. 'Cochrane Consumers and Communication Review Group: data synthesis and analysis'. http://cccrg.cochrane.org, 13 March 2019 (accessed 19/07/2022).

Ryan R; Cochrane Consumers and Communication Review Group. 'Cochrane Consumers and Communication Review Group: data synthesis and analysis'. http://cccrg.cochrane.org, 13 March 2019 (accessed 16/07/2024).

Sáenz, A., Villemonteix, T., Schuerbeek, P., Baijot, S., Septier, M., Defresne, P., Delvenne, V., Passeri, G., Raeymaekers, H., Victoor, L., Willaye, É., Peigneux, P., Deconinck, N., & Massat, I. (2021). Motor Abnormalities in Attention-Deficit/Hyperactivity Disorder and Autism Spectrum Disorder Are Associated With Regional Grey Matter Volumes. *Frontiers in Neurology*, 12. https://doi.org/10.3389/fneur.2021.666980.

Salmon, P.M., Stanton, N.A. and Young, K.L. (2012). Situation awareness on the road: review, theoretical and methodological issues, and future directions. *Theoretical Issues in Ergonomics Science, 13(4),* pp.472-492

Sanford, J.A. and Turner, A. (1995). Manual for the integrated visual and auditory continuous performance test. *Richmond, VA: BrainTrain*, *1995*.

Sartori, R.F., Valentini, N.C., Fonseca, R.P. (2020). Executive function in children with and without developmental coordination disorder: A comparative study. *Child: care, health and development*, *46*(3), pp.294-302.

Saunders, L., Green, J., Petticrew, M., Steinbach, R., & Roberts, H. (2013). What Are the Health Benefits of Active Travel? A Systematic Review of Trials and Cohort Studies. *PLoS ONE*, 8. https://doi.org/10.1371/journal.pone.0069912.

Sayal, K., Prasad, V., Daley, D., Ford, T., & Coghill, D. (2017). ADHD in children and young people: prevalence, care pathways, and service provision. *The lancet. Psychiatry*, 5 2, 175-186. https://doi.org/10.1016/S2215-0366(17)30167-0

Schwebel, D. C., & McClure, L. A. (2014). Children's Pedestrian Route Selection: Efficacy of a Video and Internet Training Protocol. Transportation research. Part F, *Traffic psychology and behaviour*, 26 Pt A, 171–179. https://doi.org/10.1016/j.trf.2014.07.005

Schwebel, D. C., & McClure, L. A. (2014c). Training children in pedestrian safety: Distinguishing gains in knowledge from gains in safe behavior. *The journal of primary prevention,* 35(3), 151-162.

Schwebel, D. C., Barton, B. K., Shen, J., Wells, H. L., Bogar, A., Heath, G., & McCullough, D. (2014a). Systematic review and meta-analysis of behavioral interventions to improve child pedestrian safety. *Journal of pediatric psychology,* 39(8), 826–845. https://doi.org/10.1093/jpepsy/jsu024

Schwebel, D. C., Combs, T., Rodriguez, D., Severson, J., & Sisiopiku, V. (2016). Community-based pedestrian safety training in virtual reality: A pragmatic trial. *Accident; analysis and prevention,* 86, 9–15. https://doi.org/10.1016/j.aap.2015.10.002

Schwebel, D. C., McClure, L. A., & Severson, J. (2014b). Teaching children to cross streets safely: a randomized, controlled trial. *Health psychology : official journal of the Division of Health Psychology, American Psychological Association,* 33(7), 628–638. https://doi.org/10.1037/hea0000032

Schwebel, D. C., Wu, Y., Li, P., Severson, J., He, Y., Xiang, H., & Hu, G. (2018). Featured Article: Evaluating Smartphone-Based Virtual Reality to Improve

Chinese Schoolchildren's Pedestrian Safety: A Nonrandomized Trial. *Journal of pediatric psychology,* 43(5), 473–484. https://doi.org/10.1093/jpepsy/jsx147

Schwebel, D.C., Barton, B.K., Shen, J., Wells, H.L., Bogar, A., Heath, G., McCullough, D. (2014). Systematic review and meta-analysis of behavioral interventions to improve child pedestrian safety. *Journal of Pediatric Psychology*, *39*(8), pp.826-845.

Scott, T. L., & Tulloch, K. (2021). Is community mobility contingent upon driving? Attitudes toward and intentions to use alternative modes of transport according to a mixed-aged sample. *Journal of Transport & Health, 20*, 100974. https://doi.org/10.1016/j.jth.2020.100974

Serrien, D., & O'Regan, L. (2020). The development of motor planning strategies in children. *European Journal of Developmental Psychology*, 18, 1 - 17. https://doi.org/10.1080/17405629.2020.1736029.

Shaaban, K. and Muley, D., 2016. Investigation of weather impacts on pedestrian volumes. *Transportation research procedia*, *14*, pp.115-122.

Shalev, R., Auerbach, J., Manor, O., & Gross-Tsur, V. (2009). Developmental dyscalculia: prevalence and prognosis. *European Child & Adolescent Psychiatry*, 9, S58-S64. https://doi.org/10.1007/s007870070009

Shaw, B., Bicket, M., Elliott, B., Fagan-Watson, B., Mocca, E. and Hillman, M. (2015). Children's independent mobility: an international comparison and recommendations for action.

Shi, W., Ono, K., & Li, L. (2025). Cognitive Insights into Museum Engagement: A Mobile Eye-Tracking Study on Visual Attention Distribution and Learning Experience. *Electronics*. https://doi.org/10.3390/electronics14112208.

Skaramagkas, V., Giannakakis, G., Ktistakis, E., Manousos, D., Karatzanis, I., Tachos, N., Tripoliti, E., Marias, K., Fotiadis, D., & Tsiknakis, M. (2021). Review of Eye Tracking Metrics Involved in Emotional and Cognitive Processes. *IEEE Reviews* *in Biomedical Engineering*, 16, 260-277. https://doi.org/10.1109/RBME.2021.3066072.

Skirrow, C., McLoughlin, G., Kuntsi, J., Asherson, P. (2009). Behavioral, neurocognitive and treatment overlap between attention-deficit/hyperactivity disorder and mood instability. *Expert review of neurotherapeutics*, *9*(4), pp.489-503.

Smith, M., Ward, E., Williams, C., & Banwell, H. (2020). Differences in walking and running gait in children with and without developmental coordination disorder: A systematic review and meta-analysis.. *Gait & posture*, 83, 177-184 . https://doi.org/10.1016/j.gaitpost.2020.10.013.

Smits-Engelsman, B., Schoemaker, M., Delabastita, T., Hoskens, J., & Geuze, R. (2015). Diagnostic criteria for DCD: Past and future. *Human movement science*, *42*, 293-306.

Soathong, A., Chowdhury, S., Wilson, D., & Ranjitkar, P. (2022). Pedestrians' Road Crossing Behavior at Unprotected Mid-Blocks among Adolescents and Adults. *Transportation Research Record*, 2677, 1731 - 1745. https://doi.org/10.1177/03611981221138524.

Soni, A., Robert, T., Rongiéras, F., & Beillas, P. (2013). Observations on pedestrian pre-crash reactions during simulated accidents. *Stapp car crash journal, 57*, pp. 157-83. https://doi.org/10.4271/2013-22-0006

Soole, D. W., Lennon, A., & Haworth, N. (2011). Parental beliefs about supervising children when crossing roads and cycling. *International journal of injury control and safety promotion*, *18*(1), 29-36.

Sroubek, A., Kelly, M., & Li, X. (2013). Inattentiveness in attention-deficit/hyperactivity disorder. *Neuroscience Bulletin*, 29, 103 - 110. https://doi.org/10.1007/s12264-012-1295-6

Stafford, J., Rodger, M., Gómez-Jordana, L., Whyatt, C., & Craig, C. (2021). Developmental differences across the lifespan in the use of perceptual information to guide action-based decisions. *Psychological Research*, 86, 268 - 283. https://doi.org/10.1007/s00426-021-01476-8.

Stav, W. (2014). Updated systematic review on older adult community mobility and driver licensing policies. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, *68*(6), 681–689. https://doi.org/10.5014/ajot.2014.011510

Stavrinos, D., Biasini, F., Fine, P., Hodgens, J., Khatri, S., & Mrug, S. (2011). Mediating factors associated with pedestrian injury in children with attention-deficit/hyperactivity disorder. Pediatrics, 128(2), 296–302. https://doi.org/10.1542/peds.2010-3829

Stoker, P., Garfinkel-Castro, A., Khayesi, M., Odero, W., Mwangi, M., Peden, M., & Ewing, R., 2015. Pedestrian Safety and the Built Environment. *Journal of Planning Literature*, 30, pp. 377 - 392. https://doi.org/10.1177/0885412215595438.

Subara-Zukic, E., Cole, M., McGuckian, T., Steenbergen, B., Green, D., Smits-Engelsman, B., Lust, J., Abdollahipour, R., Domellöf, E., Deconinck, F., Blank, R., & Wilson, P. (2022). Behavioral and Neuroimaging Research on Developmental Coordination Disorder (DCD): A Combined Systematic Review and Meta-Analysis of Recent Findings. *Frontiers in Psychology*, 13. https://doi.org/10.3389/fpsyg.2022.809455

Summers, J., Larkin, D., & Dewey, D. (2008). Activities of daily living in children with developmental coordination disorder: dressing, personal hygiene, and eating skills. *Human movement science*, 27 2, 215-29. https://doi.org/10.1016/j.humov.2008.02.002

Sumner, E., Hutton, S., Kuhn, G., & Hill, E. (2016). Oculomotor atypicalities in Developmental Coordination Disorder. *Developmental Science*, 21. https://doi.org/10.1111/desc.12501.

Sun, H., & Frost, B. J. (1998). Computation of different optical variables of looming objects in pigeon nucleus rotundus neurons. *Nature neuroscience*, *1*(4), 296-303.

Swain, R., Oswin, P., Truelove, V., & Larue, G. S. (2024). Children's and parents' perceptions on safe routes to schools: a mixed-methods study investigating factors influencing active school travel. *Journal of urban design*, *29*(2), 208-230.

Tabibi, Z., & Pfeffer, K. (2003). Choosing a safe place to cross the road: the relationship between attention and identification of safe and dangerous road-crossing sites. *Child: care, health and development*, *29*(4), 237-244.

Tabibi, Z., & Pfeffer, K. (2007). Finding a safe place to cross the road: the effect of distractors and the role of attention in children's identification of safe and dangerous road crossing sites. *Infant and Child Development*, 16, 193-206. https://doi.org/10.1002/ICD.509.

Tabibi, Z., Schwebel, D. C., & Zolfaghari, H. (2021). Road crossing Behavior in Complex Traffic Situations: A Comparison of Children With and Without ADHD. *Child Psychiatry and Human Development*. https://doi.org/10.1007/s10578-021-01200-y

Tabibi, Z., Schwebel, D. C., & Zolfaghari, H. (2022). Road crossing behavior in complex traffic situations: a comparison of children with and without ADHD. *Child Psychiatry & Human Development*, *53*(6), 1186-1193.

Tabibi, Z., Schwebel, D. C., and Zolfaghari, H. (2022). Road crossing behavior in complex traffic situations: a comparison of children with and without ADHD. *Child Psychiatry Hum. Dev.* 53, 1186–1193. doi: 10.1007/s10578-021-01200-y

Tabibi, Z., Schwebel, D., & Juzdani, M. (2023). How does attention deficit hyperactivity disorder affect children's road crossing? A case-control study. *Traffic Injury Prevention*, 24, 315 - 320. https://doi.org/10.1080/15389588.2023.2181664.

Tabibi, Z., Schwebel, D., & Zolfaghari, H. (2021). Road crossing Behavior in Complex Traffic Situations: A Comparison of Children With and Without ADHD. *Child Psychiatry & Human Development*, 53, 1186 - 1193. https://doi.org/10.1007/s10578-021-01200-y.

Tapiro, H., Meir, A., Parmet, Y., & Oron-Gilad, T. (2014). Visual search strategies of child-pedestrians in road crossing tasks. *Proceedings of the Human Factors and Ergonomics Society Europe*, 119-130.

Tapiro, H., Oron-Gilad, T., & Parmet, Y. (2020). Pedestrian distraction: The effects of road environment complexity and age on pedestrian's visual attention and crossing behavior. *Journal of safety research*, 72, 101-109. https://doi.org/10.1016/j.jsr.2019.12.003.

Taylor, J., O'Neill, M., Maddison, J., Richardson, G., Hewitt, C., Horridge, K., & Fraser, L. K. (2019). "Your Tube": the role of different diets in children who are gastrostomy fed: protocol for a mixed methods exploratory sequential study. BMJ Open, 9(10), e033831–e033831. https://doi.org/10.1136/bmjopen-2019-033831

Tefft, B. (2013). Impact speed and a pedestrian's risk of severe injury or death.. *Accident; analysis and prevention*, 50, 871-8 . https://doi.org/10.1016/j.aap.2012.07.022.

Teller, K., Abbey-Lambertz, M., Sharma, N., Waite, A., Ickes, S., & Mendoza, J. A. (2019). Parent Perceptions on a Walking School Bus Program Among Low-Income Families: A Qualitative Study. *Journal of physical activity & health*, *16*(11), 1047–1053. https://doi.org/10.1123/jpah.2018-0637

Thakur, S. and Biswas, S., 2019. Assessment of pedestrian-vehicle interaction on urban roads: a critical review. *Archives of Transport*, *51*.

Theofilatos, A., Ziakopoulos, A., Oviedo-Trespalacios, O., & Timmis, A. (2021). To cross or not to cross? Review and meta-analysis of pedestrian gap acceptance decisions at midblock street crossings. *Journal of transport and health*, 22, 101108. https://doi.org/10.1016/J.JTH.2021.101108.

Thomas, B. H., Ciliska, D., Dobbins, M., & Micucci, S. (2004). A process for systematically reviewing the literature: providing the research evidence for public health nursing interventions. *Worldviews on evidence-based nursing,* 1(3), 176–184. https://doi.org/10.1111/j.1524-475X.2004.04006.x

Thomas, F.B. (2022). The role of purposive sampling technique as a tool for informal choices in a social Sciences in research methods. *Just Agriculture*, *2*(5), pp.1-8.

Thomson, J., Ampofo-Boateng, K., Lee, D., Grieve, R., Pitcairn, T., & Demetre, J., 1998. The effectiveness of parents in promoting the development of road crossing skills in young children.. *The British journal of educational psychology*, 68 (Pt 4), pp. 475-91 . https://doi.org/10.1111/J.2044-8279.1998.TB01306.X.

Tobii Connect. (2022). How to calibrate and validate in Tobii Pro Lab. Retrieved August 27, 2024, from https://connect.tobii.com/s/article/how-to-calibrate-and-validate-in-tobii-pro-lab?language=en_US

Tobii Pro. (2024). Tobii Pro Lab [Software]. Retrieved August 25, 2024, from https://www.tobii.com/products/software/behavior-research-software/tobii-pro-lab#editions

Topolovec-Vranic, J., & Natarajan, K. (2016). The Use of Social Media in Recruitment for Medical Research Studies: A Scoping Review. *Journal of Medical Internet Research, 18*(11), e286–e286. https://doi.org/10.2196/jmir.5698

Toye, M. K. (2016). Neuropsychological Functions and Pedestrian Behaviour in Children with and without ADHD. (Unpublished PhD thesis). University of Strathclyde, Glasgow, UK.

Transport for London. (2010). *Visitor Road Safety.* Retrieved from https://content.tfl.gov.uk/visitor-pedestrian-safety-final-report.pdf

Vaughan, L., & Giovanello, K. (2010). Executive function in daily life: Age-related influences of executive processes on instrumental activities of daily living. *Psychology and aging*, 25 2, 343-55 . https://doi.org/10.1037/a0017729.

Van der Molen, H. H., Van den Herik, J., & Van der Klaauw, C. (1983). Pedestrian behaviour of children and accompanying parents during school journeys: An evaluation of a training programme. *British Journal of Educational Psychology*, *53*(2), 152-168.

Van der Weel, F. R., & van der Meer, A. L. (2009). Seeing it coming: infants' brain responses to looming danger. *Naturwissenschaften*, *96*, 1385-1391.

Vasileiou, K., Barnett, J., Thorpe, S., Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: systematic analysis of qualitative health research over a 15-year period. *BMC medical research methodology*, *18*, pp.1-18.

Vezzadini, L. (2004). Identifying Technical Limitations in Applying Virtual Reality to Human Factor Methodologies. , 3623-3628. https://doi.org/10.1007/978-0-85729-410-4_579

Wang, H., Tan, D., Schwebel, D. C., Shi, L., & Miao, L. (2018). Effect of age on children's pedestrian behaviour: results from an observational study. *Transportation Research Part F: Traffic Psychology and Behaviour*, 58, 556-565.

Wang, K., Xu, L., & Jiang, H. (2022). Analysis of the Effect of Human-Machine Co-Driving Vehicle on Pedestrian Crossing Speed at Uncontrolled Mid-Block Road Sections: A VR-Based Case Study. *International Journal of Environmental Research and Public Health*, 19. https://doi.org/10.3390/ijerph19127208.

Wann, J. P., Poulter, D. R., & Purcell, C. (2011). Reduced sensitivity to visual looming inflates the risk posed by speeding vehicles when children try to cross the road. *Psychological science*, *22*(4), 429-434.

Wann, J., Poulter, D., & Purcell, C. (2011). Reduced Sensitivity to Visual Looming Inflates the Risk Posed by Speeding Vehicles When Children Try to Cross the Road. *Psychological Science*, 22, 429 - 434. https://doi.org/10.1177/0956797611400917.

Welsh Government. (2024). *Introducing default 20mph speed limits: frequently asked questions.* Retrieved from https://www.gov.wales/introducing-default-20mph-speed-limits

Whitall, J., & Clark, J. (2018). A Perception-Action Approach to Understanding Typical and Atypical Motor Development. *Advances in child development and behavior*, 55, 245-272. https://doi.org/10.1016/bs.acdb.2018.04.004

Whitebread, D., & Neilson, K. (2000). The contribution of visual search strategies to the development of pedestrian skills by 4–11-year-old children. *The British journal of educational psychology*, 70 Pt 4, 539-57. https://doi.org/10.1348/000709900158290.

Wiggins, L. D., Bakeman, R., Adamson, L. B., & Robins, D. L. (2007). The Utility of the Social Communication Questionnaire in Screening for Autism in Children Referred for Early Intervention. Focus on Autism and Other Developmental Disabilities, 22(1), 33–38. https://doi.org/10.1177/10883576070220010401

Willcutt, E., Doyle, A., Nigg, J., Faraone, S., & Pennington, B. (2005). Validity of the Executive Function Theory of Attention-Deficit/Hyperactivity Disorder: A Meta-Analytic Review. *Biological Psychiatry*, 57, 1336-1346. https://doi.org/10.1016/j.biopsych.2005.02.006.

Wilmut, K., & Purcell, C. (2020). The Lived Experience of Crossing the Road When You Have Developmental Coordination Disorder (DCD): The Perspectives of Parents of Children With DCD and Adults With DCD. *Frontiers in psychology*, *11*, p.587042. https://doi.org/10.3389/fpsyg.2020.587042

Wilmut, K., & Purcell, C. (2020). The nature of the risk faced by pedestrians with neurodevelopmental disorders: A systematic review. *Accident Analysis and Prevention, 149*, 105886–105886. https://doi.org/10.1016/j.aap.2020.105886

Wilmut, K., & Purcell, C. (2021). The nature of the risk faced by pedestrians with neurodevelopmental disorders: A systematic review. *Accident; analysis and prevention*, *149*, 105886. https://doi.org/10.1016/j.aap.2020.105886

Wilson, B. N., Crawford, S. G., Green, D., Roberts, G., Aylott, A., & Kaplan, B. J. (2009). Psychometric properties of the revised developmental coordination disorder questionnaire. *Physical & occupational therapy in pediatrics*, *29*(2), 182-202.

Wilson, B.N., Kaplan, B.J., Crawford, S.G. and Roberts, G. (2007). The developmental coordination disorder questionnaire 2007 (DCDQ'07). *Administrative manual for the DCDQ107 with psychometric properties*, pp.267-272.

Wilson, P. H., Maruff, P., & Lum, J. (2003). Procedural learning in children with developmental coordination disorder. *Human Movement Science*, *22*(4-5), 515-526.

Wilson, P., Ruddock, S., Rahimi-Golkhandan, S., Piek, J., Sugden, D., Green, D., et al. (2020). Cognitive and motor function in developmental coordination disorder. *Dev. Med. Child Neurol.* 62, 1317–1323. doi: 10.1111/dmcn.14646

Wilson, P., Ruddock, S., Smits-Engelsman, B., Polatajko, H., & Blank, R. (2013). Understanding performance deficits in developmental coordination disorder: a meta-analysis of recent research. *Developmental Medicine & Child Neurology*, 55. https://doi.org/10.1111/j.1469-8749.2012.04436.x

Wood, M., Ayres, T., Kelkar, R., & Khatua, R. (2010). Walking and Jogging: An Analysis of Pedestrian Stopping Times and Distances. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 54, pp. 1435 - 1439. https://doi.org/10.1177/154193121005401917

World Health Organisation. (2015). *Ten strategies for keeping children safe on the road.* Retrieved from https://www.who.int/publications/i/item/9789241565684

World Health Organisation. (2018). *Global Status Report on Road Safety.* Retrieved from http://apps.who.int/iris/bitstream/handle/10665/277370/WHO-NMH-NVI-18.20-eng.pdf?ua=1

World Health Organisation. (2023). *Road traffic injuries* Retrieved from **https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries**

World Health Organization. (2018). Disease, injury and causes of death country estimates, 2000–2015. http://www.who.int/healthinfo/ global_burden_disease/estimates_country_2000_2015/en/ [Accessed JUNE 04, 2023].

Wu, O. K., Brown, T., Yu, M. L., Joshua, N., Wilson, C. J., & Campbell, H. C. (2023). Test–Retest Reliability and Convergent Validity of the Movement Assessment Battery for Children–Third Edition with Australian 3–6-Year-Olds and Their Parents. *Journal of Occupational Therapy, Schools, & Early Intervention*, 1-21.

Yang, D., & Nguyen, P. (2022). The Increasing Importance of Rigorous Real-World Evidence. *JNCI Cancer Spectrum*, 6. https://doi.org/10.1093/jncics/pkac051.

Yang, H., Stanton, B., Cottrel, L., Kaljee, L., Galbraith, J., Li, X., Cole, M., Harris, C., & Wu, Y. (2006). Parental awareness of adolescent risk involvement: implications of overestimates and underestimates. *The Journal of adolescent health: official publication of the Society for Adolescent Medicine*, 39 3, 353-61. https://doi.org/10.1016/J.JADOHEALTH.2005.12.008.

Yang, X., Abdel-Atyb, M., Huana, M., Peng, Y., & Gaoa, Z. (2015). An accelerated failure time model for investigating pedestrian behavior and waiting times at signalized intersections. *Accident Analysis and Prevention* 82, 154–162

Yeaton, W., & Bailey, J., 1978. Teaching pedestrian safety skills to young children: an analysis and one-year followup. *Journal of applied behavior analysis*, 11 3, pp. 315-29. https://doi.org/10.1901/JABA.1978.11-315.

Yepes, J., & Raviv, D. (2022). Visual Looming from Motion Field and Surface Normals. *arXiv preprint arXiv:2210.04108*.

Zare, H., Niknami, S., Heidarnia, A., & Fallah, M. H. (2018b). Improving safe street-crossing behaviors among primary school students: a randomized controlled trial.

Health promotion perspectives, 8(4), 308–314. https://doi.org/10.15171/hpp.2018.44

Zare, H., Niknami, S., Heidarnia, A., & Fallah, M. H. (2019). Traffic safety education for child pedestrians: A randomized controlled trial with active learning approach to develop street-crossing behaviors. *Transportation Research Part F: Traffic Psychology and Behaviour,* 60, 734-742. https://doi.org/10.1016/j.trf.2018.10.021

Zegeer, C. V., & Bushell, M. (2012). Pedestrian crash trends and potential countermeasures from around the world. *Accident; analysis and prevention*, 44(1), 3–11. https://doi.org/10.1016/j.aap.2010.12.007

Zhai, X., Huang, H., Sze, N.N., Song, Z. and Hon, K.K., 2019. Diagnostic analysis of the effects of weather condition on pedestrian crash severity. *Accident Analysis & Prevention*, *122*, pp.318-324.

Zhao, J., Malenje, J., Tang, Y., & Han, Y. (2019). Gap acceptance probability model for pedestrians at unsignalized mid-block crosswalks based on logistic regression.. *Accident; analysis and prevention*, 129, 76-83 . https://doi.org/10.1016/j.aap.2019.05.012.

Zoia, S., Barnett, A., Wilson, P. and Hill, E.L., 2006. Developmental coordination disorder: Current issues. *Child: care, health and development*, *32*(6), pp.613-618.

Appendices

Appendix 2.1

Examples of recruitment posts and tweets (Phase 1)

Tweet (280 characters):

Does roadside #safety of #Children with #ADHD and/or DCD matter to you? Are you a primary carer of a child with ADHD and/or DCD? Would you like to share your opinions with researchers? For eligibility & more info (link to Participant Information Sheet and consent form)

Social media security isn't guaranteed. Don't post if concerned about privacy

Facebook:

Does pedestrian #safety of #children with #ADHD and/or #DCD matter to you? Are you a primary carer of a child with ADHD and/or DCD? Would you like to share your opinions and thoughts with researchers to make a difference in the UK? Help us through participating in 45– 60 minute interview. Contact us for eligibility and more info at (link to Participant Information Sheet and consent form)

"Please also note that the privacy and confidentiality of content (text or pictures) shared on social media platforms is not guaranteed. Content may be forged, forwarded, kept indefinitely, or seen by others using the Internet whether you share publicly to everyone or privately to specific people. Do not use social media to discuss information you think is sensitive. While you may share this information with a select group of people, someone in your networks may share it more widely without your consent."

Appendix 2.2

PARTICIPANT INFORMATION SHEET (Phase 1)

Primary Carers' Experiences of Children with ADHD and/or DCD in relation to Pedestrian Skills: Sequential Mixed Method

You are being invited to take part in a research project. Before you decide whether or not to take part, it is important for you to understand why the research is being undertaken and what it will involve. Please take time to read the following information carefully and discuss it with others, if you wish. Alternatively, please contact me, if you have a question or need further clarification.

Thank you for reading this.

1. What is the purpose of this research project?

This study is being undertaken for a PhD qualification. Crossing the road can be a difficult task for all children, but we are particularly interested in how children with ADHD and/or DCD cope with this. The overall aim is to explore the perspectives of primary carers of children with ADHD and/or DCD in order to gather their experiences of pedestrian risks.

2. Why have I been invited to take part?

You have been invited because you have responded to an advert for this study and are a parent or carer of a child with ADHD and/or DCD who is:

- Aged between 6 – 11 years
- Has ADHD and/or DCD characteristics based on the completed DCDQ and SNAP-IV
- Living in the UK
- Navigating the community with you on a regular basis

3. Do I have to take part?

No, your participation in this research project is entirely voluntary and it is up to you to decide whether or not to take part. If you decide to take part, I will discuss the research project with you and ask you to sign a consent form. If you decide not to take part, you do not have to explain your reasons and it will not affect your legal rights.

You are free to withdraw your consent to participate in the research project at any time, without giving a reason, even after signing the consent form. To withdraw, you can email Rayan Falemban and ask to withdraw. You will receive a confirmation email after that.

4. What will taking part involve?

Your participation will involve taking part in an online semi-structured interview, using Microsoft Teams or an equivalent alternative (e.g. Zoom) if you do not have Microsoft Team. The interview will last approximately 45 - 60 minutes. The interview will be audio recorded for the purposes of transcription in order to enable further analysis. If after reading the information contained in this information sheet, you wish to proceed, a consent form will be sent to you and the interview will be scheduled. Bear in mind that you are free to withdraw at any time and please make sure you choose a quiet place, free of distraction with good internet connection for the interview.

5. Will I be paid for taking part?

No, you will not be paid.

6. What are the possible benefits of taking part?

There will be no direct advantages or benefits to you from taking part, but your contribution will help us understand pedestrian behaviour of children with ADHD and/or DCD. Your voice may contribute to designing future solutions aimed at improving the pedestrian safety of children with ADHD and/or DCD.

7. What are the possible risks of taking part?

There are no potential risks or disadvantages from taking part in this research project but if you become upset from talking about a sensitive matter, you can stop the interview at any time or decide not to answer any of the questions. If you require assistance with regards to road safety education, you can refer to your child's schoolteachers, Head Teacher, and/or local authority. If you have any concerns about your childs health, please discuss this with your family GP for support or referral.

8. Will my taking part in this research project be kept confidential?

All information collected from you during the research project will be kept confidential and every effort will be made to safeguard your information. Any personal information you provide will be managed in accordance with data protection legislation. The type of personal information you will asked to provide on the consent form and during the interview, will include your name, signature, contact details, description of your geographical location, child's age and medical information. Please see 'What will happen to my Personal Data?' (below) for further information. However, in the event that you disclose any wrongdoing that might cause harm to yourself or others, the researcher is obliged to follow the safeguarding policy and report the details to a Cardiff University Lead Safeguarding Officer (https://www.cardiff.ac.uk/public-information/policies-and-procedures/safeguarding) and any relevant organisations.

9. What will happen to my Personal Data?

Cardiff University is the Data Controller and is committed to respecting and protecting your personal data in accordance with your expectations and Data Protection legislation. Further information about Data Protection, including:

- your rights
- the legal basis under which Cardiff University processes your personal data for research
- Cardiff University's Data Protection Policy
- how to contact the Cardiff University Data Protection Officer
- how to contact the Information Commissioner's Office

may be found at https://www.cardiff.ac.uk/public-information/policies-and-procedures/data-protection

Over the course of the research project (3 years), only the researcher, and where necessary research supervisors, will have access to the personal data to process the information unless individuals from Cardiff University or from regulatory authorities require access to the information.

After the 3 years, the collected data including audio recordings will be stored confidentially for a minimum of 5 years in line with Cardiff University guidelines. I will anonymise all the written personal data that I have collected from, or about, you in connection with this research project, with the exception of your consent form which must be retained.

Your consent form will be securely retained for a minimum of 5 years in line with Cardiff University guidelines and may be accessed by members of the research team and, where necessary, by members of the University's governance and audit teams or by regulatory authorities. All information will be kept for a minimum of 5 years in line with Cardiff University guidelines and anonymised information may be published in support of the research project and/or retained indefinitely, where it is likely to have continuing value for research purposes.

You may withdraw from the study at any time without giving a reason. However, if you withdraw after the completion of data analysis, any anonymised information that has already been published or in some cases, irreversibly anonymised during the course of the research project will not be possible to withdraw but identifiable data will be withdrawn/deleted.

10. What happens to the data at the end of the research project?

All of the collected data from, or about, you in connection with this research project including personal data will be securely and confidentially stored for a minimum of 5 years in line with Cardiff University guidelines after the research project has ended.

11. What will happen to the results of the research project?

It is my intention to publish the results of this research project in academic journals, present findings at conferences and include findings in my PhD thesis. Anonymised excerpts and/or verbatim quotes from interviews will be used as part of research publications, my PhD thesis and conference presentations. Participants will not be identified in any report, publication or presentation.

12. What if there is a problem?

If you wish to complain or have grounds for concerns about any aspect of the manner in which you have been approached or treated during the course of this research, please contact Dr Catherine Purcell via email ------------ If your complaint is not managed to your satisfaction, please contact Dr Kate Button via email ----------------.

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, you may have grounds for legal action, but you may have to pay for it.

13. Who is organising and funding this research project?

The research is organised by Mr Rayan Falemban, PhD researcher at the School of Healthcare sciences at Cardiff University and the academic supervisor is Dr Catherine Purcell. The research is currently funded by Saudi Arabian Cultural Bureau in the UK (UKSACB) representing Umm Al-Qura University.

14. Who has reviewed this research project?

This research project has been reviewed and given a favourable opinion by the School of Healthcare Sciences Research Ethics Committee, Cardiff University.

15. Further information and contact details

Should you have any questions relating to this research project, you may contact me during normal working hours:

Mr Rayan Falemban via email

Dr Catherine Purcell via email

Thank you for considering taking part in this research project. If you decide to participate, you will be given a copy of the Participant Information Sheet and a signed consent form to keep for your records

Appendix 2.3

Gatekeeper Email (Phase 1)

Dear *(Gatekeeper Name)*

My name is Rayan Falemban, PhD researcher in the School of Healthcare Sciences, Cardiff University. I am currently starting a research project, *Primary Carers' Experiences of Children with ADHD and/or DCD in relation to Pedestrian Skills: Sequential Mixed Method.* This research project is being undertaken for a PhD qualification and has been reviewed and given a favourable opinion by the School of Healthcare Sciences Research Ethics Committee, Cardiff University. The project has two phases, and this letter is written for the purpose of the first phase. The aim of this phase is to explore the perspectives and experiences of primary carers of children with mild to moderate ADHD in relation to their child's pedestrian risks.

I am writing to you to ask for your permission and assistance to identify possible participants and distribute the study information along with consent to contact form to seek research participants to take part in a semi structured interview. Online interviews should take 45 – 60 minutes and will be arranged at a convenient date and time after receiving their contact information.

All information collected during the research project will be kept confidential and any personal information will be managed in accordance with data protection legislation. Further details about data protection and the project will be provided in the study information. No children will be involved in the research project, only primary carers of children with ADHD and/or DCD.

Thank you for your time and I hope to hear from you soon.

Yours sincerely,

Rayan Falemban

PhD researcher at Cardiff University

Mobile number:

Email:

<u>Appendix 2.4</u>

CONSENT FORM (Phase 1)

Title of research project: **Primary Carers' Experiences of Children with ADHD and/or DCD in relation to Pedestrian Skills: Sequential Mixed Method**

SREC reference and committee:

Principal Investigator: **Rayan A. Falemban,**

Email:

	Please initial box
I confirm that I have received, read, and understood the information sheet dated …......................... for this study.	
I confirm that I have had the opportunity to ask questions and that these have been answered satisfactorily.	
I understand that my participation is voluntary, and I am free to withdraw at any time without giving a reason and without any adverse consequences to my legal rights.	
I understand that data collected during the research project may be looked at by individuals from Cardiff University or from regulatory authorities, where it is relevant to my taking part in the research project. I give permission for these individuals to have access to my data.	
I consent to being audio recorded for the purposes of the research project and I understand how it will be used in the research.	
I understand that after the research project, data collected and recorded will be securely stored for a minimum of 5 years in line with Cardiff University guidelines.	
I confirm that data from the study can be used in the final PhD thesis, reports and academic publications. I understand that these will be used anonymously and that no specific participant will be identified.	

I understand that anonymised excerpts and/or verbatim quotes from my interview may be used as part of the research publication, PhD thesis and conference presentations.	
I consent to the processing of my personal information including my name, signature, contact details, description of locations, child's age and medical information. for the purposes explained to me. I understand that such information will be held in accordance with all applicable data protection legislation and in strict confidence, unless disclosure is required by law or professional obligation.	
I understand who will have access to personal information provided, how the data will be stored and what will happen to the data at the end of the research project.	
I understand that the findings and results of the research project may be presented at conferences and published in scientific journals. I understand that these will be used anonymously and that no specific participant will be identified.	
I understand how the findings and results of the research project will be written up and published.	
I agree to take part in this research project.	

Name of participant Date Signature

____

NB if facing difficulties to sign this, take a photograph of your signature on a white paper and attach it with your reply

Name of witness Date _ Signature

____

Name of person taking consent Date Signature

Rayan A. Falemban

____

Role of person taking consent

Principal Investigator

THANK YOU FOR PARTICIPATING IN OUR RESEARCH

YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP

Appendix 2.5

ADVERTISEMENT EMAIL FOR THE GATEKEEPERS USE (Phase 2)

Hi,

My name is Rayan Falemban, I am an occupational therapist and PhD researcher in the School of Healthcare Sciences, Cardiff University.

I am currently conducting a study aiming to explore the pedestrian behaviours of children with ADHD or DCD. The study has been reviewed and given a favourable opinion by the School of Healthcare Sciences Research Ethics Committee, Cardiff University. It will be a lab-based study at Cardiff University, and it should take 90-120 minutes.

The attached link provides you with further information including some frequently asked questions. Please take your time to read the information and let me know if you have any question. (link to PIS)

I look forward to hearing from you.

Many thanks,

Rayan Falemban

Appendix 2.6

Consent To Contact Form for Research Purposes (Phase 2)

Exploring pedestrian behaviours of children with ADHD or DCD

Funded by: Saudi Arabian Cultural Bureau in the UK (UKSACB) representing Umm Al-Qura University

Investigators: Rayan A. Falemban, PhD researcher in the School of Healthcare Sciences, Cardiff University.

Supervised by: Dr Catherine Purcell, Reader in the School of Healthcare Sciences, Occupational Therapy, Cardiff University.

You are being invited to provide consent for Rayan Falemban to contact you at a later date for an invitation to take part in a research project. If you are willing to be contacted by Rayan, please include your contact details below:

Your email: ……..

Your telephone: …...

You authorise *(Gatekeeper Name)* to disclose your name, email, and telephone number to the researcher for the purpose of being contacted to learn more about the project and potentially take part in the research project. Common questions and answers about the research project can be found in the attachment *(Participant Information Sheet)*.

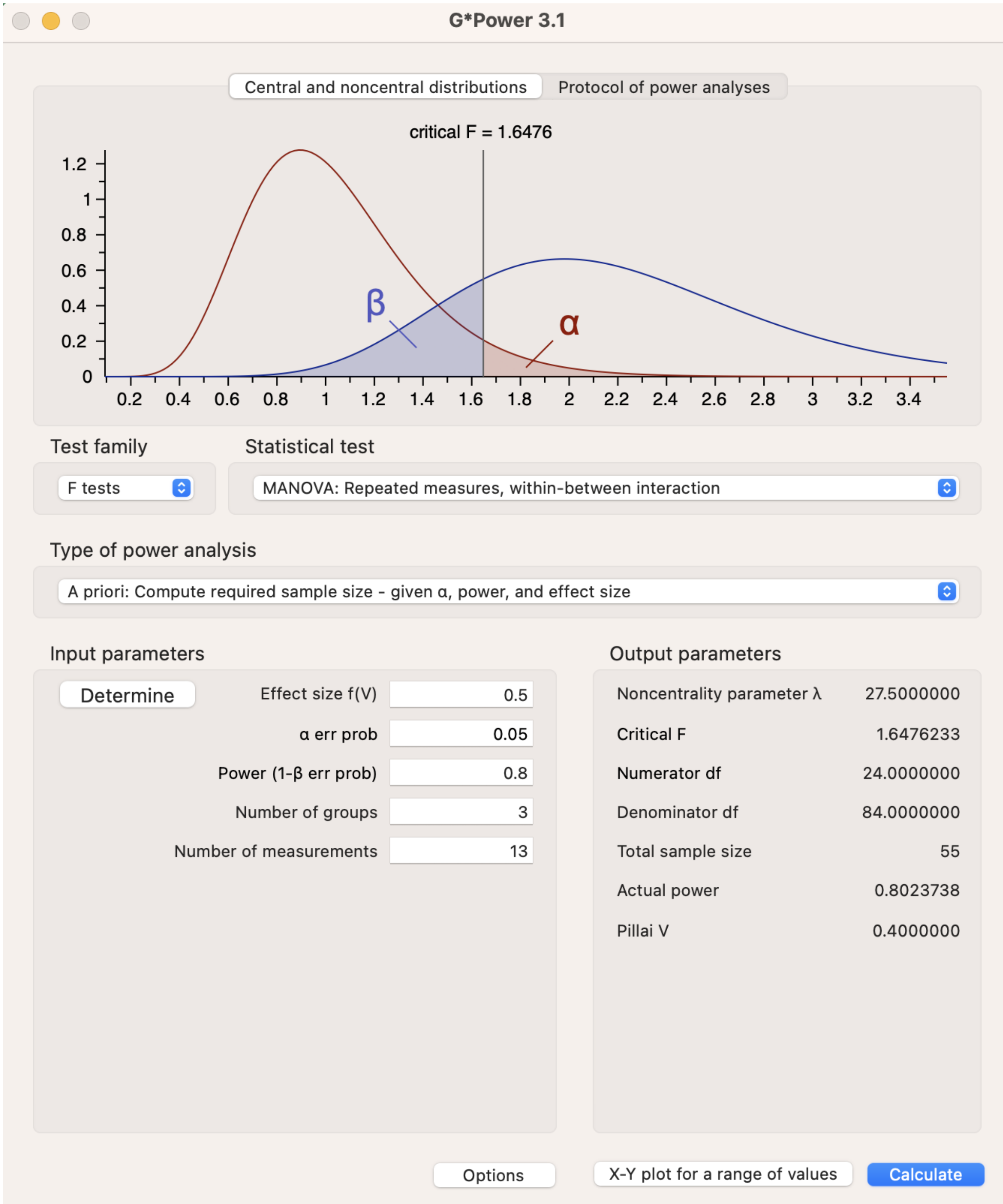
Every effort will be made to safeguard your contact information. Access to your contact information will be limited to Rayan and *(Gatekeeper Name)*.

This consent is effective immediately. Your consent to be contacted can be revoked by you at any time.

Name: ____________________________________Signature: ________________________

Date: ______________

Appendix 2.7


G*Power 3.1
Central and noncentral distributions
Protocol of power analyses
critical F = 1.6476
β
α
Test family
F tests
Statistical test
MANOVA: Repeated measures, within-between interaction
Type of power analysis
A priori: Compute required sample size - given α, power, and effect size
Input parameters
Determine
Effect size f(V) 0.5
α err prob 0.05
Power (1-β err prob) 0.8
Number of groups 3
Number of measurements 13
Output parameters
Noncentrality parameter λ 27.5000000
Critical F 1.6476233
Numerator df 24.0000000
Denominator df 84.0000000
Total sample size 55
Actual power 0.8023738
Pillai V 0.4000000
Options
X-Y plot for a range of values
Calculate

Appendix 3.1: Data extraction table for Chapter 3

Title	Citation	Location	sample characteristics	method	Aim	Sample size
Addressing safety issues along the way to school: Qualitative findings from Jerash camp, Jordan	Al-Najjar et al., 2022	Jordan	parents of refugee schoolchildren aged 6 to 15 form Jerash camp	focus group discussions	Exploring safety challenges faced by schoolchildren who travel independently inside refugee camps	10 mothers and a group of 7 fathers and 2 grandfathers

EXPLORING PARENTAL PERCEPTIONS OF A WALKING-SCHOOL BUS INITIATIVE IN NORTHERN ONTARIO	Atrooshi, 2017	Canada	parent of students from elementry school in Northern Ontario	semi-structuredd interviews (thesis)	explore parental perceptions of a WSB in order to inform an effective messaging and promotional strategy. The secondary purpose was to explore barriers and facilitators related to a WSB/ATS and to explore parent ideas about ways for their children to incorporate active travel into their daily routine.	parents of students = 16

Children's and parents' perceptions on safe routes to schools: a mixed-methods study investigating factors influencing active school travel	Swain et al., 2024	Australia	children and parents of two schools in Australia	mixed methods survey(cross sectional)	survey school children's and parents' views on their current travel modal choices, their current perceptions of safety and their preferences and attitudes towards different types of active transport infrastructure treatments.	441, 91 parents. 337 pupils (aged 12-18)
Getting more children walking and cycling to school: insights from parents in three Australian cities	Nakanishi, Dillon, and Tranter, 2017	Australia	parent of children from Sydney, Canberra and Melbourne	qualitative semi-structured interviews	investigates parental concerns about their children's journeys to school using qualitative surveys in three cities in Australia: Canberra, Melbourne and Sydney	99 interviews (Sydney: 24, Canberra: 57, Melbourne: 18)

Parent Perceptions on a Walking School Bus Program Among Low-Income Families: A Qualitative Study	Teller,2018	USA	parents of children participated in walking school bus program	interview (cluster RCT)	examine parent and child attitudes and opinions on participating in a WSB as part of a large multi-year invtervention trial	45, 80% female
Urban travel patterns and safety among school children around Accra, Ghana	Poku-Boansi, Amoako and Atuah, 2019	Ghana	pupils and their parents, teachers	semi-structured questionnaires and interviews	exploring how travel behaviours and patterns of school pupils between the ages of 6–15 years are expose to risk of fatal injury around Accra, Ghana’s capital.	370 pupils and their parents, 53 teachers

Appendix 3.2: Data extraction table for Chapter 3

Citation	Primary findings
Al-Najjar et al., 2022	Safety and Security Issues: • Traffic Collisions: Parents expressed concern about traffic congestion and speeding drivers putting children at risk. • Crime Exposure: Parents, particularly mothers, worried about harassment, bullying, and kidnapping along school routes. • Animal Attacks: Stray dogs and snakes were identified as potential threats to children on their way to school. Factors Influencing Exposure: • Environmental Factors: Distance to school, poor road conditions, lack of sidewalks, and seasonal weather variations were seen as affecting safety. • Socio-cultural & Economic Factors: Limited income restricted transportation options, while cultural norms sometimes limited girls' mobility. • Demographic Factors: Age and gender were seen as influencing both risk perception and vulnerability. Younger children and girls were perceived as more at risk. • Behavioral Factors: Speeding drivers, lack of parental supervision, and internet exposure were seen as contributing to safety concerns. Parental Suggestions: • Free Transportation: Parents felt a free bus service, especially for the distant "Manshieh" school, would significantly improve safety. • Improved Infrastructure: Parents suggested better roads, sidewalks, handrails, and drainage systems to enhance pedestrian safety. • Safety Education: Parents emphasized the need for safety awareness programs for both children and parents to address potential threats and proper behavior in risky situations.

Atrooshi, 2017	Positive Perceptions (Products): • Parents liked the idea of a WSB allowing children to walk to school regularly, providing an alternative to being driven or taking the bus. • Increased physical activity and social interaction with peers were seen as benefits. • The program potentially offered a safer alternative to walking alone, especially for younger children. • Some parents felt a WSB could help integrate them into the community. Concerns (Price): • Time constraints in the mornings were a major concern for some parents, making a WSB seem impractical. • Parents worried about the program's resources, particularly volunteer reliability and potential costs associated with running it. • Safety concerns arose regarding large group management and ensuring volunteers could keep children safe during walks. • Parents questioned the program's consistency, especially in harsh weather conditions (extreme cold, snow). Route Preferences (Place): • The lack of proper sidewalks in some neighborhoods emerged as a significant concern, impacting route safety. • Parents favored routes with sidewalks and less traffic. • The concept of designated meeting points for children to join the WSB was well-received. Promotion Strategies (Promotion): • Parents suggested social media (Facebook) and school-based communication (emails, flyers) as effective ways to promote the program. • Informational events and opportunities for children to try out the WSB were seen as potential strategies to generate interest. Overall: Parents generally viewed a WSB program positively for its potential to increase physical activity, social interaction, and safe walking to school. However, concerns regarding time constraints, weather conditions, volunteer reliability, and lack of proper sidewalks need to be addressed for successful program implementation. The study also highlights the importance of effective promotion strategies to reach parents and ensure program uptake.

Swain et al., 2024	Children's Responses: • Desire for Improved Public Transport: Many children requested improved public transport options, with comments like wanting buses closer to home or direct routes to school. • Desire to Walk and/or Cycle: Some children expressed a desire to walk or cycle to school, but safety concerns were a barrier. Examples included long distances or lack of safe crossings. • Longer Crossing Times at Signals: Several children requested more time to cross streets at signalized intersections. • Stranger Danger: A few children mentioned stranger danger as a concern. Parents' Responses: • Desire for Improved Public Transport: Similar to children, parents wanted better public transport options to reduce traffic congestion and improve children's safety. • Improved Car-Oriented Infrastructure: Some parents requested drop-off zones or wider roads to improve traffic flow, although this was less common than requests for improved public transport. • Desire to Walk and/or Cycle: Parents also expressed a desire for their children to be able to walk or cycle to school safely. Concerns about safety were a major barrier. • More Active Transport Infrastructure: Many parents requested improvements to active transport infrastructure,including better footpaths, separated bike lanes, and safer crossings. • Speed Limit Reduction: Parents, but not children, requested measures to reduce traffic speed around the school. • Stranger Danger: A few parents mentioned concerns about safety related to the environment, like lack of surveillance at bus stops. Overall: • Both children and parents prioritized improved public transport and active transport infrastructure (better sidewalks,bike lanes, crossings) to enhance safety and reduce traffic congestion. • Children felt more limited by crossing times and safety concerns when walking or cycling. • Parents expressed a wider range of concerns, including stranger danger in certain areas. • Speed limit reduction was a concern only for parents.

Nakanishi, Dillon, and Tranter, 2017	Safety is the Top Priority: • Parents across all cities prioritized safety as the biggest concern for allowing children to walk or cycle to school. • Fear of traffic, stranger danger, and high vehicle speeds were commonly mentioned. City Design Makes a Difference: • Well-maintained sidewalks, proper crossings, and separated bike lanes made parents feel more comfortable with their children's independent mobility. • Conversely, poorly designed roads with heavy traffic discouraged parents from letting children walk or cycle. Impact of Commute Times: • Parents in Sydney and Melbourne, with longer commutes, reported complex family routines influencing their children's travel mode. Driving children to school fit better into their schedules despite a desire for active travel options. Car Dependence Creates a Cycle: • Traffic congestion around schools due to drop-off and pick-up added to safety concerns, further discouraging parents from letting children walk or cycle. Canberra's Uniqueness: • Parents in Canberra expressed less fear about traffic safety compared to the other cities. • This might be due to factors like better urban planning or a culture more supportive of active travel. • Environmental concerns also played a role for some Canberra parents, making them more likely to choose walking or cycling if it was convenient. Age for Independent Travel is Flexible: • There wasn't a strict consensus on the appropriate age for independent travel, but most parents felt comfortable around 10 years old. • Age seemed to be a more significant factor than gender. Challenges Beyond School Hours: • After-school activities like sports often require car transportation because facilities are not easily accessible otherwise. Overall, the research highlights the need for: • Improved infrastructure for pedestrians and cyclists, especially around schools. • Traffic calming measures to reduce vehicle speeds and create a safer environment. • Urban planning that considers the needs of children and encourages active travel options.

Teller,2018	Barriers to Participation: • Time Constraints: Both parents and children struggled to fit the WSB route into their schedules, especially for families with multiple children or complex routines. • Weather: Cold, rainy weather discouraged participation. • Health Issues: The child's asthma or parent's mobility limitations could make walking difficult. • Social Concerns: Some children were hesitant to join if they didn't know others or preferred walking with different friends. • Safety Fears: Parents worried about pedestrian safety, suspicious characters, and letting their children walk unsupervised. • Route & Distance: For some families, the WSB route was longer than their usual walking path, making parent participation less appealing. • Logistical Difficulties: Confusion about meeting spots or changes in pick-up/drop-off plans caused inconvenience. Facilitators that Encouraged Participation: • Exercise and Physical Health: Many parents saw the WSB as a way for their children (and themselves) to get exercise and improve overall health. • Socialization: The program provided opportunities for children to make new friends and interact with peers. • Safety Education: Parents appreciated that children learned pedestrian safety rules while walking with the group. • Convenience: The WSB helped some families with morning routines by eliminating the need to drive children to school. • Increased Independence: Walking with the WSB fostered a sense of responsibility and independence in children. • Positive Role Models: Parents valued the interaction with WSB chaperones who served as positive adult role models for their children. • Community Awareness: Walking with the WSB allowed children to learn about their neighborhood and develop a sense of community. • Cost Savings: Not driving to school meant saving gas money. Proposals for Improvement: • Increased Awareness and Marketing: Parents wanted better communication about the program to encourage more families to participate. • Route Expansion or Modification: Making the route longer or creating multiple routes could accommodate more families. • Incentives: Ideas included offering snacks, small rewards, or highlighting positive experiences to attract more participants. • Improved Communication: Parents requested a platform (e.g., email) for communication and updates about the program. • Parental Involvement: Some parents suggested ways for parents to be more involved, such as joining the walking group occasionally. • Addressing Safety Concerns: Background checks for parent volunteers and additional safety measures for children were proposed. Overall, the research highlights the need for: • Improved communication and outreach to promote the WSB program to low-income families. • Addressing time constraints, weather concerns, and safety fears to make the program more accessible. • Considering route adjustments to better serve the needs of the target population.

Poku-Boansi, Amoako and Atuah, 2019	Travel Patterns: • Walking is the dominant mode of travel for most schoolchildren (over 60%). • The average distance travelled is less than 2 km for the majority of children. • Private schools tend to be located further away from residential areas, requiring longer commutes. Safety Concerns: • Parents and guardians express concerns about the safety of children crossing roads near schools. • The lack of designated pedestrian crossings and traffic wardens at schools is a major safety concern. • Parents observe risky behaviours by children, such as playing while crossing or not looking both ways. • Overcrowding and speeding by public transport vehicles carrying children are safety hazards. Risk Factors: • Unaccompanied children are more vulnerable to traffic accidents. • Weak enforcement of traffic regulations contributes to unsafe conditions. • The poor condition and overloading of school buses pose a significant risk. Limitations: • The study doesn't directly explore parental perspectives on road crossing behaviours. Overall: The research highlights the challenges of child pedestrian safety in urban Ghana. While it doesn't directly address parental views, it provides valuable context for understanding the risks children face and the need for improvements in infrastructure, enforcement, and potentially, parental education on safe road crossing habits.

Maybe ASD 12 yrs/ 3 subtypes
Officially diagnosed last yrs
[redacted] Wait and not pay. Not able to pay attention around about his surroundings, so he will literally just walk straight across the road without looking"
He does not look
[redacted] grap his arm/ hold his hands when crossing the road
[redacted]
Worse during the bad temperament, more like oppositional defiance disorder leading to not stop and shoot across roads and I think he did hear anything around.
Many times, we pulled him back off a road before cars come "been quite terrifying"
Urban place, residential area.
Usually crossing from the middle of the st and from st with island in the middle

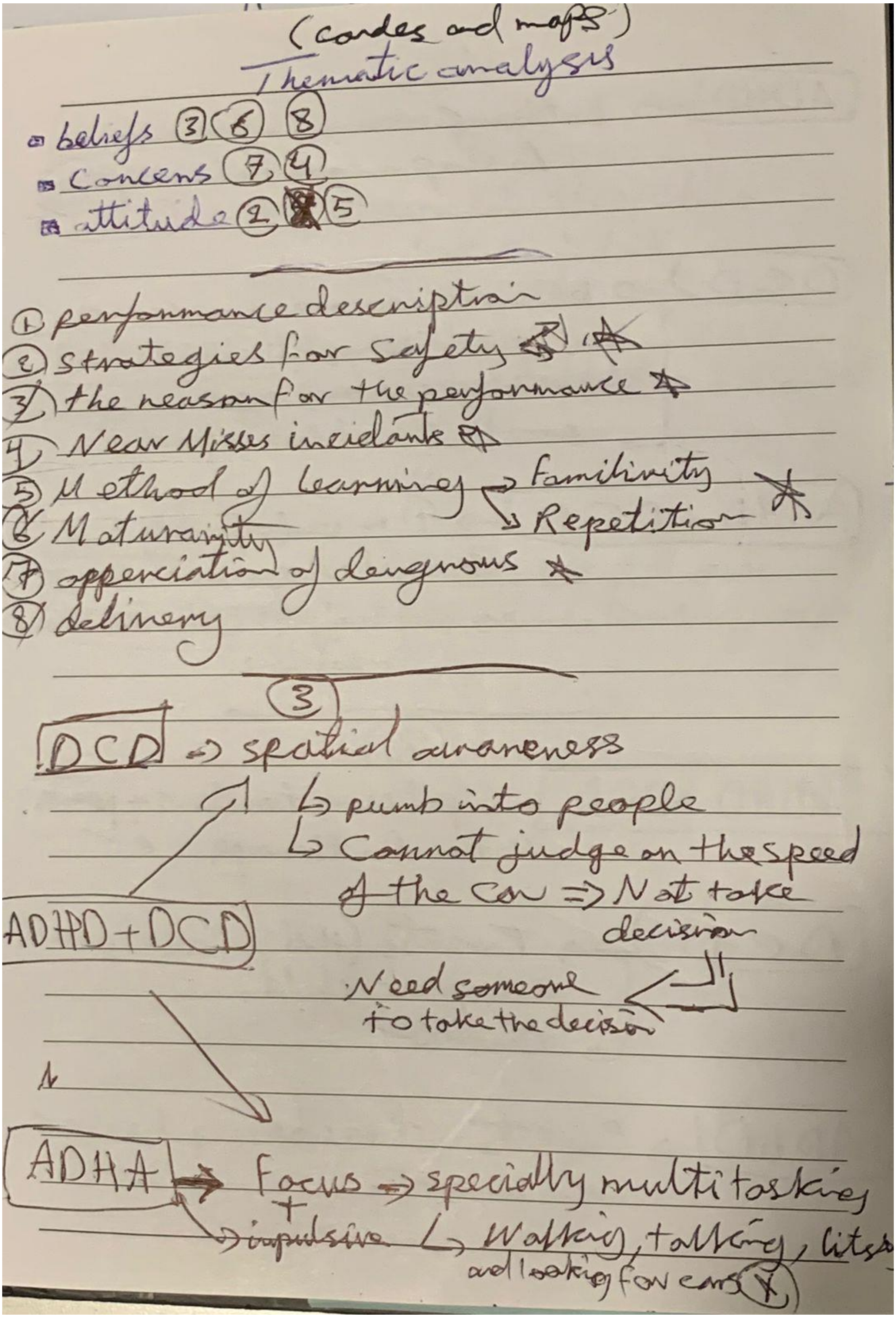
Appendix 4.2

Phase 1 Semi-structured interview questions

1 Questions

1. To start, I would like you to walk me through your normal day while you're walking around the community with your child? What does it look like?
2. Can you describe the physical environment that you typically walk around everyday such as streets and type of road crossings?
3. Can you tell me more about your child's behaviour at the roadside and when crossing a road?
4. How do you feel about your child's performance at the roadside and when crossing a road? Why?
5. What could be the reason for this roadside behaviour?
6. What do you think would help your child to increase his/her safety at the roadside?
7. Do you think ADHD and/or DCD medication makes any difference to your child's performance at the roadside?
8. Has your child completed any road safety education at school? If so do you remember what this involved and whether it made a difference to your child's road safety behaviour ?
9. What do you think an effective training programme might include for your child? Why?
10. Who do you think should deliver road crossing training? Why?
11. Can you tell me how you deal with any risk at the roadside when you are with your child?

Appendix 4.3



(cordes and maps)

Thematic analysis

- beliefs (3) (6) (8)
- Concerns (7) (4)
- attitude (2) (5)

1. performance description
2. strategies for safety
3. the reason for the performance
4. Near Misses incidents
5. Method of learning → familiarity → Repetition
6. Maturarity
7. apperciation of dangerous
8. delivery

(3)

DCD → spatial awareness
↳ pumb into people
↳ Cannot judge on the speed of the car ⇒ Not take decision

ADHD + DCD

Need someone to take the decision

ADHA → Focus ⇒ specially multitasking
+ → impulsive ↳ Walking, talking, lits and looking for cars (X)

(6)

ADHD → better crossing performance
↳ stop + look both ways (13)

DCD → become more concerned
as parent thought about
secondary school age
→ small did not think about it

ADHD + DCD → ↑ in understanding +
knowledge but have
no control over the behaviour
impulsive?

(8)

ADHD + DCD → police + teachers + parents
No time for therapy ←

DCD → Parents (that's called parents
of dyspraxic child
→ Teacher

ADHD → Parents + teacher + beaver
local autority
Scouts
online resources +

(3)

ADHD → He does appraciate the risk

DCD → Yes appriciate the risk + becoming less confident

DCD + ADHD → Yes understand the risk but deos not reflect on behaviour

(4)

ADHD →
DCD →
DCD + ADHD →

Yes, but still does not know the consequences

Appendix 5.1 : study characteristics

Code	Citation	Location	Study design	Sample Size	Aim	Participant characteristics

1	Clancy et al., 2006	New Zealand	case-control	ADHD = 24 | 24 no ADHD	to determine whether ADHD adolescents exhibit more unsafe road crossing behavior than controls using an immersive virtual reality traffic gap-choice task	aged 13 to 17 years old. There were equal numbers of boys and girls in each group (n = 12). Additionally, ADHD participants did not take stimulant medication on the day of testing.

2	Tabibi et al., 2022	Iran	Case-control study	38 children = 17 diagnosed with ADHD and 21 typically-developing	to examine the pedestrian behavior of children with ADHD in comparison to TD children, particularly in relation to traffic complexity.	Age: 8-12 years, The sample of 17 children with ADHD was 58% girls and had a mean age of 9.47 years (SD = 1.37). | 21 typically-developing children had a mean age of 10.05 years (SD = 1.61). They were 43% girls. There were no statistical differences between the two groups in child age

3	Parr et al., 2021	the University of Iowa, USA	Expcross sectional	92 children	to examine the relationship between individual variation in inattention and hyperactivity, motor timing difficulties, and performance in a virtual road crossing task.	Age: The study involved 92 children aged 9 to 11 years old (average age: 10.3 years). Gender: 52 participants were male and 40 were female. Ethnicity: 85% Caucasian 4% African American 11% Other/Multiracial Socioeconomic Status (SES): Measured by maternal education: 16% high school degree or some college 35% bachelor's degree 29% master's degree 20% doctoral degree ADHD: 7 children were diagnosed with ADHD/ADD according to parental report. 3 children were taking medication for ADHD symptoms but weren't diagnosed (parents didn't report it).

5	Tabibi et al., 2023	Iran	case-control	50 children = 28 children with ADHD and 22 TD	to examine differences in pedestrian behavior between children with ADHD and typically-developing children, and to investigate the relationship between pedestrian skills and attention, inhibition, and executive function in both groups.	Total: 50 children Age: Mean age: 9 years old (range: 7-12 years) Gender: 54% boys, 46% girls Diagnosis: 56% diagnosed with ADHD, 44% typically-developing ADHD medication: None for children with ADHD Intellectual and other disabilities: Children with intellectual or other disabilities that prevented understanding of the study protocol were excluded

6	Stavrinos et al., 2011	USA	matched case-control	78 children	to examine the differences in pedestrian behavior between children with ADHD-C and typically-developing children, and to investigate the mediating factors that might link ADHD-C with pedestrian injury risk.	Total: 78 children Age: Mean age: 9.16 years (range: 7-10 years) Gender: 71% boys (n = 56) Ethnicity: 49% African American (n = 38) Diagnosis: 39 children with ADHD-C, 39 typically-developing children ADHD Medication: Children with ADHD-C were off medication for 24 hours before participation Exclusion Criteria: Cognitive limitations, learning disabilities, pervasive developmental disorders, psychoses, physical disabilities hindering participation

7	Purcell et al., 2012	UK	Matched case-control and Within-subjects design	Total: 22 children (11 with DCD, 11 typically developing)	to investigate the relationship between DCD and looming sensitivity in children, and to explore the potential impact of this on road crossing behaviour	Age: 6-11 years old Gender: Matched for age and gender between groups Diagnosis: DCD diagnosis based on DSM-IV-TR criteria, confirmed by teacher assessment and M-ABC-2 scores Exclusion criteria: Children with reported history of behavioral or neurological problems, or intellectual or other disabilities that would interfere with study participation

8	Purcell et al., 2011	UK	Matched case-control and Within-subjects design	Total: 30 children DCD group: 9 children Typically developing group: 15 children At-risk group: 6 children (those with M-ABC-2 scores between 5th and 16th percentile)	to investigate the relationship between developmental coordination disorder (DCD) and pedestrian behavior, specifically focusing on the ability to judge relative approach rates of vehicles and select appropriate crossing gaps. The study aimed to identify whether children with DCD have deficits in these skills and to explore the underlying mechanisms contributing to these difficulties.	Age: 6-11 years old Gender: Matched for age and gender between groups Diagnosis: DCD diagnosis based on DSM-IV-TR criteria, confirmed by teacher assessment and M-ABC-2 scores ADHD: Four children with DCD had elevated ADHD scores, but were included in the analysis as per the Leeds Consensus Statement. Cognitive ability: 26 of 30 children (87%) fell at or above intellectually average for their age. Motor skills: Assessed using the M-ABC-2 test battery.

9	Purcell and Romijn, 2017	UK	Repeated measures design (within-subjects) with case-control matching between groups	42 children (21 DCD, 21 TD)	to investigate the appropriateness of different pedagogical approaches to road safety education for children with DCD. Specifically, the study aimed to compare the effectiveness of allocentric (aerial viewpoint) and egocentric (first-person viewpoint) virtual reality tasks in teaching road safety skills to children with DCD and typically developing children.	Age: 6-12 years old Gender: Matched for age and gender between groups Diagnosis: DCD diagnosis based on DSM-5 criteria, confirmed by M-ABC-2 and teacher assessment ADHD: Excluded children with ADHD symptoms above the top 5% on the SNAP-IV Intellectual ability: Excluded children with below-average IQ (below 80) on the KBIT-2 Prior road crossing experience: Assessed through a questionnaire

10	Purcell et al., 2017	UK	Repeated measures design (within-subjects) with case-control matching between groups	50 children. This included 25 children with DCD and 25 typically developing children, matched for age and gender	to investigate the use of visually guided behavior in children with DCD when crossing a virtual road. Specifically, the study aimed to examine how children with DCD make decisions about crossing gaps in traffic and whether their decisions are influenced by their motor skills and visual perception	Total: 50 children (25 with DCD, 25 typically developing) Age: 6-11 years old Gender: Matched for age and gender between groups Diagnosis: DCD diagnosis based on DSM-5 criteria, confirmed by M-ABC-2 and teacher assessment Motor skills: Assessed using the M-ABC-2 test battery (DCD group scored below 16th percentile, indicating significant movement difficulties) Intellectual ability: Most children (86%) fell at or above intellectually average (25th-100th percentile) Neurological conditions or attention difficulties: None reported

11	Parr , 2023	USA	cross sectional	Total: 103 children	to investigate the relationship between motor coordination, executive functioning, processing speed, and road crossing behavior in children. Specifically, the study aimed to examine how these factors contribute to children's ability to make safe decisions when crossing roads.	Age: 9-11 years old Gender: 53% male Ethnicity: 67% Caucasian/White, 4% African American/Black, 5% Asian, 3% Hispanic, 9% Bi-racial/Mixed Identity Socio-economic status: 74% mothers had at least a 4-year college degree ADHD: 36 children (35%) met criteria for suspected ADHD IQ: 3 participants had FSIQ below 80 (76, 77, 79) Motor coordination: 6 children (5.9%) met the cutoff for DCD (5th percentile and below), 18 children (17.6%) met the cutoff for at-risk for DCD (9th and 16th percentiles) Medication: 17 children completed a 24- or 48-hour medication washout prior to participation.
12	Toye, 2016	UK				

12.1	experimental between-groups and cross-sectional	122 children (61 ADHD, 61 controls)	to investigate differences in safe place finding ability between children with ADHD and typically developing children. The study also aimed to examine the relationship between conceptual understanding and perceived difficulty of the task in both groups.	age range 5 - 12 years | 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. 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).

12.2	same	same	to investigate differences in visual gap timing ability between children with ADHD and typically developing children. The study also aims to examine the perceived difficulty of the visual gap timing task in both groups.	same

12.3	same	same	the aim is to investigate whether children with ADHD have difficulties in predicting the intentions of road users, and if so, to understand how this relates to their cognitive functions and social skills.	same

Appendix 5.2: Studies description and findings

Code	Citation	Study Description	Outcome Measures	Key Findings

1	Clancy et al., 2006	The study used an immersive virtual reality traffic gap-choice task to assess the road crossing behavior of adolescents with and without ADHD. Participants were exposed to simulated traffic scenarios and asked to make decisions about when to cross the road. The study measured various outcomes, including margin of safety, walking speed, gap utilization, variability in road crossing behavior, and collisions	**Margin of safety**: This measure likely assessed how close participants were to crossing the road when the vans were closest. A lower margin of safety indicates a riskier crossing. **Walking speed**: The speed at which participants walked across the road. **Gap utilization**: The percentage of the available gap between vans that participants used when crossing. **Collisions**: Whether participants collided with a virtual van during the task.	1. Increased risk of collisions: Adolescents with ADHD were significantly more likely to have collisions in the virtual reality traffic gap-choice task compared to controls. This suggests a potential increase in accident risk for this population. 2. Slower walking speed: Adolescents with ADHD walked significantly slower than controls, which could contribute to increased risk as they may have less time to react to approaching traffic. 3. Reduced margin of safety: The ADHD group demonstrated a lower margin of safety when crossing the road, indicating a greater willingness to take risks. 4. Variable performance: The ADHD group exhibited more variability in their road crossing behavior, suggesting difficulty in consistently applying safe crossing strategies. 5. Impact of covariates: While some factors such as reading achievement and IQ were

associated with group differences in certain outcomes, the core finding of increased risk for adolescents with ADHD persisted even after controlling for these covariates.

2	Tabibi et al., 2022	The study used a virtual reality street-crossing task to assess the pedestrian behavior of children with ADHD and typically-developing children. Participants completed 21 virtual street crossings in three (7 in each) levels of traffic complexity: low, medium, and high	**Unsafe crossings**: The number of times participants crossed the street in a potentially unsafe manner **Start-delay to enter the road**: The time it took participants to start crossing the road after the traffic signal turned green **Time to contact with oncoming vehicles**: The amount of time between the start of crossing and the nearest approach of an oncoming vehicle **Wait time to cross**: The amount of time participants waited before crossing the road **Look ratio**: The proportion of time participants spent looking at traffic during the crossing task	**Children with ADHD had more unsafe crossing**s: This was particularly evident in more complex traffic environments. **Children with ADHD had longer start-delays**: They were slower to initiate their crossing. **Children with ADHD had higher time to contact:** They were less likely to adjust their speed to avoid oncoming traffic. **Children with ADHD had longer wait times**: They were more cautious and waited longer before crossing. **Look ratio was not significantly different**: There were no significant differences in the amount of time participants spent looking at traffic between the two groups. These findings suggest that children with ADHD may have difficulties in: **Risk assessment:** They may not accurately assess the risk of crossing in complex traffic environments. **Decision-making**: They may struggle to make quick and appropriate decisions when crossing the road.

Motor coordination: They may have difficulty coordinating their movements with the traffic flow.

3	Parr et al., 2021	The study used a VR environment to simulate road crossing scenarios and assess the pedestrian behavior of children with ADHD. Participants crossed virtual streets with varying levels of traffic complexity while wearing a VR headset. The study measured performance on tasks related to motor timing, inattention, and hyperactivity, and compared the results between children with ADHD and typically-developing children.	Outcome Measures Used in the Study The study used a combination of questionnaires, virtual reality tasks, and statistical analyses to assess the relationship between inattention/hyperactivity, motor timing, and virtual road crossing performance in children. Here's a breakdown of the specific measures: 1. Questionnaires: Parents completed questionnaires that assessed their child's inattention and hyperactivity symptoms. Specific questionnaires mentioned in the results section include: Conners Rating Scales (measuring inattention and hyperactivity) ADHD-DSM-IV Diagnostic Interview Schedule (ADHD/DBD scales for inattention and hyperactivity)	The key findings of the study are: **Inattention/hyperactivity predicted poorer motor timing performance:** Children with higher levels of inattention/hyperactivity exhibited poorer performance in the duration discrimination and synchronization-continuation tasks. **Motor timing performance predicted road crossing performance:** Poorer performance in the motor timing tasks (duration discrimination and synchronization-continuation) was associated with poorer timing of entry and greater variability in timing of entry in the virtual road crossing task. **Inattention/hyperactivity did not directly predict road crossing performance:** While inattention/hyperactivity was associated with motor timing deficits, it did not directly predict performance in the virtual road crossing task when controlling for motor timing. These findings suggest that motor timing deficits, rather than inattention/hyperactivity alone,

Child Behavior Checklist (CBCL attention problems scale)
Behavior Rating Inventory of Executive Function (BRIEF)
2. Virtual Reality Task:

Participants completed a virtual road crossing task where they crossed virtual streets with varying traffic complexity while wearing a VR headset. The following performance measures were obtained:
Timing of entry: This measured the average time it took participants to start crossing the road after the light turned green.
Variability of timing of entry: This measured the consistency in the timing of entry across multiple trials.
3. Simple Timing Tasks:

Participants completed two tasks designed to assess their motor timing skills:
Duration discrimination: This measured the ability to

may be a key factor in predicting the road crossing performance of children with ADHD.

distinguish between short and long durations of a visual stimulus.

Synchronization-continuation: This measured the ability to synchronize finger taps with a visual stimulus and then continue tapping at a consistent pace after the stimulus ended. Performance was assessed by tap onset asynchrony, which represents the difference between the participant's taps and the visual stimulus.

Statistical Analysis:

The study used linear multiple regressions to analyze the relationships between inattention/hyperactivity, motor timing performance, and road crossing performance while controlling for age and gender as potential confounding variables.

5	Tabibi et al., 2023	The study used a case-control design to compare pedestrian behavior between children with ADHD and typically-developing children. Participants completed an auditory-visual test to assess attention, inhibition, and executive function (IVAþPlus), and then engaged in a virtual reality pedestrian task to assess pedestrian skills. The study focused on unsafe crossings, looking behavior, and start delay as key indicators of pedestrian safety.	Pedestrian Skill Measures: **IVAþ**: Sustained attention Focused attention Response control **BDEFS-CA**: Total score of deficits in executive functions **MVR (Mobile Virtual Reality) Task:** Unsafe crossings (count) Looking left/right ratio Start-delay (seconds)	Key Findings: **ADHD and Pedestrian Safety:** Children with ADHD exhibited significantly more unsafe crossings in the virtual reality pedestrian task compared to typically-developing children. **Executive Function and Pedestrian Safety:** For both groups, higher scores on the BDEFS-CA (executive function deficits) were positively correlated with a higher number of unsafe crossings. This suggests that executive dysfunction is a risk factor for unsafe pedestrian behavior in both ADHD and typically-developing children. **Relationship between ADHD, Executive Function, and Pedestrian Safety:** The study found that ADHD was associated with deficits in executive function, which in turn were related to riskier pedestrian behavior. This suggests that executive function deficits may mediate the increased risk of pedestrian injury among children with ADHD. **In summary, the study provides evidence that children with ADHD are at an increased risk of**

pedestrian injury due to deficits in executive function, which can impact their decision-making and motor control while crossing the road.

6	Stavrinos et al., 2011	Participants completed a virtual pedestrian environment task to assess various aspects of their pedestrian behavior, including decision-making, crossing initiation, and safety within the crossing environment. The study also examined the role of mediating factors, such as executive function, in the relationship between ADHD-C and pedestrian injury risk.	Pedestrian Behavior: Before the cross: Evaluating aspects of the crossing environment (e.g., assessing traffic conditions, looking for gaps) Making the cross: Deciding to cross and initiating movement Safety of the cross: Gap size used Hits and close calls Time left to spare These measures assessed different stages of the pedestrian crossing process to provide a comprehensive understanding of pedestrian behavior. Note: The study further aggregated these variables into three factors: "before the cross," "safety of the cross," and "initiating the cross." These factors were calculated by standardizing and averaging the relevant variables.	Key Findings: Children with ADHD-C chose riskier pedestrian environments to cross. They were more likely to cross in situations with less time to spare and smaller gaps. No significant differences were found in other aspects of the crossing process: Children with ADHD-C evaluated the crossing environment and initiated the cross similarly to typically-developing children. Executive function played a mediating role: Executive dysfunction fully mediated the association between ADHD-C and unsafe pedestrian behavior. This suggests that children with ADHD-C may have difficulty processing perceived information to cross safely due to executive function deficits. Overall, the study provides evidence that children with ADHD-C are at increased risk of pedestrian injury due to their tendency to choose riskier crossing environments, likely mediated by executive function deficits.

7	Purcell et al., 2012	The study used an experimental design to investigate the relationship between developmental coordination disorder (DCD) and looming sensitivity in children. Participants were presented with visual simulations of approaching vehicles at different speeds and under different viewing conditions. Looming detection thresholds were measured to assess participants' ability to detect the approaching vehicles. The study also examined the potential impact of looming sensitivity on road crossing behaviour.	The primary outcome measure in this study was looming detection sensitivity. The study also measured the equivalent vehicle speeds that participants could reliably detect under each condition. This allowed for a more practical interpretation of the results in terms of real-world road crossing scenarios.	Children with DCD have lower looming detection sensitivity than typically developing children. This was evident in both foveal and perifoveal viewing conditions. Children with DCD may fail to detect vehicles approaching at speeds exceeding 22 km/h. This suggests that their perceptual acuity is below what is required to cope with standard urban speed limits. Looming detection sensitivity is associated with motor skills: Significant negative correlations were found between perifoveal looming detection thresholds and overall M-ABC-2 percentiles, indicating that children with lower motor skills may also have difficulty detecting looming stimuli. Overall, the study provides evidence that children with DCD may have deficits in low-level motion processing, which could contribute to errors in road crossing behavior and increase their risk of pedestrian accidents.

8	Purcell et al., 2011	Participants were presented with visual simulations of approaching vehicles in a road crossing scenario and asked to make judgments about vehicle approach rates and select appropriate crossing gaps. The study measured participants' ability to detect looming stimuli, estimate relative approach rates, and choose safe crossing gaps.	1. Relative approach rate judgments: Threshold errors for different vehicle sizes (car vs. truck) Threshold errors for different vehicle approach speeds (32, 48, 64, and 80 km/h) 2. Crossing gap selection: Temporal gap thresholds accepted for different vehicle approach speeds	Children with DCD have difficulty judging relative approach rates: They were less accurate in determining which vehicle was approaching faster, especially when the size difference between the vehicles was small. Children with DCD leave longer crossing gaps: They were more likely to accept longer gaps before crossing the road, even at higher vehicle approach speeds. DCD children may rely more on distance cues: The study found that children with DCD may be less able to compensate for speed and rely more on distance cues when judging crossing gaps. Looming detection sensitivity may be affected: While not directly measured in this study, the authors suggest that deficits in looming detection sensitivity, as found in previous research, could contribute to the difficulties children with DCD face in judging relative approach rates. Overall, the study provides evidence that children with DCD may have deficits in visual processing and decision-making skills that can impact their pedestrian behavior and increase

their risk of
accidents.

9	Purcell and Romijn, 2017	The study used a repeated measures design to compare the effectiveness of different pedagogical approaches to road safety education for children with DCD and typically developing children. Participants completed a virtual reality road crossing task in both allocentric (aerial) and egocentric (first-person) viewpoints. The primary outcome measure was accuracy in identifying and using the safest crossing route. The study also assessed participants' self-reported prior road crossing experience, confidence, and knowledge.	Road crossing accuracy: The primary outcome measure was the number of trials out of 10 where the child successfully identified and used the safest crossing route.	Overall accuracy: Both groups performed significantly better in the egocentric condition compared to the allocentric condition. Group differences: TD group: Significantly higher accuracy in the egocentric condition compared to the DCD group. DCD group: No significant difference between allocentric and egocentric conditions. Secondary analyses: No significant differences in accuracy based on school stage, age group, prior road crossing experience, or self-reported road crossing skills. In summary, the study found that both TD and DCD children benefited from the egocentric viewpoint in the virtual reality road crossing task. However, TD children demonstrated significantly higher accuracy overall, suggesting that they may benefit more from this type of instruction.

10	Purcell et al., 2017	The study used an experimental design to investigate the relationship between developmental coordination disorder (DCD) and road crossing behavior. Participants were presented with a virtual road crossing task involving a stream of traffic approaching at different speeds and from different directions. The study measured participants' ability to select suitable temporal crossing gaps and to make decisions about whether to cross the road safely.	Temporal crossing gaps: The minimum gap participants accepted before crossing the road.	Children with DCD selected insufficient temporal crossing gaps across all approach speeds (20, 30, and 40 mph). Typically developing children: Accepted gaps sufficient for 20 and 30 mph but insufficient for 40 mph. Walking speeds: No significant differences between groups in walking speeds. Distance judgment: TD group showed a trend towards using a mixed strategy (combining time and distance cues), while DCD group relied more on distance cues. Overall, the study suggests that children with DCD may have difficulties in visually guided behavior related to road crossing, which could increase their risk of accidents.

11	Parr , 2023	The study used an experimental design to investigate the relationship between motor coordination, executive functioning, processing speed, and road crossing behavior. Participants completed a series of behavioral tasks to assess these cognitive and motor skills, as well as a virtual road crossing task. The study measured participants' performance on these tasks to identify how these factors contribute to safe road crossing decisions.	Motor coordination: MABC-2 Executive functioning: Complex span task, Conners CPT-III, go/go task Processing speed: Numerosity discrimination task (DDM analysis) Road crossing: Gap selection, timing of entry, variability of timing	**Relationship between motor coordination, executive functioning, and motor timing:** **Processing speed mediated the relationship between poorer executive functioning (inhibitory control, working memory) and more variable motor timing.** **Movement coordination difficulties and slower processing speed predicted more variable interval timing performance.** **Impact on road crossing:** **Movement coordination difficulties and poorer motor timing predicted riskier gap selection and poorer road crossing timing.** **Processing speed marginally predicted larger timing of entry and more variability of timing of entry.** **Additional Findings:** **Parent-reported measures: Higher parent-reported behavior problems were associated with poorer movement coordination, slower processing speed, and more variability in timing of entry.** **Distance judgment: No significant differences between groups in distance judgment for gaps accepted (Table 4).**
12	Toye, 2016			

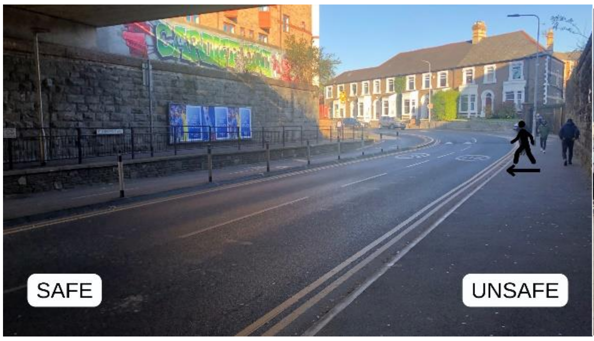
12.1	The study used a between-groups design, with participants divided into ADHD and control groups matched on age and gender. Participants completed a safe place finding task using a virtual environment, and their performance was assessed in terms of safe route selection, conceptual understanding, and perceived difficulty.	Safe place finding: Proportion of safe routes selected. Conceptual understanding: Categorised as high, low, or no understanding. Perceived difficulty: Pre- and post-trial estimations.	**Overall Performance:** **ADHD group performed worse: Children with ADHD selected significantly fewer safe routes than controls across all age groups.** **Age-related improvement: Both ADHD and control groups showed improved performance with age, but the gap between groups widened with age.** **Conceptual Understanding:** **ADHD group performed worse: Children with ADHD had significantly lower conceptual understanding than controls.** **Age-related improvement: Both groups showed improvement, but the increase was less pronounced for ADHD children.** **Perceived Difficulty:** **No group differences: Before the task, both groups rated the task similarly.** **Age-related differences: Younger children underestimated difficulty, while older children rated it as harder.** **Post-trial ratings: Control children rated the task as more difficult after completing it, while ADHD children rated it as less difficult.** **In summary, children with ADHD struggled with safe place finding skills compared to controls, particularly in older age groups. They also had lower conceptual understanding and tended to underestimate the task's difficulty.**

12.2	The procedure involved participants completing a visual gap timing task on a laptop computer. They first completed practice trials to familiarize themselves with the task and then undertook 24 experimental crossing trials. Perceived difficulty was assessed using a sliding bar before and after each trial.	Accepted gap size: The size of the gap between vehicles that participants were willing to cross. Starting delay: The time it took participants to initiate their crossing after a safe gap appeared. Effective gap size: The actual size of the gap that participants used to cross. Estimated crossing time: Participants' estimates of how long it would take them to cross. Missed opportunities: The number of times participants missed a safe opportunity to cross. Tight fits: The number of times participants were still on the road when a car arrived at their crossing line. Perceived difficulty: Pre- and post-trial estimations of the task's difficulty.	Accepted gap size: Children with ADHD accepted significantly smaller gaps than controls, especially in older age groups. Starting delay: Children with ADHD had significantly longer starting delays, indicating they were less focused and less anticipatory. Effective gap size: Children with ADHD had smaller effective gaps, suggesting they were less efficient in using the available time to cross. Estimated crossing time: There were no significant differences in estimated crossing time between groups or with age. Missed opportunities: There were no significant differences in missed opportunities between groups or with age. Tight fits: Children with ADHD made significantly more tight fits, indicating they were less able to adjust their crossing speed to the traffic conditions. Perceived difficulty: Children with ADHD did not rate the task as significantly more difficult than controls, even though their performance was poorer. In summary, children with ADHD demonstrated deficits in various aspects of visual gap timing, including accepting smaller gaps, having longer starting delays, and making more tight fits. These findings

suggest that they have difficulties in perceiving and using gaps safely in traffic.

12.3	The study likely used a similar design to the previous studies, with a focus on comparing the performance of children with ADHD to typically developing controls. It probably involved presenting participants with scenarios or videos depicting road traffic situations and asking them to predict the intentions of the road users involved. Based on the information provided, it seems that the study used a between-groups design, where participants were divided into ADHD and control groups. The key outcome measure was likely the accuracy of participants' predictions about road user intentions. To confirm the exact study design and outcome measures, you would need to consult the full text of the study.	Accuracy of predictions: The number of correct predictions made by participants about road user intentions. Identification of cues: The number of environmental cues (e.g., traffic signals, vehicle movements) identified by participants as relevant to predicting road user intentions.	ADHD group performed worse: Children with ADHD were less accurate in predicting road user intentions than controls, particularly in older age groups. Cue identification: Children with ADHD identified fewer environmental cues than controls, especially in the older age groups. Perceived difficulty: There were no significant differences in perceived difficulty between groups or with age. In summary, children with ADHD struggled to accurately predict road user intentions, particularly in older age groups. They also had difficulty identifying relevant environmental cues, suggesting deficits in social perception and information processing.

Appendix 6.1: Visual Stimuli and scenarios used for the identification task of safe crossing site.



Blind Bend

Zebra crossing

Traffic Light

Traffic Island

Pelican Crossing

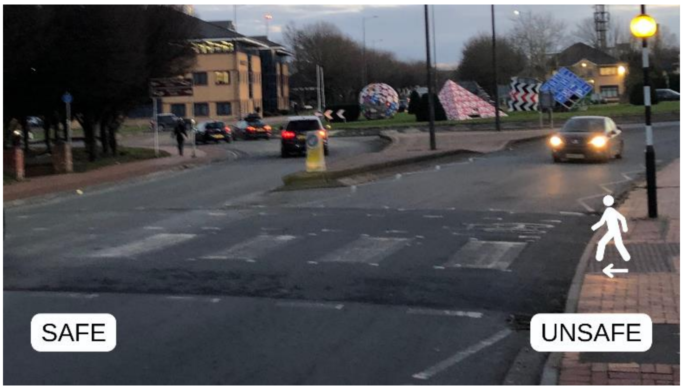
Parked Car

Brow of a hill

Road Crossing Patrol

Stright Road

Junction



Roundabout