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THE ROLE OF ATTENTIONAL, COGNITIVE AND SPATIAL SKILLS IN INJURY PRONENESS AND RISK TENDENCY

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Abstract

The objective of the project was to study injury proneness and its main characteristics. A questionnaire was created to analyze this predisposition (Injury Proneness Questionnaire - IPQ), considering also individual and cognitive factors. The IPQ was applied in studies involving adolescents, adults and elders. In addition, considering the role of attentional and spatial factors in injuries proneness, the relation between spatial skills and attentional problems was studied in Attention Deficit Hyperactivity Disorder (ADHD) through a meta-analysis. The IPQ demonstrated good reliability and was significantly related to questionnaires and tests. Cognitive and individual differences significantly influenced injury propensity: injury risk decreased with age, males had injuries more often after risky situations, whereas females after committing errors. Better spatial, attentional and cognitive skills were associated with lower injury predisposition during adolescence but higher in adulthood. The meta-analysis showed that individuals with ADHD, who are characterized by great injury predisposition, struggle with spatial skills. Results suggest that injuries are explained by individual and environmental factors.

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1 General introduction

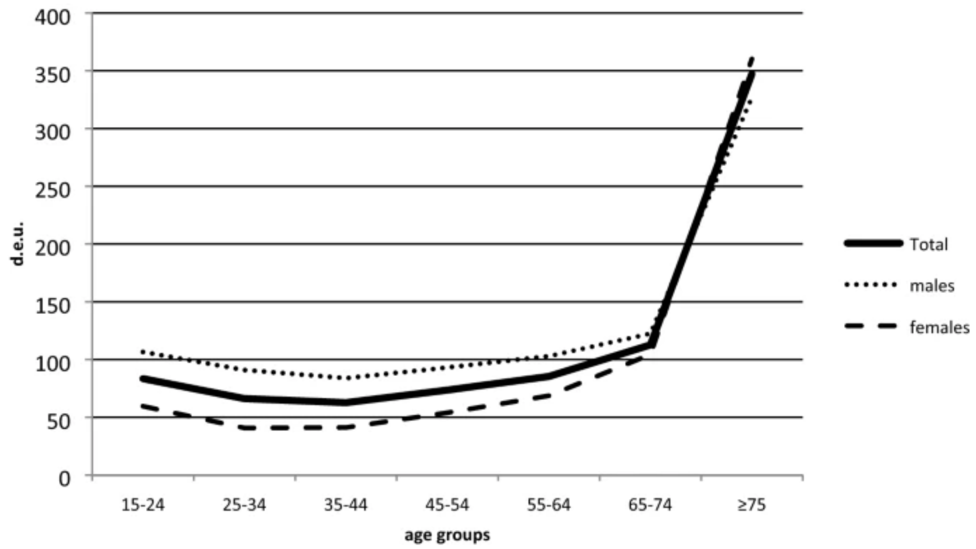
The main topic of this dissertation is the exploration of accidental injuries and their characteristics and effects on daily life. Accidental injuries are a kind of event that occurs unexpectedly without premeditated intentions (Jamison et al., 2006), on the contrary of self-harm or violence inflicted by others. Usually, these events are caused by falls, accidents, errors, drownings, fires or poisoning. The concept of injuries is quite vast and will be explored across the following chapters: throughout the lifespan (chapters 2 and 3) and during school years (chapter 4); in association with cognitive tasks (chapters 3 and 4) and with behavioral characteristics (chapter 2 and 4). In particular, the association of injury proneness to inattentive and impulsive behaviors and with some spatial abilities led to summarize the extant literature on spatial abilities in Attention Deficit Hyperactivity Disorder (ADHD; chapter 5).

Accidental injuries have been a critical concept for the World Health Organization (WHO), which dedicated several reports on it. Indeed, it has been stated that accidental injuries are a main concern for public health, and more than 80% of deaths are caused by the consequences of injuries (WHO, 2008). They also cause 3.2% of deaths in Europe and are the third cause of death in the USA (Eurostat 2020; Centers for Disease Control and Prevention, CDC, 2020). Furthermore, accidental injuries are the main cause of death among children and adolescents from 1 to 18 years of age (National Center for Injury Prevention and Control, NCIPC, 2008). There are many factors and types of injuries described in research so far; in this section a brief summary of the state of the art, as well as a general theoretical outline of this project, will be provided.

One common aspect that is explored is the one of gender, often indicating a stronger injury tendency in males. Such a predisposition seems to be present starting from childhood and continues in adolescence (Mattila et al., 2004), adult life at work (Abegglen et al., 2017) and when traveling (Steffen, 1991). Moreover, age plays the role of mediator between intellectual abilities and injury episodes, with a double effect size in males compared to females (Bonander & Jernbro, 2017). Male elders are also at risk, according to Wolf and Rivara (1992) who reported that males were 2.5 times more likely than females to get hurt, especially from 65 years of age. Despite this evidence, females have certain predispositions towards injuries. Indeed, it has been proven that significant injury proneness was present among females when considering heritability, this was studied by examining monozygotic and dizygotic twins (Rowe et al., 2007). In this work, injury proneness was measured by parents with unintentional injury scales, and it emerged that injury proneness was stronger in monozygotic twins, regardless of gender. Furthermore, when considering the effect of genetic and environmental factors, the results indicated that unintentional injury was significantly explained from a genetical point of view in females and environmentally in both genders. The progression of age does not help females either because with age, medical expenses tend to grow, especially among female elder patients, across all medical treatment settings (Stevens et al., 2006). Camarero (2021) stated that males tend to get hurt more often during youth and adult life, whereas females encounter more injuries later in life. More details regarding gender will be discussed in the following chapters.

Another important aspect to consider is age. Once again, Camarero (2021) offered some insight by calculating the Accidental-Injury Proneness Index (AIPI) based on the total number of injuries weighed based on the severity of their consequences, in the general population. The AIPI represents the total volume of injuries experienced by people of different ages or social categories within a year. Indeed, it emerged that the likelihood of encountering injuries varied with age, with a slightly higher probability in adolescence until age 24, followed by a gradual decrease in adult age and a spike starting from age 65, following a "J"-shaped trajectory (Figure 1). The trend was similar in males and females, with a slightly greater probability in men before 65 years of age and a greater probability in women after that age. Besides this, the author wanted to verify whether the greater volume of injuries was explained by a greater number of accidents or by a greater severity of the accidents. Hence the distribution of nonmortal accident rates and accidents causing mortality were examined separately. When considering accident rates explaining injuries, the trajectory would change: accident rates were higher during adolescence and early adulthood, gradually decreasing in adult years and increasing starting from 60 years of age, which is around the moment of retirement in many participants. Moreover, by looking at gender in detail, it emerged that males encountered more accidents than females in their youth, whereas females later in life. When looking at fatal injury rates, it emerged that fatality grew constantly with age, registering a noticeable spike starting from 65 years of age. Males were more involved in fatal injuries than females at every age. So injury proneness was higher in elders because they were involved in a greater number of accidents and they suffered from accidents with greater severity. The study in question explains injury proneness on the basis of effective accident and mortality rates collected from different health centers. However, it is also true that injury proneness can be studied, though to a lesser extent, from a personal point of view, measuring propensity from self-reported information. Some questionnaires had already been created and applied (Rowe & Maughan; Speltz et al., 1990); a more detailed description of these measures, as well as the one introduced in this dissertation (Injury Proneness Questionnaire-IPQ), will be provided in chapter 2.

Figure 1. *Accidental-Injury Proneness Index (AIPI), by age groups and sex. European Union Countries-2014. Units: death equivalent units (d.e.u.) × 100,000. Sources: European Health Interview Survey, EHIS-2014; Hospital Discharges, HDS-2014; Causes of Death, COD-2014*



Regardless of gender, age remains a risk factor for everyone. According to Ambrose and colleagues (2013), falls are the main cause of morbidity and mortality in elders; 1 out of 3 elders over 65 years of age falls at least once a year. The probability increases to 50% once people reach 80 years of age.

The type of injury is another interesting factor and is often related to the person's age and context: indeed, certain types of injury are more likely to happen in a specific age or context (e.g. work or during physical activity). The most common types of accidents are drownings, falls, fires, poisoning and road accidents (De Ramirez et al., 2012). According to Dellenger and Stevens (2006), 63% of injuries in the general population are due to falls, followed by road accidents (7%), overextension (6%) and cuts or stabbing (4%). Therefore, falls are often listed as the most common cause of injuries (WHO, 2008). Furthermore, a research branch is specifically dedicated to the road environment, considering accident and death rates. Indeed, it has been found that more than half of the deceased are represented by pedestrians, cyclists and motorbikers (WHO, 2020).

Evidence regarding the impact of social aspects is present. For instance, De Ramirez and colleagues (2012) analyzed socio-economic status (SES) and noticed that injury proneness varied according to the SES and the residing country. In countries with high income, having a low SES was a risk factor; the contrary happened in countries with low/medium income: in this case having a high SES was riskier for injury proneness. The role of family is also essential, and especially that of the caregiver. Higher injury tendencies occurred when families were composed of single parents, numerous siblings or caregivers that would consume substances (Rivara & Mueller., 1987; Nathens et al., 2000; Nathorst Westfelt, 1982). Hospitalization due to falls is also influenced by social status. Indeed, social status was not relevant in children and adolescents, but it played a critical role in old age, with lower SES being associated with higher hospitalization rates.

Individual differences and emotional characteristics have their own impact on injury proneness. It has been observed that emotional dissatisfaction, impulsiveness, extroversion, external locus of control, hostility and antisocial behaviors are often associated with risk tendency (Vavrik, 1999). Being an extrovert seems to be a risk factor also for Rowe and colleagues (2007), often leading to more distractibility and poorer focus towards the environment, and therefore possible dangers. Anxiety is associated with poisoning and head injuries, whereas depression is related to bone fractures (Rowe et al., 2007; Rowe et al., 2004). Sensation seeking is often cited in the literature, since it is frequently linked to more injury and risk tendencies (Rosenbloom, 2003).

Cognitive and executive functions are often tested when dealing with injury proneness. Specific focus was given to intellectual abilities (Batty et al., 2009: Whitley et al., 2010); it emerged that there is a negative correlation between IQ and injury. This fact was justified considering that a slower and inefficient elaboration of information entails a more inefficient evaluation of risk, thus inducing more risk behaviors. In these cases, motor coordination is often less accurate. Moreover, lower IQ is often accompanied by lower SES; therefore, the individual is more exposed to environmental risks and has more issues with medical expenses or access to specific services. Simple cognitive failures in daily life (e.g. forgetting to carry out a certain routine activity) are also associated with greater injury probability, especially in the road environment (Larson et al., 1997) or at work (Simpson et al., 2005; Allahyari et al., 2014). Individuals with poorer executive functions are prone to injuries (Shen et al., 2021).

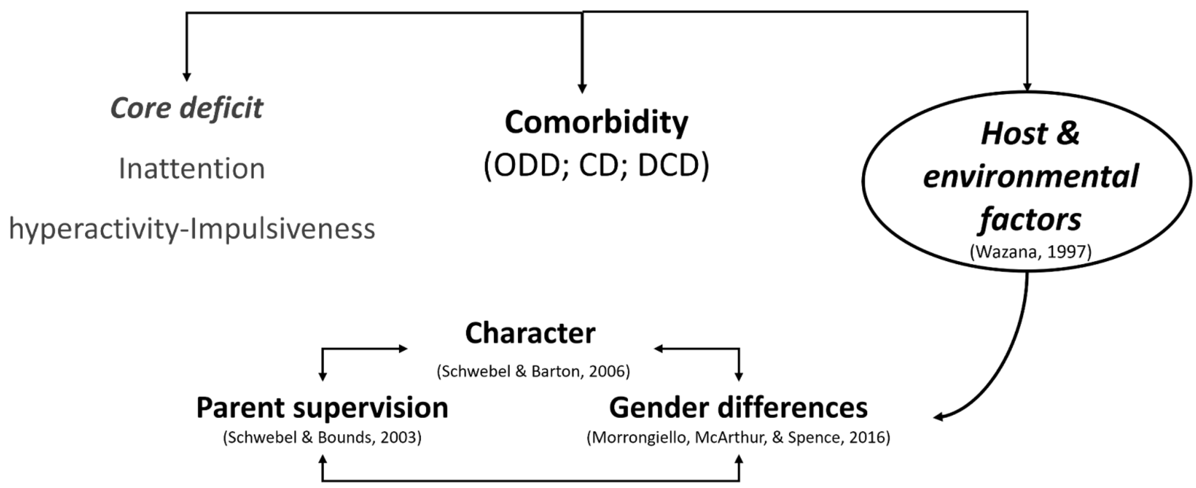
One of least explored factors in injury proneness, at least to our knowledge, lies in visuospatial skills. Voyer and Voyer (2015) explored the impact of mental rotation abilities and sense of direction, considering gender differences. It emerged that spatial skills were responsible for explaining injury proneness. Male participants performed better in these tasks, yet they also had more history of injuries compared to female participants, who often perceived themselves as more clumsy, and therefore less prone to risky behaviors. Good spatial skills are a protective factor in old age; indeed, people with better spatial skills were less prone to experience injuries due to falls (Martin et al., 2009).

After an analysis of the literature, the present project was organized and the following main objectives were set:

- adaptation of an instrument for measuring reported and self-reported injury proneness that could be used across different ages. As a result, different versions of a questionnaire were drafted and presented to adults, adolescents and parents;
- analysis of the role of specific aspects: cognition, spatial abilities and attentional features in injury proneness throughout the lifespan;
- analysis of self-perceived and observer-rated injury proneness in adolescents, in relation to cognitive and spatial skills, symptoms of inattention and hyperactivity.

The third objective is related to a possible extension of the project to the ADHD population. A specific line of research is dedicated to people with ADHD who have demonstrated to be more prone to injuries and risky behaviors compared to individuals with typical development (Brunkhorst-Kanaan et al., 2021). Many odds are stacked against people with ADHD, mainly due to the characteristics of ADHD *per se*, as well as other derived social and cognitive consequences. For example, people with ADHD are prone to commit errors due to a Positive Illusory bias, which induces the overestimation of personal abilities and the underestimation of dangers ahead. For such reasons they often think that they are able to resist distractions, maintain their focus or perform more efficiently (e.g. driving) than in reality. The present model (Figure 2) summarizes the causes of injury proneness in ADHD.

Figure 2. *Model summarizing the characteristics of ADHD causing injury and risk proneness. ODD = Oppositional Defiant Disorder; CD = Conduct Disorder; DCD = Developmental Coordination Disorder.*



As illustrated in the model, the core deficits of ADHD are inattention, hyperactivity and impulsiveness, which often drive individuals towards risky behaviors. This predisposition is exacerbated when comorbidities are present. As mentioned in the previous paragraphs, environmental factors are crucial as well, for they influence the person's background and social condition.

The ADHD profile can be an interesting candidate for understanding cognitive factors associated with accidental injuries.

With the aim of extending the analysis of injury proneness in ADHD, I decided to start updating the results on the cognitive ADHD profile in terms of spatial abilities. The findings collected so far in the course of project have indeed suggested that spatial abilities may play a role in accidental injuries. For example, past meta-analyses studying visuospatial working memory in individuals with ADHD, compared to peers with typical development, found a significant difference, with a poorer performance demonstrated by the ADHD group (Martinussen et al., 2005; Willcutt et al., 2005; Kasper et al., 2012). However, few other measures of visuospatial skills, other than visuospatial working memory, have been covered extensively in the literature. Hence, the aim of the work (chapter 5) was to extend this knowledge regarding spatial skills and see if the results in visuospatial working memory could be replicated, and if further research about other spatial measures could be pursued.

To summarize:

The first objective was covered in the first 3 studies, the first 2 focusing on lifespan and the third one considering the school environment, thus involving students and their parents and teachers. Different versions of a questionnaire, i.e. the Injury Proneness Questionnaire (IPQ) were presented. This custom-made instrument is inspired by the Children's Injury Related Behaviour (CIRB) questionnaire proposed by Rowe and Maughan (2009). The reason the IPQ was built was to create an instrument that could measure injury proneness across different ages and contexts. Hence, a self-report version was created, along with another one addressed to parents. Studying perceived and self-perceived injury proneness could be effective when considering individual differences and beliefs regarding injury and risk probability. Hence it is an alternative, but complementary method to the one based on objective data (e.g. injury rates), to describe injury predisposition.

The second objective was explored in the first 3 studies, in which self-report instruments such as questionnaires were presented along with objective measures considering spatial, cognitive, attentional and executive skills.

The third objective is analyzed partly in the third study (chapter 4), which is still in progress, and in the final part dealing with a meta-analysis. This research in particular summarizes the literature regarding spatial skills and ADHD, as a starting point for exploring whether spatial skills could explain injury proneness also in ADHD.

2 Chapter 1: Accidental injuries

2.1 Definition

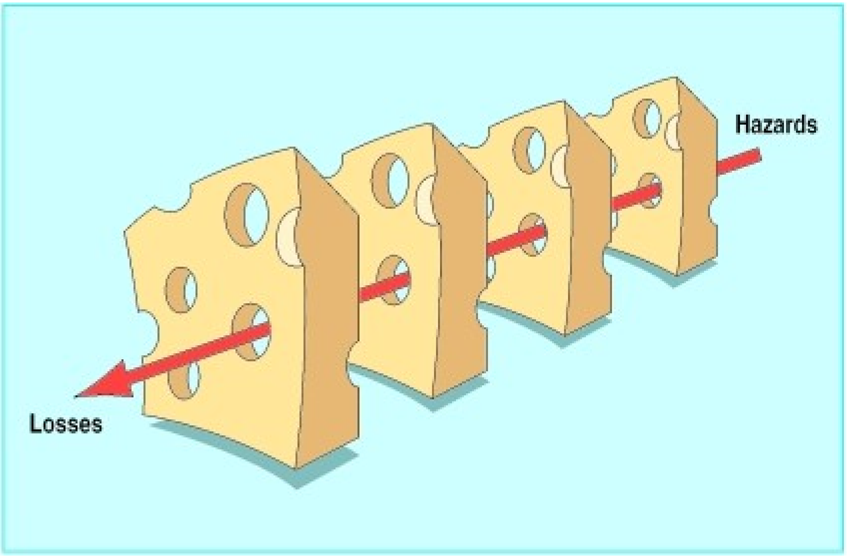
Accidental injuries, as already mentioned in the general introduction, consist in all those events which cause undesired damages to the person or people involved. It is a concept that has already been considered in the past century. Indeed, Greenwood and Woods (1919) started discussing *accident proneness* when they conducted a study about accident rates and productivity among the employees of a British weapons factory. After observing the workers for 5 weeks, they came to the conclusion that the injury rates were uneven, and that some people had a greater predisposition to get hurt, compared to others. Later on, Newbold (1926) followed up the work of Greenwood and Woods in large samples of workers from 13 factories, and noticed that a small number of workers contributed to the majority of injuries within the company. The author justified this result by stating that stable personal characteristics could have played a role; however she also argued that there was not enough evidence to confirm this finding, since it was very difficult to identify whether and how much this could have been due to individual differences in work conditions, or to general personal tendencies. Farmer and Chambers (1926) officially used the term *accident proneness* when defining a new syndrome, characterized by a greater predisposition to injuries and riskier situations in certain individuals. The results of Greenwood and Woods were taken into account and criticized by Sass and Crook (1981); the authors described some limits of the study, such as short observation periods, no clear categorization of the injury gravity and no attention to contextual variables. Nonetheless, the idea of a greater predisposition to injury in certain people was generally accepted and confirmed in the following decades, especially in the industrial and medical working fields (Burnham, 2008).

2.2 Theoretical models

Some theoretical models in injury proneness are discussed in the following section. Particularly, the first one that was mentioned, i.e. the *Health Belief Model* (HBM; Hochbaum, 1958), considered the importance of risk evaluation and tried to explain why people avoid adopting preventive measures. The main concept is that people are more likely to avoid risky conduct, which often leads to potential injuries, when they realize that the risk is plausible; consequently they modify their actions and habits. This process consists of 4 components: a first one, during which the individual perceives his/her own vulnerability, a second one, during which the gravity of the situation is perceived, a third one, characterized by the estimation of possible advantages with the avoidance of the risky situation, and a final one of obstacle perception, when the person evaluates the possible sacrifices and losses that are necessary to modify the initial conduct. To summarize, there are two main moments in the model: the first one characterized by the perception of risk and its possible threat, and a second one employed in the evaluation of counteractions and the advantages or disadvantages they could bring. When these processes are not followed, people are more likely to follow risky conduct. Risk evaluation is an important aspect for injury prevention and it is often developed starting from childhood, with the help of parental supervision. In fact, a significant correlation is present between parental supervision and injury proneness in childhood. Moreover, when parents felt confident of their own capacities of teaching risk prevention, their children had lower probability to experience injuries (Peterson et al., 1990).

The next model is based on the concept of human error, hypothesized by Reason (2000), also known as the *Swiss Cheese Model* (Figure 3).

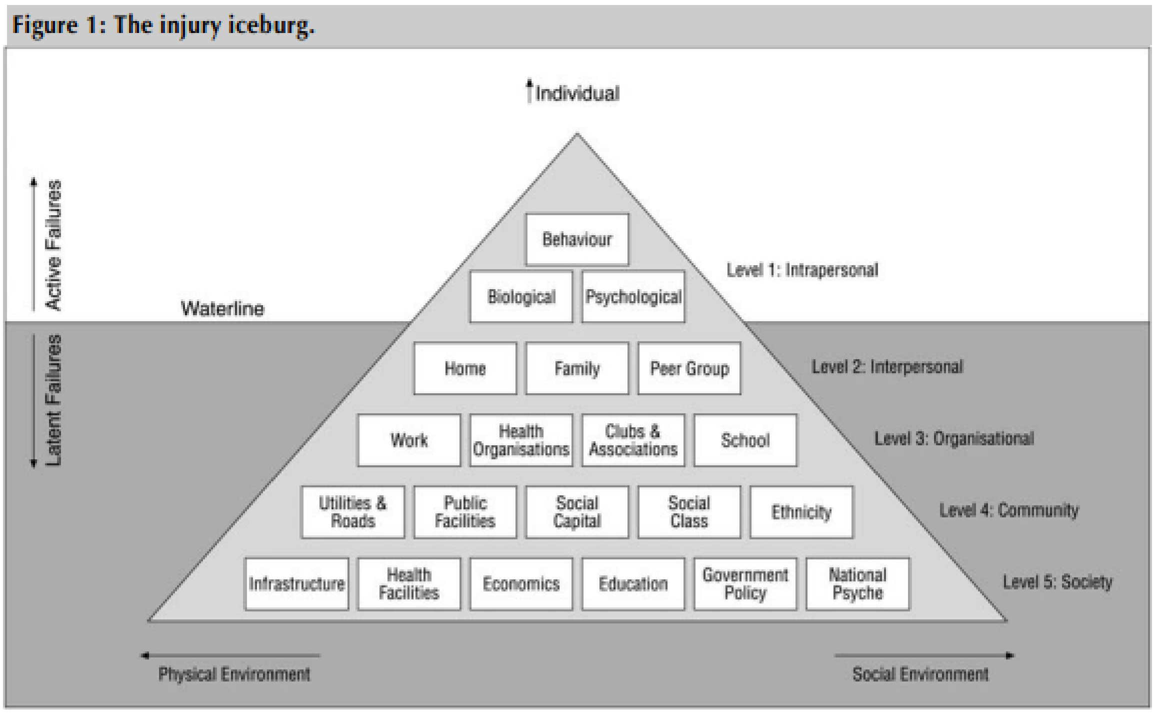
Figure 3. *Graphical representation of the Swiss Cheese Model from Reason (2000).*



The author explained that human error could be viewed in 2 ways: the person approach and the system approach. The first one refers to forgetfulness, inattention, poor motivation or negligence, and therefore all the errors committed by the individual, who ultimately gets blamed for these errors because they could have been avoided. The second approach is based on the fact that errors are inevitable despite human effort; so they are not justified by the perversity of human nature, but rather by unexplained systemic factors. Hence, this approach focuses on the individual's conditions and the possible defenses that could be applied to counteract these errors as much as possible. Considering the cheese metaphor, each slice represents a specific layer of defenses against accidents. For example, when thinking of an organization, a slice could represent safety programs for personnel or allocation resources. However, each layer has its own set of holes, or limits, which could be caused either by active failures, or latent factors beyond human error. Moreover, some slices can have more holes than others. When putting all the slices together, some holes could be covered by other layers, or in other cases holes could overlap and go through all the slices, thus allowing the accident to occur. This model illustrates the fact that errors cannot be traced to a common cause, so accidents happen when various factors are combined.

Another model that theorized the effect of multiple factors was Hansons and colleagues' *Iceberg Model* (2005, Figure 4), describing the human as an element interacting with the physical and social environment. The human is represented as the tip of the iceberg, coinciding with the visible component of a complex system, characterized by other hidden layers below the water level, which represent all the environmental and behavioral determinants of risk. Hence, the model suggests that injury risk may never decrease if we were to work on the personal level alone, i.e. the tip of the iceberg. So changes on multiple levels, from an environmental and contextual point of view, are necessary.

Figure 4. *Graphical representation of the Iceberg Model (Hanson et al., 2005).*



This model has various significant implications, especially in injury prevention interventions (Allegrante et al., 2010). For instance, it has been found that multifaceted interventions for fall injury prevention in elders have proven to be effective (Marks & Allegrante, 2004). Another example is the road context, which has proven to benefit from intervention programs promoting personal, contextual and social changes, such as educational programs, legislative policies or safe road building (Gielen & Sleet, 2003; Dellinger et al., 2008). Despite some differences, all of the models presented here highlight the heterogeneous nature of risk and injury proneness, specifying that such events are often caused by multiple factors, each playing a relevant role. The following sections will focus on some of the aspects that emerged in the course of these studies, and more specifically cognitive and individual variables related to injury proneness.

2.3 Cognitive factors associated with accidental injuries

A series of abilities within the domain of cognition, starting with intelligence, will be described. There is evidence that injury proneness is correlated with I.Q. Bonander and Jernbro (2017) found that children with lower I.Q. scores experienced more injuries; this relation was moderated by gender, with a double effect size in males compared to females. Moreover, a relationship between lower I.Q. and earlier death was identified (Deary & Der, 2005; Whalley & Deary, 2001); the authors hypothesized 4 possible explanations. The first one suggested that I.Q. tests might capture a first red flag by showing problematic cognitive skills associated with the incoming illness. Another reason could be that people with a higher I.Q. tend to adopt healthier habits in life (e.g. avoidance of smoking, alcohol or drug use), and are more likely to stop risky behaviors as soon as they become aware of potential dangers. The third motive suggested that people with a higher I.Q. are more likely to have higher occupational positions; consequently, it is also possible that they are less at risk because these environments ensure greater safety than others. The final explanation hypothesized that I.Q. tests are predictive of premature death because they evaluate some aspects of bodily integrity, such as information processing (often measured through reaction times).

Another relevant aspect of cognition lies in spatial skills. First of all, there are different kinds of spatial skills, each evaluating a specific aspect of spatial cognition. Some abilities imply spatial memory processes or nonverbal intelligence, whereas others involve high-order skills. Linn and Petersen (1985) proposed a classification of these spatial skills, such as mental rotation (i.e. the ability to mentally rotate and manipulate objects), spatial perception (the ability to imagine certain elements from different perspectives) or spatial visualization (the ability to manipulate spatial stimuli). However, these abilities are small-scale; indeed spatial skills cover other aspects, such as navigation, route and landmark knowledge, all of which are categorized as large-scale abilities (Hegarty et al., 2006). Further details about the distinctions and characteristics of these spatial abilities will be discussed in chapter 5 when describing the meta-analysis, which examines spatial skills across a population with typical and atypical development, in this case Attention Deficit Hyperactivity Disorder (ADHD). The meta-analysis was created with the purpose of exploring spatial skills in a clinical population that has demonstrated significant injury proneness; indeed there is some evidence of the influence of spatial skills in injury proneness. One study in particular (Voyer & Voyer, 2015) focused on spatial skills, such as navigation with the Santa Barbara Sense of Direction Scale (SBSOD; Hegarty et al., 2002) and mental rotation, demonstrating that people who manifested more efficient navigational and mental rotation skills were also those who experienced more injuries. Moreover, the effect of gender was significant, with males feeling more confident of their spatial abilities and more prone towards exploration and riskier conduct. On the contrary, women participants felt uncomfortable and less confident about their skills; as a result, they would also avoid riskier situations, thus explaining their more limited experience of injuries. Motor coordination is another significant element that is often mentioned together with spatial skills, suggesting that they are linked to one another. Wilson and Mckenzie (1998) analyzed information processing deficits in children with motor coordination deficits with a meta-analytical research. The authors found that lower motor coordination was more likely associated with a greater risk of injuries, and hypothesized in their paper that this could be because the poor processing of visuospatial information could impair motor coordination and consequently increase the risk of injuries. Other evidence confirmed the results of Wilson and Mckenzie (1998); however, there is also a line of research with contrasting results, at least when considering children and youths. When testing children, Schwebel and colleagues (2003) found no significant correlation between motor coordination skills and injury tendency. This could mean that individuals with good motor coordination, and therefore athletic skills, could be more predisposed because they are exposed to riskier situations more often or because they feel overconfident about their skills Indeed, athletes of different ages and various sports are known to be at risk of injuries, due to both physical and psychological factors (Taimela et al., 1990). For such a reason, a growing research body and more prevention programs, addressed to athletes and coaches, are carried out to contrast injury risk.

The next factor to be discussed is attention, defined by James (1890) as when the mind takes possession of a certain object or thought, even simultaneously. This process implies withdrawal from some elements in order to deal more effectively with others. It is a basic function present since birth which allows us to focus on certain information in order to create memories. There are different kinds of attention. The first one mentioned is sustained attention, i.e. the ability to concentrate on one stimulus over an extended period of time (Ko et al., 2017). Instead, alternate attention involves more than one stimulus, and attention is shifted towards two or more stimuli with different cognitive demands (Hennawy et al., 2019). Selective attention is the ability to filter only relevant stimuli (Stevens & Balivier, 2012). Limited attention, on the contrary of alternate attention, requires multitasking, and hence an effective division of attentional resources among multiple at the same time, considering that attention is a limited resource (Srna et al., 2018). In the present work, inhibitory control will be analyzed by applying the Go/No-go task (chapters 3 and 4). Generally, inhibition, is referred as the ability to ignore irrelevant and interfering stimuli (Garavan et al., 1999). Indeed, this kind of task requires the participant to only respond to a certain type of stimuli while ignoring irrelevant ones.. Different kinds of errors can be committed with the Go/No-go test when inhibition is not efficiently controlled: false alarms (or commission errors), which occur when answering an irrelevant stimulus, or omission, which is the lack of signal in response to a relevant stimulus. The Go/No-go task has provided significant results in research. For example, it emerged that poor performance in the Go/No-go task was associated with risk taking tendencies and problematic driving among young drivers (O'Brien & Gormley, 2013). The results from the study illustrated a significant difference in the Go/No-go task between adolescents and young adults with a history of speeding when driving (who have been caught by the police) and those without a history of speeding. The offender group would answer the relevant stimuli more quickly than the control group but they would also commit more false alarms, hence sacrificing accuracy for the sake of speed and demonstrating lower inhibition skills.

Evidence regarding the relation between injuries and executive functions was identified. A first definition of executive functions was provided by Lezak (1983), who described them as cognitive activities that allow the individual to act in an independent, adaptive and finalized manner in order to complete a specific task or solve a problem. They have also been defined as a series of high-order cortical activities, like planning behaviors for certain objectives, attention monitoring and organization (Anderson, 1998). These activities, which are already present in childhood, involve the prefrontal cortex and continue to develop until adulthood; moreover, executive functions have different characteristics (Zelazo & Carlson, 2012). In fact, the authors mentioned a distinction between "hot" and "cool" executive functions. The first category is related to the emotional dimension, including all the processes that promote emotion regulation, whereas the second one is associated with more cognitive and procedural processes, such as memory or inhibition. Executive functions significantly determine injury proneness, even during childhood (Shen et al., 2021): a weaker mastery of executive functions was correlated with greater injury proneness and injury-related risky behaviors. On the contrary, good executive functions (both hot and cool) were a protective factor against injury tendency, regardless of participants' age. Poor executive functions also have a significant impact on pedestrian (Barton & Morrongiello, 2011) and cyclist safety (Plumert & Kearney, 2014). This predisposition is often seen in children and adolescents, and it can be explained by the possible discrepancy between executive skills, which are still unripe during youth, and motor skills, which are much more developed. Thus, a poor synergy between planning and consequent actions could be the cause.

This final section summarizes decision making and related aspects, such as biases; indeed, there is data considering the relevance of biases, which eventually influence decision making. The classical availability heuristic of Tversky & Kahneman (1973) well explains the perception people have about danger probability; for instance, people tend to judge a phenomenon as more frequent than another if the former is easier to imagine than the latter. This explains why people consider themselves to be immune to danger from situations they have never experienced up close, compared to others they have more knowledge and memory about (Slovic et al., 1985). Another bias that influences beliefs regarding injury predisposition, consists in cognitive dissonance (Adhikari, 2015). As the theory suggests (Festinger, 1957), people tend to act differently than expected and contradict themselves, thus creating a dissonance between themselves and the situation; when such dissonance is created, mechanisms to reduce it, such as rationalization, are applied. For example, despite the presence of a possible risk, individuals might deny all the objective evidence about the risk in order to feel more assured about their own coping skills, thus rationalizing the issue. Biases and framing methods can potentially influence risk estimation and decision: a classical task that evaluates executive functions and decision making is the Iowa Gambling Task (IGT). It is interesting to note that risky decision making is a different process compared to physical risk taking; one study in particular used a children's version of the IGT in relation to measures of sensation seeking and risk taking (Morrongiello et al., 2009). More specifically, the authors noticed that sensation seeking tendencies, measured with a self-report questionnaire (The Sensation Seeking Scale for Children, Morrongiello & Lasenby, 2006) correlated positively with physical risk taking but not with risky decisions in the IGT. This finding supports the idea that physical risk and risky decisions seem to be independent from one another, at least in children. Another work focused on adolescents and adults (Overman et al., 2004), and specifically verified performance in the same kind of task. In this case as well, aspects such as self-reported sensation seeking, substance abuse or impulsivity did not correlate with the IGT. Despite the compelling results described previously, further evidence is necessary to confirm these possible relations. A computerized version of the IGT was also employed in this project, with the purpose of verifying the presence of a relationship between decision making and injury proneness; the methodology and results attained using this instrument will be described in detail in chapter 4.

2.4 Individual differences and accidental injuries

Some variables describing individual differences, such as age, gender and cognitive failures, will be discussed in relation to their effect on injury proneness.

Age is a relevant aspect in many studies dealing with injury proneness, and explaining the frequency and type of injury. Such predisposition is often explored through objective data, such as accident, hospitalization and mortality rates. On the basis of these demographic details, injury proneness has been calculated by means of probability indexes, such as the Accidental-Injury Proneness Index described in the previous chapter (AIPI; Camarero, 2021). According to the AIPI, injury predisposition in relation to age is characterized by a “J”-shaped trajectory, with a slight decrease of injury predisposition in early adulthood, followed by a slight increase during middle age and an exponential increase after 60 years of age. When considering the type of injury, age remains an influential factor; some injuries are indeed more frequent in certain periods of life compared to others. One of the most studied causes of injuries consists in falls, which occur more frequently during seniority (Ambrose et al., 2013). This phenomenon could be explained by the fact that cognitive, motor and spatial skills decrease with age, thus causing a greater risk of falls (Martin et al., 2009). Moreover, social factors could influence fall injuries and hospitalization (Neudorf et al., 2010). It has been observed that the neighborhood of origin of children and youths did not affect hospitalization rates, while lower socio-economic status in elders explained a higher hospitalization rate.

Regarding gender, most studies point out a greater predisposition in males to get hurt. In the European context alone, males reported more injuries than females and showed a twofold probability to get hurt (Assailly, 1997). This predisposition seems to already be present in childhood and adolescence (Mattila et al., 2004) as well as in adulthood, especially in the working environment (Abegglen et al., 2017). There are also gender differences in rehabilitation times. For instance, Abegglen and colleagues (2017) found that males declared, with self-report instruments, that they took longer to recuperate after injuries; the results showed that being female was predictive of fewer days of working disability. Men tend to be more at risk of also encountering injuries in their later years, according to the records analyzed by Wolf and Rivara (1992), stating that they are 2.5 times more likely to get seriously hurt than women at 65 years of age and later on. On the other hand, females encounter some risks as well. Indeed, a greater predisposition in females towards injuries was found when studying genetic correlates (Rowe et al., 2007); injury proneness (evaluated by parents) was found to be hereditary and stronger in monozygotic twins, thus explaining proneness, which figured significantly in girls compared to boys. Moreover, socio-economic factors play a critical role according to Stevens and colleagues (2006): medical expenses increase with age, particularly with females (which comprise 58% of the older adult population), who deal with frequent injuries and increasingly expensive medical treatments regardless of the medical treatment setting. Despite some different findings in the literature, it seems that males are generally more at risk and get hurt more frequently during adolescence and adult life, whereas females are at greater risk during their seniority. Furthermore, gender has played the role of moderator when considering spatial skills (Voyer & Voyer, 2015) and intellectual level (Bonander & Jernbro, 2017). Different reasons were suggested by the literature. A first one states that the social context is what encourages males to partake in risky situations that lead to injuries, such as outdoor activities (Schwebel & Gaines, 2007). A second reason (Morrongiello & Rennie, 1998) focuses on personal beliefs regarding injury and risk taking during childhood. Based on the results collected by the authors, it emerged that boys would dismiss their injury experiences as unfortunate events they could not control and predict; they were also more likely to commit them again. On the contrary, females justified their injuries as a consequence of their errors, and therefore put more effort into avoiding similar situations later on. A third reason is based on parenting styles and beliefs (Morrongiello & Dawber, 2000): when boys were involved in risky situations, parents would intervene less frequently or later than with girls. So, parents indirectly encouraged boys to carry on with the activities, while girls were treated with more caution. Another element often associated with the male gender and responsible for injuries is sensation seeking, characterized by a stronger predisposition to incur injuries with higher levels of sensation seeking behavior (Zuckerman, 2007; Flynn, Slovic & Mertz, 1994).

A consistent research body studied the effect of cognitive failures, i.e. cognitive errors that occur when carrying out routinary actions that should have been concluded without any issues (Wallace et al., 2002). An example of cognitive failure could consist in entering a familiar room and forgetting the reason we entered this room. These kinds of failures are more likely to happen in moments of anxiety, boredom or when multitasking (Robertson et al., 1997). An instrument used to measure the frequency and pervasivity of this phenomenon is the Cognitive Failures Questionnaire (Broadbent et al., 1982) that addresses different episodes of possible cognitive failures in daily life. An Italian adaptation of the questionnaire (De Beni et al., 2008) was used in the present project as well; further details will be discussed in chapters 2 and 3. The reason why cognitive failures are worth mentioning is their relevance in injury proneness. In fact, a significant correlation between the amount of cognitive failures and injury rates was found. Furthermore, the people who were more at risk of getting injured were those who were involved in professions in which cognitive failures were more likely to happen and significantly impair job performance, such as freelancers or workers with frequent night shifts (Simpson et al., 2005; Allahyari et al., 2014).

2.5 Accidental injuries in the clinical population

Another risk factor for injury probability is the presence of psychopathologies, for example anxiety (Rowe et al., 2007), or depression (Rowe et al., 2004). As anticipated in the previous paragraphs, ADHD is a clinical population that has demonstrated a strong predisposition to injuries compared to other people (Brunkorst-Kanaan et al., 2021). This predisposition is mainly due to the characteristics of the ADHD profile *per se*, such as the presence of inattention and hyperactivity symptoms, aspects which are crucial in vigilance and danger estimation. Furthermore, the risk of injuries is amplified when individuals with ADHD present comorbidities (Brunkhorst-Kanaan et al., 2021), those usually being Oppositional Defiant Disorder (ODD), Conduct Disorder (CD) or Developmental Coordination Disorder (DCD). An ulterior element that often plays against people with ADHD is their perception of dangers and their own abilities to overcome them. Indeed, they are more prone to be affected by a Positive Illusory Bias, which leads them to underestimate potential dangers because they overestimate their abilities (Farmer & Peterson, 1995; Bruce et al., 2009). A practical example of this bias could be the erroneous belief people with ADHD have about their vigilance capacities when driving, even after drinking or under conditions that could influence their cognitive faculties.

3. Chapter 2: How to measure accidental injuries: adaptation of a questionnaire to the Italian context

As stated in the previous chapter, accidental injuries are quite common events in daily life, to a certain degree. They are defined as accidental when they happen unexpectedly, often as a consequence of falls, burnings, drowning or vehicle collision. Furthermore, injuries could occur in different contexts such as work (Abegglen et al., 2017), sports (Ristolainen et al., 2019), and traveling (Steffen, 1991) on the road (Aduen et al., 2020) or at home (Gudnadottir et al., 2018). The present work focused on the individual characteristics that could influence such proneness, particularly age and gender. Studying the characteristics of accidental injuries could be beneficial for health-promoting purposes and the prevention of conduct that could lead to potentially risky situations causing serious injuries or death. Indeed, injuries are a common cause of death: it is known to be the third main cause of death in the USA (CDC; 2020), and it accounts for 3.2% of total mortality in Europe (Eurostat, 2020). According to De Ramirez and colleagues (2012), the most common causes of injury are: poisoning, drowning, fires and road accidents. Other causes, such as overexertion, stabbings, and the most frequent, i.e. falls (Dellinger & Stevens, 2006; Tinetti et al., 1988) were also studied. Considering the relevance of accidental injuries for individual and social health, the objective of the first study was to devise a measure for assessing accidental injuries. Before presenting the questionnaire that was used in the current study, a brief review of the literature dealing with measures for accidental injuries is provided.

3.1 How accidental injuries are measured in the literature

Before delving further into the next part covering the description of the questionnaires, a premise is necessary. Injury proneness has often been measured in an objective manner, calculating injury probability indexes on the basis of statistical data (e.g. accident or mortality rates), as seen previously with the AIPI (Camarero, 2021). Nonetheless, other measures for injury proneness are present in the literature. Some of these are still based on objective data, such as accident reports, which are often used to discover the number of episodes that caused accidental injuries. Accident reports can be addressed to participants or they can require an external observer's point of view, usually that of parents when the participants in question are particularly young. An example is the *Unintentional injury history* survey (Plumert, 1995; Schwebel & Plumert, 1999) which is addressed to parents and requires them to express the number of times their child experienced certain kinds of injuries in their life, such as burns, cuts, bruises, broken bones and other categories of listed injuries. A different method was applied by Tang and colleagues (2021) when they examined traffic violations and the behaviors of electric bike riders. Among other variables, accident proneness was explored in a self-report methodology with 2 questions: the first being the number of times they suffered from e-bike-related accidents (from "None = 1" to "More than three times = 5), and the second asking to rate the most severe episode (from "No crash = 1" to "Serious e-bike damage and serious injuries = 5") by means of a Likert scale. Hence, in this particular study, objective (first question) and subjective, self-perceived information (second question) was gathered. What makes this previously mentioned study (Tang et al., 2021) interesting is the fact that it is one of the few examples of studies that use some sort of self-perceived modality when evaluating injuries, at least to our knowledge. Indeed, there are few measures that estimate injury predisposition with Likert scales without requesting exclusively numerical data of some sort. In the present chapter, some of the best known measures estimating injury proneness are introduced, i.e. the Children's Injury Related Behaviour Questionnaire (CIRB; Rowe & Maughan, 2009) and the Injury Behavior Checklist (Speltz et al., 1990); both of these examine injury tendencies in children by asking the parents' point of view with Likert scales. The objective of this study, in particular, was to provide a new self-report measure of self-perceived injury proneness, called the Injury Proneness Questionnaire (IPQ). The questionnaire was also adapted and applied in the studies that follow (chapters 3 and 4). Further details are provided in the following paragraphs.

3.1.1 The Children's Injury Related Behaviour questionnaire (CIRB; Rowe & Maughan, 2009). The present questionnaire was the main reference that was used when creating the Injury Proneness Questionnaire (IPQ), since it gathers a series of items evaluating different aspects of injury proneness. The CIRB questionnaire is an instrument addressed to parents, who rate how often each of the dangerous scenario that are described in the items, have happened to their children. The instrument was designed as a prevention measure against injury proneness by rating and classifying eventual precursors to accidental injuries. The authors considered the distinction between injuries caused by errors and those caused by violations, as hypothesized by Reason's theory (1990). Errors are described as elements that impair the correct execution of certain activities and are often unplanned. On the contrary, violations are intentional deviations from a certain activity. For example, events of clumsiness could be considered errors, while risky conduct could be associated with violations. Hence, the CIRB questionnaire was built considering these 2 plausible factors. In their study, Rowe and Maughan involved a sample of children between 4 and 11 years of age and their parents. Furthermore, the CIRB questionnaire was administered with other measures, such as the Injury History Questionnaire (created ad hoc by Morrongiello) addressed to parents and evaluating the frequency of certain kinds of injuries experienced by children, and the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) measuring eventual emotional or behavioral issues that had occurred in the previous 6 months. Results confirmed the presence of 2 main factors in the CIRB, representing items regarding errors and those regarding violations. This finding confirmed the distinct nature of errors and violations, as suggested by Reason (1990), meaning that both contribute separately to injury predisposition. The factors correlated with one another, as well as with injury predisposition, conduct and hyperactivity issues, whereas emotional issues correlated only with the violations factor.

3.1.2 The Injury Behavior Checklist (IBC; Speltz et al., 1990). The present instrument is another measure used for identifying potential precursors of injuries. A series of risky events or accidents are described, and the parent rates how often such events have happened to their child within the last 6 months, following a 5-point Likert scale. A higher score in the IBC corresponds to a higher risk of injuries; generally, a total score above 48 indicates high risk of encountering injuries. The measure is often used with preschoolers although it is still a valid instrument with older children (Cotney et al., 2009), generally up to 9 years of age (Potts et al., 1997). The IBC is composed of one factor and has demonstrated good internal consistency (α = 0.92; Potts et al., 1997). The main types of injuries that could be caused by the scenarios listed in the questionnaire are head traumas, bone fractures, muscular injuries, cuts or bites, burns, poisoning or electrocution. The IBC is often used in studies dealing with children with typical development, but it has been also applied in studies with the clinical population. Specifically, the home safety measures adopted by the mothers of children with Intellectual Disability (ID) and Autism Spectrum Disorder (ASD) positively correlated with the IBC score (Yıldırım Sarı et al., 2016). Home safety measures were considered by the authors using a checklist, including a series of 36 possible safety measures. The mothers would select all the measures they used, so a higher score in the checklist meant that a greater amount of safety measures had been adopted at home. This finding seems to suggest that the mothers of children who manifested greater risk of injuries, would try to contrast this predisposition as best as possible with a greater series of home safety measures.

3.2 Adaptation of a questionnaire to the Italian population

3.2.1 Objectives. In light of the gathered evidence, the first objective was to devise a measure of self-perceived injury proneness. Following the literature, a questionnaire was devised to measure injury tendency in daily life. The main questions that were addressed with the new instrument were:

- how did people answer in the IPQ, and what could the main structure of the instrument be. In this case, exploratory factor analyses were carried out in order to identify the most significant items of the questionnaire and the factors related to them;
- what the role of age and gender was, especially in injury proneness measured by participants. More specifically, the intent was to see if and how age and gender could explain differences in injury proneness;
- what the role of other factors, such as motor coordination, cognitive failures, self-perceived navigation abilities or injury history (frequency of mild injuries and times at the emergency room) was.

As reviewed in the previous chapter, age and gender are commonly analyzed in relation to injuries proneness. Injury risk seems to be greater in certain periods of life, such as adolescence and late adulthood, at least when considering objective data as a reference (Camarero, 2021), while very little is known about self-perceived injury risk. Considering the literature, gender differences are supposed to emerge in this study, with a greater predisposition in men to get hurt. Cognitive failures (Wadsworth et al., 2003) and poor motor coordination skills (Wilson & Mckenzie, 1998) are considered a risk factor in injury predisposition. Spatial skills have been explored to a lesser extent than other variables, nonetheless a past study (Voyer & Voyer, 2015) demonstrated that people with greater self-reported navigation abilities and mental rotation were more prone to injuries. In this chapter, a specific domain of spatial skills, i.e. self-perceived navigation, with the Sense of Direction and Spatial Representation questionnaire (SDSR; Pazzaglia et al., 2000; Pazzaglia &

Meneghetti, 2017) was evaluated. And finally, objective data such as injury history, was introduced to verify the correspondence between self-perceived and objective information.

3.2.2 Methods

3.2.2.1 Participants. A total of 468 participants across the lifespan, i.e. from 14 to 86 years of age, volunteered to participate in this research. Since the sample was characterized by significant heterogeneity, age ranges were set in order to better analyze certain specific aspects for each generation (see Table 1 for details regarding sample size). The minimum sample acceptable for conducting an exploratory factor analysis (EFA) was hypothesized. According to Hair and colleagues (2010) a sufficient sample size should include a number of observations equal to 5 times the number of observed variables. For a more adequate sample size ,the number of observations should be equal 10 times. In this case, the questionnaire analyzed with the EFA was composed of 36 items, therefore a sample of at least 360 participants was considered adequate enough. The inclusion criteria for participant enrollment were: sufficient knowledge of the Italian language, and the possession of a computer and stable internet connection. Exclusion criteria consisted in: a history of psychiatric or neurological diseases, or diseases capable of causing cognitive, visual, auditory and/or motor impairments (Crook et al., 1986), and, in the case of older participants, a score below 9 in the short version of the Italian Checklist for the Multidimensional Assessment of the elderly (SVAMA, Gallina et al., 2006) to rule out individuals with cognitive impairment. Four participants were excluded from these analyses because they reported taking medicine for anxiety or depressive disorders. As a result, 464 participants were included in the definitive research (age M = 46.21, SD = 18.56; males = 223, females = 241) with an educational level of M = 12.10, SD = 5.64 years. All participants were tested from January 2021 to September 2021, and were recruited through word of mouth and personal connections. The Ethical Committee for Psychological

Research at the University of Padova approved the study (number: 3870). All participants were informed of the purposes of the study and gave their informed consent in accordance with the Declaration of Helsinki (World Medical Association, 2013). Informed consent was gathered before the experiment, and minors provided the signed consent of their parents (or guardians).

Table 1. *Sample size (n), age and years of education (mean and standard deviation) for each age group*

	Age range						
	14-19 years	**20-29 years**	**30-39 years**	**40-49 years**	**50-59 years**	**60-69 years**	**≥ 70 years**
(n) males	26	29	32	32	40	41	23
(n) females	26	26	36	36	48	44	25
(n) total sample	52	55	68	68	88	85	48
Age M(SD)	17.30 (1.40)	25.10 (2.56)	33.10 (3.07)	44.80 (2.89)	54.20 (2.76)	63.90 (2.63)	76.40 (4.72)
Education M(SD)	16.00 (3.03)	15.40 (2.09)	16.30 (2.36)	15.40 (2.69)	16.00 (2.72)	15.80 (2.75)	12.20 (5.64)

3.2.2.2. Materials

3.2.2.21 Injury Proneness Questionnaire (IPQ). The following questionnaire was inspired by the CIRB Questionnaire (Children's Injury Related Behaviour; Rowe & Maughan, 2009), which was directly translated from English to Italian by a native speaker. The current version used for this research contains fewer items than the original one and includes questions that are suitable for the general population, regardless of age, gender or parenthood. Indeed, the excluded items were either too generic or they evaluated specific situations in childhood, hence not addressable to adolescents or adults in general. Therefore, the questionnaire was reduced to 36 total items, by removing the following ones:

- "being unable to name a familiar person, place or object";
- "being picked for a ball-sports team";
- "taking risks";

- “putting fingers/objects into electrical sockets”;
- “paying particular attention to water-related hazards”.

People self-report their injury proneness in different daily situations, by means of a Likert scale (from “never = 0” to “very often = 4”), with a total from 0 to 144. The Score will be analyzed following a factor analysis structure of the questionnaire. However, considering all the items, the total score is given by the sum of points in each item; therefore the greater the total score, the greater the severity of the injury. Some questions evaluate good skills or safety conducts (e.g. “I avoid hazardous objects” or “I am careful when I am around animals I am not familiar with”), hence the given scores should be flipped, before calculating the total score in the questionnaire. In this study, scores in items: 13, 26, 27, 28, 35 and 36 were flipped before carrying on with the analyses.

3.2.2.2.2 Demographic information (adaptation of De Beni et al., 2008). At first, basic information about each participant, such as age, gender, years of education and medical history (past or current diagnoses and eventual medicine intake) was collected. Some of these questions required a written answer (e.g. type of school or university the person attended or type of medicine that are being taken) while others were multiple choice questions (e.g. type of current occupational status).

3.2.2.2.3 Injury history. Participants report the number of episodes they had in the emergency room, ranging from 0 to more than 6 times. In another question they self-rate the frequency of lighter injuries in daily life with a Likert scale (from “almost never = 1” to “very often = 4”). These questions were treated independently, and therefore never summed up.

3.2.2.2.4 Motor coordination. This part includes 4 questions evaluating agreement level and the self-rating of motor coordination skills. More specifically, each question focuses on: balance, distance estimation, fine-motor movements and rhythm. Each question is rated with a Likert scale, from "never true = 1" to "always true = 4". The total score in this section goes from 4 to 16, with a higher score indicating a larger issue in motor coordination.

3.2.2.2.5 Cognitive failures . The Cognitive Failures Questionnaire (CFQ) introduced by Broadbent and colleagues (1982), in its Italian adaptation (De Beni et al., 2008) was used to assess the frequency of self-rated cognitive failures in daily life. The questions mainly address episodes of clumsiness and forgetfulness (e.g. "Do you happen to forget the reason why you entered a certain room?") for a total of 25 items to be rated with a Likert scale (from "never = 0" to "very often = 4"). The total score ranges from 0 to 100.

3.2.2.2.6 Self-reported navigation abilities. The Sense of Direction and Spatial Representation scale (SDSR; Pazzaglia et al., 2000; Pazzaglia & Meneghetti, 2017) was used to evaluate participants' sense of direction, visuospatial representation and knowledge of cardinal points. Ratings are made by expressing a level of agreement for each sentence, according to a Likert scale (from "not at all = 1" to "very much = 5"), with a total score ranging from 16 to 80. For example, one question states "When you are outside/in a natural environment (in the countryside, mountains, or by the sea) do you spontaneously look for the cardinal points, that is north, south, west and east?". For this research, the total score in the questionnaire was considered by adding the scores in each item.

3.2.2.3 Procedure. The whole experiment was carried out online, with each participant individually. The experimenter guided and provided instructions through the Zoom platform throughout the whole experiment (two sessions were carried out on two different days: the first one lasting about one hour and the second one around 45-50 minutes). During the first session the participant would complete the SVAMA checklist (verbally), the introductory questionnaire, the Injury history questionnaire, the Dysfunctional motor coordination questionnaire and the IPQ Questionnaire through the Qualtrics platform, in fixed order. The second session included the Cognitive Failures questionnaire and the Sense of Direction questionnaire. Apart from the measures considered here, participants also completed other measures at the end that are not presented or analyzed here, as they are beyond the scope of the present research.

3.2.3 Results

3.2.3.1 Data analysis. Firstly, descriptive statistics of all questionnaires were conducted, followed by specific item per item statistics of the IPQ. Secondly, after a parallel analysis method of extraction, a methodology which has proven to efficiently identify the number of factors to retain (Glorfeld, 1995), an exploratory factor analysis (EFA) was carried out. Then, the quality of items was assessed: those that did not load adequately (< 0.40; Comrey & Lee, 2013; Ford et al., 1986; Hair et al., 2010) were excluded before re-running the EFA analysis. Thirdly, the effect of age and gender on the IPQ was evaluated, considering a series of regression models. Finally, correlations with the variables from other questionnaires (i.e. number of episodes at the emergency room, mild injuries frequency, motor coordination, cognitive failure and navigation abilities) in relation to the IPQ, were calculated.

The analyses were carried out by means of the “psych” (Revelle, 2022) and “lavaan” (Rosseel et al., 2022) packages of the R software (RStudio Team, 2022).

3.2.3.2 Descriptive statistics **.**Mean scores in the main tests and questionnaires were carried out considering gender, age decades and totals. See (Table 2)

Table 2. *Mean and standard deviation for each age group regarding: number of episodes in the emergency room (E.R.), frequency of mild injuries in daily life, motor coordination, Injury Proneness Questionnaire (IPQ), Cognitive Failures Questionnaire (CFQ) and the Sense of Direction and Spatial Representation scale (SDSR).*

	Age ranges							
Questionnaire	**14-19 years**	**20-29 years**	**30-39 years**	**40-49 years**	**50-59 years**	**60-69 years**	**70-79 years**	**Total sample**
Number of episodes at the E.R.	1.69 (1.46)	1.82 (1.84)	1.91 (1.87)	1.87 (1.73)	1.86 (1.92)	2.19 (2.06)	1.31 (1.27)	1.84 (1.80)
Mild injuries frequency	2.27 (0.74)	2.36 (0.80)	2.21 (0.76)	1.99 (0.50)	2.09 (0.70)	1.94 (0.58)	1.75 (0.73)	2.08 (0.71)
Motor coordination	5.58 (1.14)	5.82 (1.35)	5.47 (1.35)	5.16 (1.36)	5.05 (1.29)	4.99 (1.16)	5.08 (1.33)	5.27 (1.31)
IPQ Total	44.80 (13.10)	40.30 (14.70)	37.10 (13.00)	34.20 (12.00)	31.90 (11.20)	28.10 (11.40)	24.00 (10.00)	33.93 (13.55)
CFQ Total	40.80 (10.70)	45.00 (12.40)	41.10 (8.72)	36.70 (10.40)	34.90 (12.80)	30.20 (12.00)	29.30 (12.70)	36.52 (12.86)
SDSR Total	41.80 (6.44)	39.70 (8.83)	41.10 (8.72)	40.60 (8.78)	41.30 (8.79)	42.20 (8.29)	41.20 (8.28)	41.18 (8.39)

Initial descriptive values for the IPQ questionnaire were calculated, in particular item-rest correlations, mean values and standard deviations for each item, before carrying out with the EFA (Table 3)The questionnaire demonstrated good internal consistency with Cronbach's $\alpha = 0.86$ and the data was normally distributed according to the Shapiro-Wilk normality test ($p > 0.05$).

Table 3. *Frequentist Individual Item Reliability Statistics, including correlations, mean and standard deviations (sd).*

Item	Item-rest correlation	mean	sd
IPQ1	0.52	1.11	0.89
IPQ2	0.53	0.69	0.75
IPQ3	0.44	0.98	0.83
IPQ4	0.36	1.26	0.89
IPQ5	0.19	1.70	1.15
IPQ6	0.46	0.96	0.86
IPQ7	0.36	1.44	0.90
IPQ8	0.42	1.28	0.87
IPQ9	0.51	1.52	0.95
IPQ10	0.29	0.72	0.77
IPQ11	0.47	0.78	0.75
IPQ12	0.46	1.27	0.89
IPQ13	-0.004	1.11	1.03
IPQ14	0.37	0.98	0.83
IPQ15	0.36	0.89	0.71
IPQ16	0.49	0.73	0.89
IPQ17	0.47	0.55	0.83
IPQ18	0.47	1.07	1.20
IPQ19	0.48	1.11	1.12
IPQ20	0.51	1.33	0.89
IPQ21	0.43	0.36	0.62
IPQ22	0.47	0.56	0.77
IPQ23	0.41	1.28	0.96
IPQ24	0.37	0.90	0.93
IPQ25	0.20	1.16	1.23
IPQ26	0.22	1.06	1.13
IPQ27	0.28	1.45	0.87
IPQ28	0.38	0.99	0.91
IPQ29	0.34	0.77	0.89
IPQ30	0.42	0.40	0.80

IPQ31	0.24	0.36	0.77
IPQ32	0.32	0.44	0.77
IPQ33	0.27	0.33	0.62
IPQ34	0.09	0.45	0.90
IPQ35	0.27	0.69	0.98
IPQ36	0.33	1.12	1.06

3.2.3.3 Factorial analyses. Before conducting the EFA, factor adequacy was measured following Kaiser's (1974) guidelines. A suggested cutoff for determining factorability of the data was Kaiser-Meyer-Olkin (KMO) = 0.60. The present data demonstrated total KMO = 0.87; therefore, according to this test, it was plausible to conduct a factor analysis.

After verifying the appropriate number of factors to extract by performing parallel analyses and minimizing the squared residuals ("fa.parallel" function, method= "minres"), 3 components emerged. (Table 4, Appendix A). Promax rotation was applied for each model and fit indices were considered: the comparative fit index (CFI), the Tucker Lewis Index (TLI), the Bayesian Information Criterion (BIC), the standardized root mean squared residual (SRMR) and the root mean square error of approximation (RMSEA).

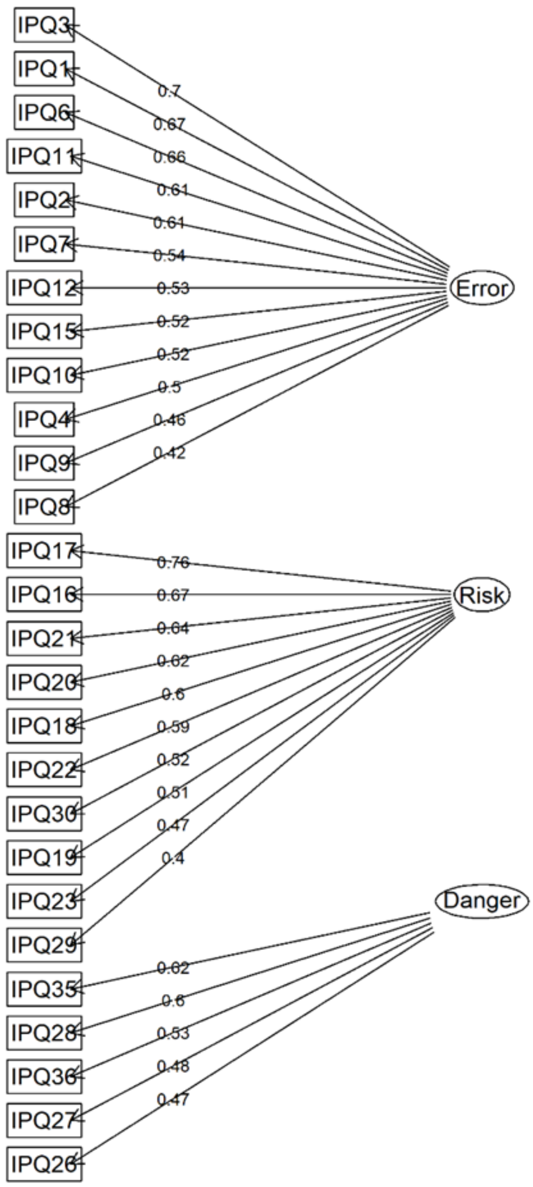
The factor analysis explained 30% of the overall variance. The first component explained 13% of the total variance, corresponding to 43% of the relative amount of explained variance. The second component explained 12% of the variance, corresponding to 42% of the relative amount of explained variance. The third factor explained 5% of the total variance, which corresponded to 15% of the relative amount of explained variance.

The second component showed the highest positive correlations with the first (0.32) and third (0.28) components respectively, whereas the correlation between the first and third component was (0.18). The root mean square of the residuals was RMSR = 0.05, with $\chi 2 = 1236.45$ ($p < 0.001$) and the root mean square error of approximation was RMSEA = 0.05 [90% CI: 0.05, 0.05]. However, the Tucker Lewis Index was barely acceptable, with TLI = 0.82. The model had BIC = -2079.27. Factor loadings with saturation below or equal 0.40 were excluded from further analyses, a procedure recommended by the literature as well (e.g. Comrey & Lee, 2013; Ford et al., 1986). Nine items featured this characteristic, and more specifically:

- item 5: “I carry out actions automatically, without being told”;
- item 13: “I can catch a ball that gets tossed towards me”;
- item 14: “I forget to bring necessary objects for the day (e.g. cellphone, notebook, house keys)”;
- item 24: “I run knowing that I should walk”;
- item 25: “I write in an unreadable manner”;
- item 31: “I tease animals I’m not familiar with”;
- item 32: “I put non edible objects in my mouth”;
- item 33: “I forget to look both ways before crossing the road”;
- item 34: “I refuse to wear a seat belt when I’m in a car”.

Therefore, the model was conducted again without the previously mentioned items (Figure 5).

Figure 5. *Exploratory Factor Analysis (EFA) of the IPQ questionnaire, with its 27 remaining items from the previous EFA. Factor loadings for each item with the 3 factors (Error, Risk and Danger) are illustrated.*



The factor analysis explained 36% of the overall variance. The first component explained 16% of the total variance corresponding to 44% of the relative amount of explained variance. The second component explained 14% of the variance, corresponding to 40% of the relative amount of explained variance. The third factor explained 6% of the total variance, which corresponded to 16% of the relative amount of explained variance.

The second component showed the highest positive correlations with the first (0.35) and third (0.31) components respectively, whereas the correlation between the first and third component was (0.17). The root mean square of the residuals was RMSR = 0.04, with $\chi 2 = 587.83$ ($p < 0.001$) and the root mean square error of approximation was RMSEA = 0.05 [90% CI: 0.05, 0.06]. However, the Tucker Lewis Index was barely acceptable, with TLI = 0.86. The model had BIC = -1028.81.

The first factor grouped items associated with error and clumsiness, hence we ultimately called this the “Error” factor. The second factor included items dealing with risky behaviors; for this reason, it was called “Risk”, for risk taking tendencies. The third and final factor contained items that were more neutral than those from other categories, mainly focusing on prudence and danger evaluation. Therefore, this factor was called “Danger” as in danger evaluation. The complete list of the items is present in Table 5.

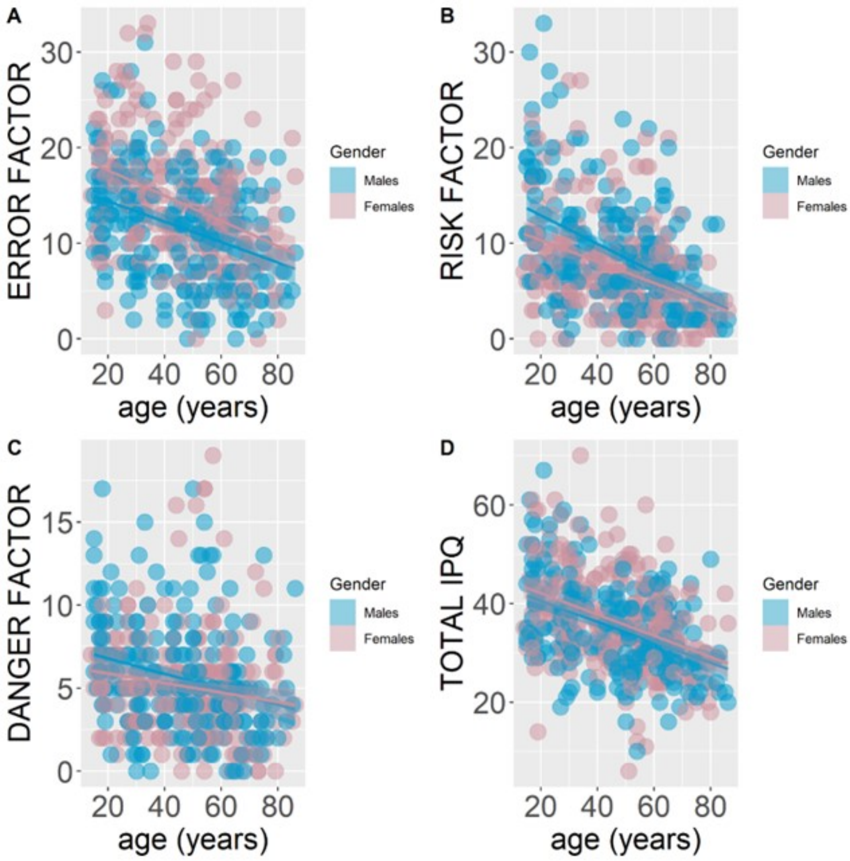
Table 5. *Remaining items of the IPQ questionnaire from the factor analyses including: Cronbach's α values for each item when dropped, item-rest Pearson's correlations and the types of factors associated with each of the items. The factors identified were: Error, Risk taking and Danger evaluation (Error, Risk and Danger).*

Item (number and text)	Factor	Cronbach's α	Item-rest correlation
IPQ1: I behave in a clumsy manner	Error	0.86	0.55
IPQ2: I don't look where I go	Error	0.86	0.55
IPQ3: Objects slip from my hands involuntarily	Error	0.86	0.46
IPQ4: I look for objects that I already have with me	Error	0.86	0.36
IPQ6: I trip over objects on the floor at home	Error	0.86	0.47
IPQ7: I go into a room but I forget the reason why I entered	Error	0.86	0.35
IPQ8: I listen to or read something without actually understanding it	Error	0.86	0.40
IPQ9: I happen to have my head in the clouds	Error	0.86	0.51
IPQ10: I trip when I walk quickly	Error	0.86	0.30
IPQ11: I spill drinks	Error	0.86	0.49
IPQ12: I struggle finding objects at home or at work	Error	0.86	0.46
IPQ15: I accidentally break objects at home	Error	0.86	0.36
IPQ16: I do things in a reckless matter	Risk	0.86	0.48
IPQ17: I do unusual things for the thrill	Risk	0.86	0.47
IPQ18: I skip some steps when I go down the stairs	Risk	0.86	0.47
IPQ19: I climb over some furniture if I have to reach something elevated	Risk	0.86	0.51
IPQ20: I do things even if they scare me	Risk	0.86	0.55
IPQ21: I have risky behaviors at parks or places with physical equipment	Risk	0.86	0.43
IPQ22: I enter unauthorized areas	Risk	0.86	0.47
IPQ23: I stand on top of chairs or stairs even if it's dangerous	Risk	0.86	0.42
IPQ26: I avoid using hazardous objects	Danger	0.87	0.22

IPQ27: I complete tasks without making mistakes	Danger	0.87	0.25
IPQ28: I am reliable in handling delicate objects	Danger	0.86	0.37
IPQ29: I intentionally cross the road in dangerous points	Risk	0.86	0.32
IPQ30: I play with fire	Risk	0.86	0.42
IPQ35: I am careful when I am around animals I am not familiar with	Danger	0.87	0.25
IPQ36: I decide to stop an activity if I think it's too dangerous	Danger	0.86	0.33

3.2.3.4 Regressions. A series of regression models were carried out, considering each of the 3 factors from the EFA and the total IPQ score as dependent variables (see Figure 6). Age and gender were included in the models; more specifically, age was treated as a continuous variable with the purpose of analyzing developmental trajectories in self-reported injury proneness. Standardized beta values from the regression models were considered and described.

Figure 6. *Regression models for each factor, and total score of the IPQ as dependent variable. Age and gender are considered as factor and covariate.*



Error factor (A)

The effect of age on the error factor of the IPQ questionnaire was significant with β = -0.35 [95% CI: -0.44, -0.27], $p < 0.001$. The effect of gender was significant with β = 0.41 [95% CI: 0.24, 0.58], $p < 0.001$; females therefore reported higher scores in the items included in this factor compared to males. The model had $R^2 = 0.16$.

Risk factor (B)

The effect of age was significant with β = -0.42 [95% CI: -0.50, -0.34], $p < 0.001$. The effect of gender was significant with β = -0.28 [95% CI: -0.45, -0.12], $p = 0.001$; males therefore reported higher scores in the items included in this factor compared to females. The model had $R^2 = 0.20$.

Danger factor (C)

The effect of age was significant with β = -0.21 [95% CI: -0.30, -0.12], $p < 0.001$. The effect of gender was not significant with β = -0.13 [95% CI: -0.31, 0.05], $p = 0.144$; therefore no particular difference between genders emerged. The model had $R^2 = 0.05$.

Total IPQ score (D)

The effect of age was significant with β = -0.41 [95% CI: -0.49, -0.33], $p < 0.001$. The effect of gender was not significant with β = 0.14 [95% CI: -0.02, 0.31], $p = 0.093$; therefore no difference between genders emerged. The model had $R^2 = 0.17$.

3.2.3.5 Correlations. Pearson's correlations were carried (Table 6) out with the purpose of analyzing the relationship between the variables that had already been considered, such self-reported injury proneness, with other measures such as injury history (number of times at the E.R. and mild injury frequency), cognitive failures (CFQ) and general visuospatial and sense of direction skills (SDSR).

Table 6. *Pearson's Correlations including all variables in the study (464 participants). Significant values are flagged:*

** p<0.05, **p<0.01, ***p<0.001. CFQ = Cognitive Failures Questionnaire; SDRS = Sense of Direction and Spatial Representation scale; IPQ-Error = Injury Proneness Questionnaire-Error factor from CFA; IPQ-Risk = Injury Proneness Questionnaire-Risk taking factor from the CFA; IPQ-Danger = Injury Proneness Questionnaire-Danger evaluation from the CFA; IPQ-Total = Injury Proneness Questionnaire- Total score (sum of the 3 factors).*

	IPQ - Error	*IPQ - Risk*	*IPQ - Danger*	*IPQ Total*
1 number of episodes at the E.R	0.10*	0.18***	-0.01	0.18***
2 mild injuries frequency	0.32***	0.32***	0.12**	0.36***
3 Disfunctional motor coordination	0.48***	0.14**	0.11*	0.36***
4 CFQ Total	0.721***	0.35***	0.22***	0.61***
5. SDSR Total	-0.17***	0.10*	-0.08	-0.03

Significant values emerged. The questions from the injury history part (i.e. number of episodes at the E.R. and mild injuries frequency) correlated positively with the factors that emerged from the IQP. Dysfunctional motor coordination and cognitive failures correlated positively with all parts of the IPQ, whereas self-reported navigation abilities had a negative correlation with the IPQ Error factor ($r = -0.17$, $p < 0.001$) and a positive correlation with IPQ Risk ($r = 0.10$, $p < 0.05$).

3.2.4 Discussion

Accidental injuries have proven to create serious social and medical issues, causing a great amount of distress and, in the worst case scenario, death (CDC, 2020; Eurostat, 2020). A general summary of the literature was discussed, theorizing the effect of certain aspects in injury proneness, such as age, gender, navigational skills, motor coordination, cognitive failures and effective amount of injuries, both mild and serious, experienced. A stronger predisposition of getting hurt was often encountered in males, especially in their youth and adult years. With age, injury proneness calculated from statistical evidence (accident and death rates) tends to increase (Camarero, 2021); for example, injuries due to falls increase when balance and spatial skills decrease with age (Martin et al., 2009). Moreover, methods for injury rating are present in different contexts, such as the work environment (Abegglen et al., 2017) or for younger ages, according to parents' perspective (Rowe & Maughan, 2009). However, to our current knowledge no instrument has evaluated self-perceived injury proneness across a general population, considering different ages, ranging from adolescence to old age, and its relation to other individual characteristics such injury history and self-reported navigation skills. A self-perceived instrument could be beneficial for better understanding possible factors associated to injuries, as well as the beliefs and motivations that people have regarding such causes. Hence, the validity of a new questionnaire (IPQ) was tested. After verifying the possibility to conduct a factor analysis, an EFA was conducted. The first EFA signaled the least representative items that had insufficient factor loadings; as a result, a total of 9 items were excluded from the following analyses. A second EFA was carried out and fitted slightly better than the previous one. In general, the items gathered around 3 main clustersThe first one included many items that dealt with situations of errors and clumsiness, therefore the factor was ultimately called "Error". The second factor was labeled as "Risk", for risk taking and the final one as "Danger", since it included situations considering danger evaluation. Once the factors of the IPQ were identified, they were included as dependent variables in linear regression models with the purpose of examining the effect of gender and age in self-reported injury proneness. The result showed a significant effect of age, with a decrease of injury proneness with age; furthermore, some gender differences were found. Female participants gave higher scores in the items associated with the Error factor, hence they perceived themselves as more likely to get in situations of clumsiness. On the contrary, males reported higher scores in items related to the Risk factor. This evidence was similar to that had been found by Voyer & Voyer (2015), who identified gender differences in spatial tasks and injury rates; indeed, females felt less secure of their skills compared to males, and the latter reported more injuries and risk tendencies. The 3 factors were examined once again with Pearson's correlation models including the remaining variables of interest, such as injury history, motor coordination, cognitive failures and self-reported navigation abilities. Significant relations were found between more than one factor of the IPQ and injury history, correlating positively with both questions. This means that people who gave a higher score in the IPQ also experienced a greater number of injuries, both mild and serious enough to require help from the emergency room. Positive and significant relations between the IPQ (all the components) and dysfunctional motor coordination emerged. The SDSR questionnaire, evaluating orientation and sense of direct, was correlated to IPQ Error ($r = -0.17$, $p < 0.001$) and IPQ Risk ($r = 0.10$, $p < 0.05$), showing that people with higher scores in the Error scale reported lower navigation abilities, whereas people with higher injury proneness due to risk (IPQ Risk) presented higher values in the SDSR. This result could be justified by the fact that people who are, or simply perceive themselves as, clumsy or prone to get hurt because of errors are less likely to explore the environment to improve their orientation and spatial representation skills altogether. On the contrary, people who expose themselves to risks are more prone to explore the environment and look for stimulation. As a consequence, frequent explorations bring more experience and expertise, as well as confidence in orientational skills. The present work yielded interesting results regarding accidental injuries; however some limitations should be acknowledged. Firstly, injuries were evaluated from a personal point of view, with information that was entirely provided by the participants. Hence objective data and reported information (from other figures related to the participants, such as family) should be included in future research when possible. Secondly, only questionnaires were considered in the work, and therefore other aspects, such as cognitive failures and spatial skills, were evaluated in self-reported modality, with no objective measures to support these measures. Thirdly, spatial skills were evaluated marginally, considering only orientation and sense of direction, but it is also true that injury tendency could be explored in various spatial domains, for example mental rotation or spatial perception.

In conclusion, self-reported injury has proven to be an interesting topic and a relation between individual characteristics and injuries was identified. Indeed, gender and age differences impacted on predisposition self-perceived by people; moreover past experiences with injuries, spatial and cognitive skills have shown to affect injury predisposition in some way. Perceived or self-perceived injury proneness can vary according to the people involved. Indeed, some people might think they are more likely to get hurt in a specific context or for a specific cause more than others (e.g. after committing an error or as a consequence of a risky conduct), or they could think that they might be safer because of certain skills or resources they are confident in (e.g. good orientation or cognitive resources). The IPQ questionnaire could gather further evidence regarding individual differences and perception of injury predisposition. Moreover, if self-perceived injury proneness depends on people's beliefs, it could be possible to further employ and evaluate the questionnaire also in different populations, such as pre-teens for example, which represent an age during which people start approaching different environments autonomously, other than home.

4 Chapter 3: Cognitive factors associated with accidental injuries in young adults, adults and older adults

As mentioned in the previous sections (general introduction and chapter 1), accidental injuries bring noticeable consequences across all ages and situations. Injuries of this nature often entail physical and psychological effects. In particular, a systematic review analyzed psycho-traumatological issues in people who suffered from accidental injuries (Schnyder & Buddeberg, 1996) and their clinical profiles. The most observed effects were depression, somatoform disorder, anxiety and (more rarely) post-traumatic stress disorder (PTSD). However, the authors also mentioned that most of the material they found dealt with aspects following the injury, rather than individual resources, such as protective psycho-social factors. Indeed, studying these characteristics could be beneficial for health-promotion and prevention purposes. Cognitive skills have been demonstrated to be linked to injury proneness also in an apparently simple context like the domestic one. For example, Spano and colleagues (2018) studied a group of healthy elderly people, measuring memory complaints, general cognitive functioning, risky behavior and the number of accidents that caused minor injuries, in the course of a year (reported by participants). Results showed that memory complaint and cognitive functioning directly influenced risky behavior and the number of injuries experienced; furthermore, risky behavior mediated the effect of cognitive functioning and memory complaint on the number of injuries. In light of these findings, the present chapter will focus on cognitive characteristics related to injury proneness. So, whereas the previous chapter presented the features of the new questionnaire and the changes of self-reported accidental injuries in function of age and gender, this one will consider performance tasks and other measures, each evaluating a specific domain of cognition across adulthood.

4.1 Cognitive and individual factors

As mentioned above, cognitive aspects have proven to affect injury proneness. For instance, a negative correlation between I.Q. and injuries was found (Batty et al., 2009; Whitley et al., 2010; Bonander & Jernbro, 2017). The reason for this association is based on the fact that slower processing speed causes a more inefficient evaluation of risks, thus inducing the person to adopt risky behaviors more frequently. Another aspect associated with lower I.Q. is poorer motor coordination and lower socio-economic status: indeed, people with lower socio-economic status are more likely to be exposed to dangerous situations or environments, and to have fewer chances to obtain adequate health care. Spatial skills have provided interesting results as well. Voyer and Voyer (2015) measured performance in a mental rotation task and injury experience. It emerged that male participants performed better than females in the task, although they also had more experience with risky situations and injuries. On the contrary, females performed less efficiently than males, had more self-doubt in their visuospatial abilities and felt clumsier when performing. Nonetheless, they were more prudent and had less injury experience in daily life. This tendency could be explained by the fact that people with more confidence and extroversion get more distracted and are more likely to ignore danger signals from the environment, thus adopting riskier behaviors (Rowe et al., 2007). Nevertheless, good spatial skills have proved to be a protective factor against injuries caused by falls, especially in old age (Martin et al., 2009). Attention is an ulterior relevant element to take into account when dealing with injury tendency; more specifically, people with lower sustained attention and vigilance tend to get hurt more often. People struggling with sustained attention tend to often fall in a positive illusory bias, which makes them underestimate the surrounding danger and overestimate their own capacities (Farmer & Peterson, 1995; Bruce et al., 2009). Executive functions, along with attention, play a relevant role in injuries. In fact, poor executive functions are related to a greater risk of incurring injuries (Shen et al., 2021). There are different tasks that can be employed when analyzing executive functions, however in this particular study greater focus was given to the Iowa Gambling Task, i.e. a measure evaluating (risky) decision making specifically, in terms of gains and losses.

4.2 Objectives

After considering the main aspects described by the literature, an in-depth analysis regarding injury proneness and individual differences was necessary. Therefore, the Injury Proneness Questionnaire (IPQ), a previously tested questionnaire measuring self-perceived injury, was applied again to compare it to objective measures. The main questions that warranted answering were:

- How people answered the IPQ and its subscales and how they performed in the tasks;
- How IPQ was related to other variables, such as spatial skills, cognitive skills and sustained attention. More precisely, we wanted to know if there were specific trends in each subscale of the IPQ;
- How all these measures were related to one another and the strength of such relations.

4.3 Method

4.3.1 Participants. The same sample of participants described in chapter 2 was employed, and therefore a total of 464 participants ranging from 14 to 86 years of age (age M = 46.21, SD = 18.56; males = 223, females = 241) volunteered. The same inclusion and exclusion criteria described in chapter 2 were applied.

4.3.2 Materials

4.3.2.1 Injury Proneness Questionnaire (IPQ). The questionnaire that has been introduced and adapted in chapter 2 was adopted, hence a total of 27 items and 3 main subscales were included in the instrument: Error, Risk taking, Danger evaluation and the Total IPQ score (see Table 5 from chapter 2).

4.3.2.2 Cattell (2/3B; Cattell & Cattell, 1954). This instrument evaluates fluid reasoning regardless of language or level of education. A series of tasks with images are presented, and the participant has to complete them as accurately as possible within a specific limit of time. Two versions were used for this research: the 2B version for people under 20 years of age, and the 3B version for those aged 20 and over. Each version is divided into 4 parts, including a set of items. Each item includes an incomplete target image: the objective of the task is to choose the option (among those presented) that best completes the target image by following its pattern in a logical sense. One point is rewarded for each correct answer, with the exception of the second part of version 3B, which requires the identification of two correct answers in order to obtain 1 point. Hence, the total score for version 2B ranges from 0 to 48, while for 3B it ranges from 0 to 49. The total raw scores were considered in the analyses of the present study.

4.3.2.3 Water level task (Amponsah & Krekling, 1994). The task evaluates spatial perception, considering the inclination of a liquid within a container. In each item a group of 9 images are presented: all of them depict glasses with the same shape, dimensions and inclinations, but with the exception of the water level, which is inclined in different manners and to different degrees. The participant has to choose the image that correctly represents the inclination of the water level if the glass were in that specific position. There is only one correct choice, and the participant is given 3 minutes (for 6 items) to complete the entire task. The total score ranges from 0 to 6.

4.3.2.4 Mental rotation test (short version; De Beni et al., 2014). The present test is a shorter version of the classical Vandenberg & Kuse (1978) task, with 10 items to be completed within 4 minutes. Each item presents a target image; and the objective is to identify 2 options that coincide with the target image despite its being rotated in different positions. If the person identifies both correct options, the score is 1, otherwise the score is 0. The total score in the task ranges from 0 to 10.

4.3.2.5 Go/No-go task. The task evaluates inhibition control, i.e. the ability to concentrate on relevant stimuli while ignoring irrelevant ones. The entire task lasts a few minutes (about 4 or 5), with 300 stimuli being presented one after another. The participant has to press the spacebar of a computer keyboard every time the relevant (Go) stimulus appears, and do nothing whenever the irrelevant (No-go) stimulus appears. Mean reaction time (in milliseconds) and error rates are considered. Two types of errors are possible: false alarms, whenever the person clicks when it is not necessary, or omissions, which happen when the person is supposed to click and signal the presence of the go stimulus but does not do so. The task includes a total of 200 Go stimuli and 100 No-go stimuli that are presented in randomized order for each participant.

4.3.3 Methods

The experiment was carried out online, with each participant individually. The experimenter guided and provided instructions to the participant through the Zoom platform throughout the entire experiment (two sessions were carried out on two different days: the first one lasting about one hour and the second one around 45-50 minutes). During the first session, the participant had to complete the SVAMA checklist (verbally), the IPQ Questionnaire, the Cattell test and the Water level test through the Qualtrics platform, in fixed order. The second session included the Mental rotation test and the Go/No-go task. The former task was implemented with Qualtrics, whereas the latter with the Psytoolkit platform (Stoet, 2010; Stoet, 2017). Aside from the measures considered here, participants also completed other measures (questionnaires) at the end that are not presented or analyzed here, as they beyond the scope of the present research.

4.4 Results

Descriptive statistics, including mean scores and standard deviations for each measure (Table 7), were carried out. Then, Pearson's correlations were used to verify the relationship among all variables, i.e. age, gender, IPQ Error, Risk, Danger and Total scores, Cattell, Mental rotation, Water level, Go/No-go errors and mean reaction time. Afterwards, regression models were built, with each IPQ score as a dependent variable, and age, gender and total scores in the tests (Cattell, Water level, Mental rotation and Go/No-go) as predictors (see Figures 7, 8, 9, 10 for regressions). Therefore, a full model was built for each IPQ component in order to understand the effects of individual and cognitive characteristics on the specific IPQ subscale or Total score.

The IPQ was analyzed considering its total score and the 3 subscales: Error, Risk taking and Danger evaluation. The analyses were carried out using the R software (RStudio Team, 2022).

4.4.1 Descriptive statistics. Mean scores for each measure were calculated across the total sample and between decades, since the sample size featured a wide age range (Table 7).

Table 7. *Mean and standard deviation for each age group regarding: Injury Proneness Questionnaire (IPQ), Cattell test, Water level Test, Mental rotation test, Go/No-go task.*

	Age ranges							
Questionnaire	**14-19 years**	**20-29 years**	**30-39 years**	**40-49 years**	**50-59 years**	**60-69 years**	**70-79 years**	**Total sample**
IPQ Total	44.80 (13.10)	40.30 (14.70)	37.10 (13.00)	34.20 (12.00)	31.90 (11.20)	28.10 (11.40)	24.00 (10.00)	33.93 (13.55)
CFQ Total	40.80 (10.70)	45.00 (12.40)	41.10 (8.72)	36.70 (10.40)	34.90 (12.80)	30.20 (12.00)	29.30 (12.70)	36.52 (12.86)
Cattell Total	32.60 (5.17)	23.85 (5.72)	25.04 (4.80)	22.98 (5.15)	22.70 (4.80)	22.19 (4.31)	16.65 (5.65)	23.61 (6.32)
Water level Total	1.46 (2.42)	1.18 (1.81)	1.75 (2.08)	1.84 (2.43)	1.62 (1.95)	1.80 (1.94)	1.83 (2.11)	1.66 (2.07)
Mental rotation Total	2.83 (2.46)	3.31 (3.04)	3.54 (2.53)	3.43 (2.28)	2.73 (2.00)	2.40 (1.60)	2.02 (1.59)	2.89 (2.27)
Go/No-go mean reaction time(msec)	441.96 (96.35)	448.27 (123.34)	425.61 (74.87)	449.45 (86.24)	469.08 (91.13)	508.07 (100.31)	585.45 (125.09)	473.51 (108.58)
Go/No-go false alarm errors	2.92 (2.80)	2.96 (3.30)	2.07 (2.04)	1.66 (1.92)	2.27 (3.12)	1.94 (2.56)	3.56 (3.53)	2.38 (2.81)
Go/No-go omission errors	0.98 (2.39)	1.16 (2.85)	0.54 (0.10)	0.56 (2.06)	0.65 (1.63)	1.45 (4.28)	3.46 (4.65)	1.15 (3.01)

4.4.2 Correlations. Pearson's correlations were carried out with the purpose of analyzing the relationship between self-reported injury proneness and other variables such as age, gender, total scores in the Cattell test, Mental rotation test, Water level test, total number of errors in the Go/No-go task (false alarm and omission) and mean reaction times in the Go/No-go task (Table 8). Gender was considered as a continuous variable in this case, in order to include it in the model and verify its relationship with the other measures. In these analyses, a significant focus was given to age by including it in the correlations. However, when partializing the same correlations for age and applying Bonferroni correction, changes are to be expected. Indeed, Table 9 (Appendix B) provides the this kind of analyses, demonstrating the presence of fewer significant relations. Gender and Go/No-go mean reaction time maintained significant relations with the IPQ subscales.

Table 8. *Pearson's Correlations including all variables in the study (464 participants). Significant values are flagged: * p<0.05, **p<0.01, ***p<0.001. IPQ-Error = Injury Proneness Questionnaire-Error subscale; IPQ-Risk = Injury Proneness Questionnaire-Risk taking subscale; IPQ-Danger = Injury Proneness Questionnaire-Danger evaluation subscale; IPQ-Total = Injury Proneness Questionnaire- Total score (sum of the 3 subscales).*

	IPQ - Error	*IPQ - Risk*	*IPQ - Danger*	*IPQ Total*
1 age	-0.35***	-0.42***	-0.21***	-0.41***
2 gender	0.20***	-0.15**	-0.07	0.07
3 Go/No-go false alarm	-0.02	0.02	0.02	-0.01
4 Go/No-go omission	-0.12**	-0.12*	0.01	-0.15***
5 Go/No-go mean reaction time	-0.24***	-0.28***	-0.04	-0.31***
6 Water level	-0.04	0.08	-0.10*	0.05
7 Cattell	0.06	0.19***	-0.05	0.17***
8 Mental rotation	0.19***	0.33***	0.03	0.31***

Significant values emerged. Age correlated significantly with all components of the IPQ questionnaire. Therefore, with the increase of age, people were more likely to report lower injury proneness. Male participants had a significant correlation with the IPQ Risk subscale ($r = -0.15$, $p < 0.01$). In contrast, females were related to the IPQ Error subscale ($r = 0.20$, $p < 0.001$). Go/No-go errors, especially omissions, correlated negatively with IPQ Error ($r = -0.12$, $p < 0.01$), Risk ($r = -0.12$, $p < 0.05$) and Total ($r = -0.15$, $p < 0.001$); the same trend happened with Go/No-go mean reaction times. Another significant result emerged with the Water level task and IPQ Danger subscale ($r = -0.10$, $p < 0.05$). The Cattell test shared significant relations IPQ Risk ($r = 0.19$, p <

0.001) and Total ($r = 0.17$, $p < 0.001$). Mental rotation correlated with almost all components of the IPQ ($r = 0.19$, $p < 0.001$ for Error; $r = 0.33$, $p < 0.001$ for Risk; $r = 0.31$, $p < 0.001$).

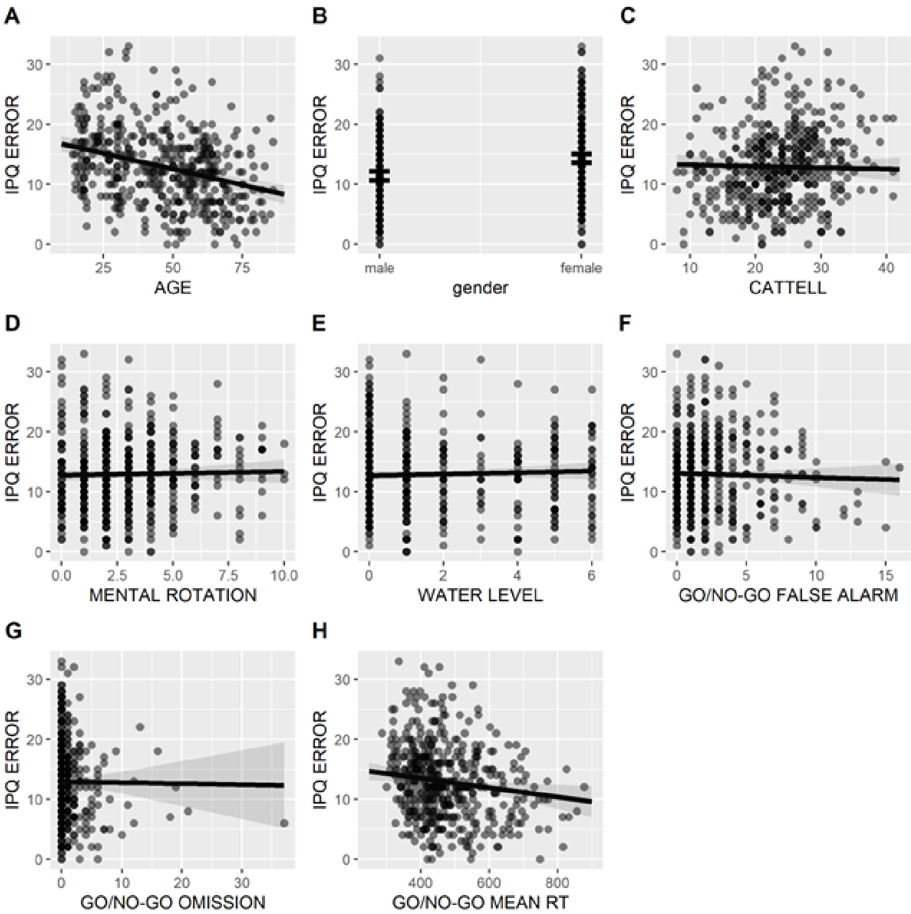
4.4.3 Regression models A regression model for each IPQ subscale and total score was built, including multiple predictors such as age, gender and cognitive abilities (e.g. non-verbal reasoning, mental rotation, spatial visualization, sustained attention) on self-reported injury proneness, which was measured by the IPQ.

Since the questionnaire demonstrated a structure composed of the same 3 main factors as in the previous study (chapter 2), each factor and the total IPQ score were analyzed separately as dependent variables. Standardized beta values were calculated and described for each regression model (Figures 7, 8, 9 and 10).

IPQ Error

Age was a significant predictor with $\beta = -0.31$ [95% CI: -0.41, -0.21], $p < 0.001$ (Figure 7A). Gender was significant with $\beta = 0.47$ [95% CI: 0.29, 0.65], $p < 0.001$, thus demonstrating that females gave higher scores in the items included in this scale compared to male participants (Figure 7B). Performance in the Cattell test was not significant with $\beta = -0.02$ [95% CI: -0.13, 0.09], $p = 0.674$ (Figure 7C). Mental rotation was not significant with $\beta = 0.02$ [95% CI: -0.07, 0.12], $p = 0.634$ (Figure 7D). Water level was not significant with $\beta = 0.04$ [95% CI: -0.05, 0.14], $p = 0.389$ (Figure 7E). The amount of false alarm errors in the Go/No-go task was not significant with $\beta = -0.03$ [95% CI: -0.12, 0.06], $p = 0.474$ (Figure 7F). The amount of omission errors in the Go/No-go task was not significant with $\beta = -0.01$ [95% CI: -0.10, 0.09], $p = 0.869$ (Figure 7G). Mean reaction time (msec) in the Go/No-go task was significant with $\beta = -0.13$ [95% CI: -0.24, -0.03] $p = 0.012$ (Figure 7H). The model had $R^2 = 0.18$.

Figure 7. *Regression model considering the IPQ Error subscale. There is one model but the effect of each predictor on the IPQ is graphically shown separately.*

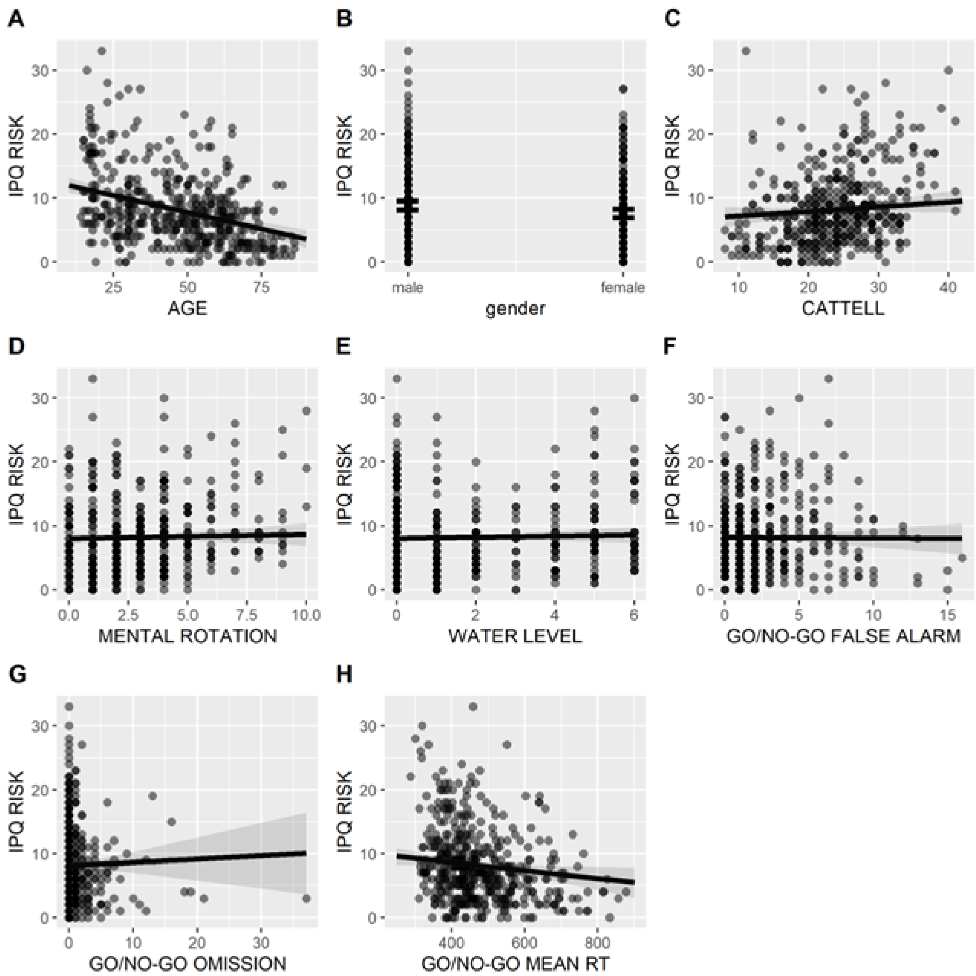


IPQ Risk

Age was a significant predictor with β = -0.34 [95% CI: -0.44, -0.24], $p < 0.001$ (Figure 8A). Gender was significant with β = -0.22 [95% CI: -0.39, -0.04], $p = 0.015$, thus demonstrating that males gave higher scores in the items included in this scale compared to female participants (Figure 8B). Performance in the Cattell test was not significant with β = 0.08 [95% CI: -0.03, 0.19], $p = 0.135$ (Figure 8C). Mental rotation was not significant with β = 0.03 [95% CI: -0.07, 0.12], $p = 0.587$ (Figure 8D). Water level was not significant with β = 0.03 [95% CI: -0.06, 0.13], $p = 0.512$ (Figure 8E). The amount of false alarm errors in the Go/No-go task was not significant with β = -

0.01 [95% CI: -0.09, 0.08], p = 0.881 (Figure 8F). The amount of omission errors in the Go/No-go task was not significant with β = 0.03 [95% CI: -0.07, 0.12], p = 0.561 (Figure 8G). Mean reaction time (msec) in the Go/No-go task was significant with β = -0.12 [95% CI: -0.22, -0.02], p = 0.022 (figure 8H). The model had $R^2 = 0.22$.

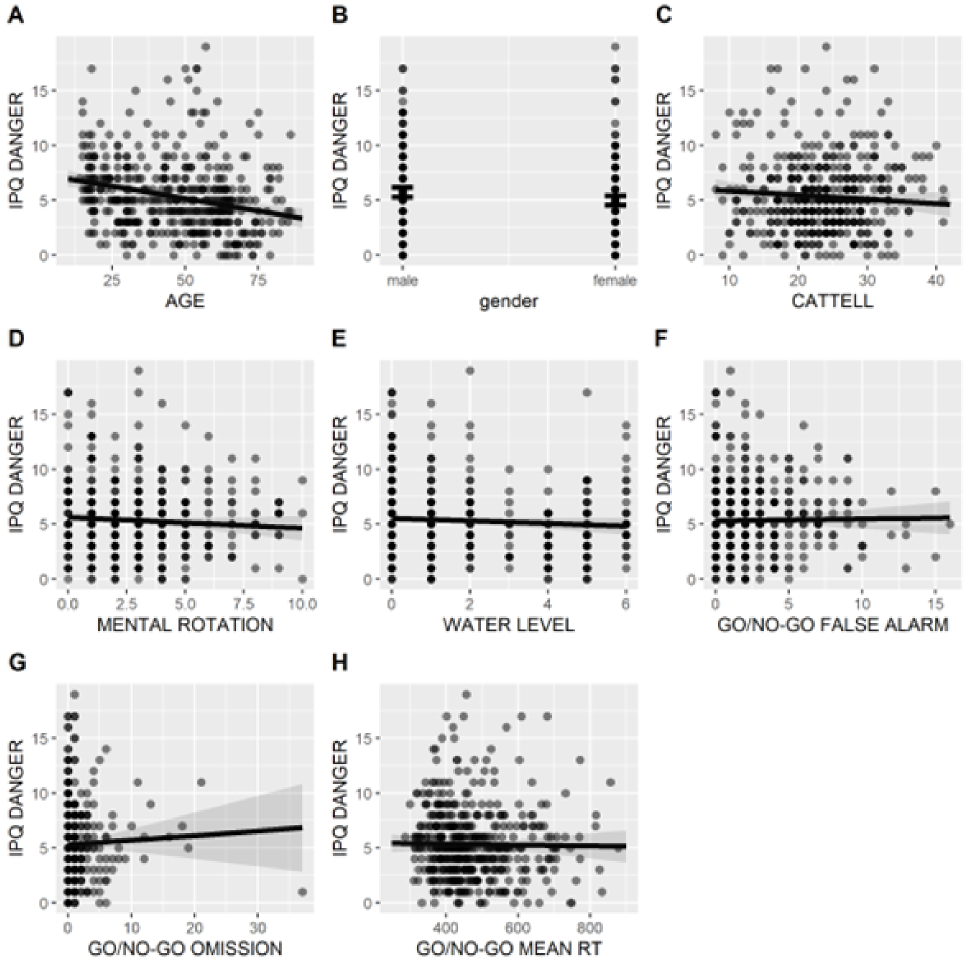
Figure 8. *Regression model considering the IPQ Risk subscale. There is one model but the effect of each predictor on the IPQ is graphically shown separately.*



IPQ Danger

Age was a significant predictor with β = -0.25 [95% CI: -0.36, -0.14], $p < 0.001$ (Figure 9A). Gender was significant with β = -0.23 [95%CI: -0.42, -0.04], $p = 0.020$, thus demonstrating that males gave higher scores in the items included in this scale compared to female participants (Figure 9B). Performance in the Cattell test was not significant with β = -0.07 [95% CI: -0.19, 0.04], $p = 0.226$ (Figure 9C). Mental rotation was not significant with β = -0.07 [95% CI: -0.17, 0.03], $p = 0.193$ (Figure 9D). Water level was not significant with β = -0.07 [95% CI: -0.18, 0.03], $p = 0.165$ (Figure 9E). The amount of false alarm errors in the Go/No-go task was not significant with β = 0.02 [95% CI: -0.08, 0.11], $p = 0.742$ (Figure 9F). The amount of omission errors in the Go/No-go task was not significant with β = 0.04 [95% CI: -0.06, 0.14], $p = 0.462$ (Figure 9G). Mean reaction time (msec) in the Go/No-go task was not significant with β = -0.02 [95% CI: -0.13, 0.10] $p = 0.787$ (Figure 9H). The model had $R^2 = 0.07$.

Figure 9. *Regression model considering the IPQ Danger subscale. There is one model but the effect of each predictor on the IPQ is graphically shown separately.*

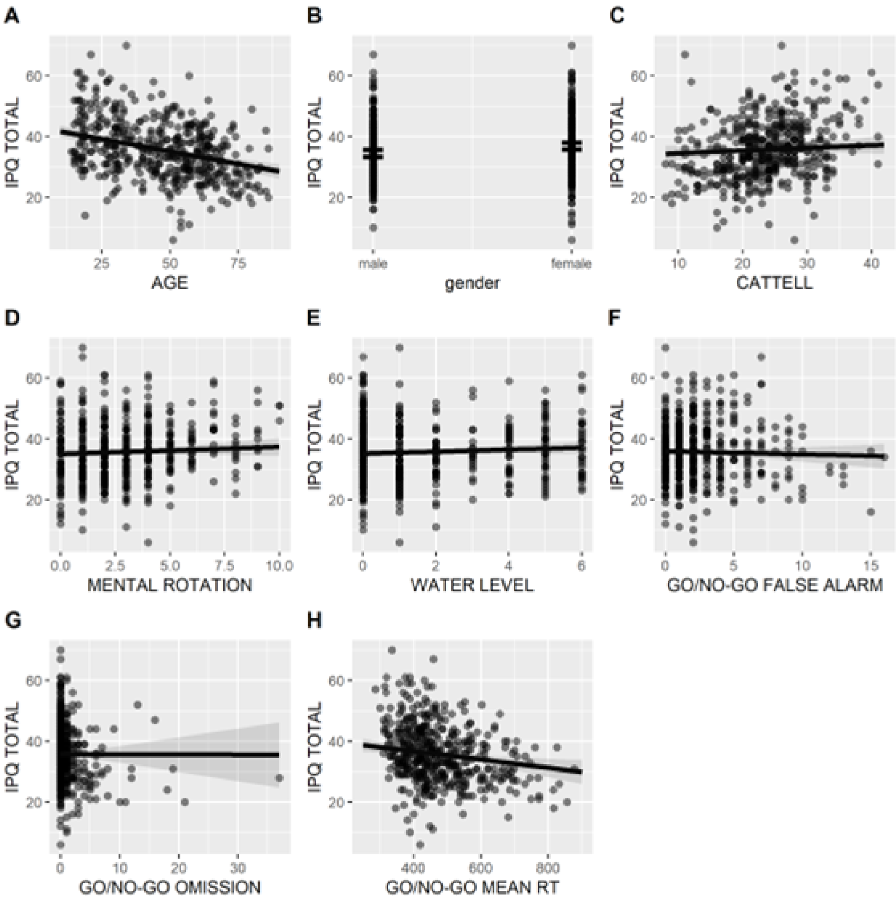


IPQ Total

Age was a significant predictor with β = -0.32 [95% CI: -0.42, -0.22], p < 0.001 (Figure 10A). Gender was significant with β = 0.25 [95%CI: -0.42, -0.04], p = 0.020, thus demonstrating that females generally gave higher scores in the questionnaire compared to male participants (Figure 10B). Performance in the Cattell test was not significant with β = 0.006 [95% CI: -0.05, 0.16], p = 0.288 (Figure 10C). Mental rotation was not significant with β = 0.05 [95% CI: -0.04, 0.15], p = 0.260 (Figure 10D). Water level was not significant with β = 0.07 [95% CI: -0.02, 0.17], p = 0.139 (Figure 10E). The amount of false alarm errors in the Go/No-go task was not significant with β = -

0.03 [95% CI: -0.11, 0.06], p = 0.492 (Figure 10F). The amount of omission errors in the Go/No-go task was not significant with β = -0.00 [95% CI: -0.10, 0.09], p = 0.970 (Figure 10G). Mean reaction time (msec) in the Go/No-go task was significant with β = -0.15 [95% CI: -0.26, -0.05], p = 0.003 (Figure 10H). The model had $R^2 = 0.22$.

Figure 10. *Regression model considering the IPQ Total score. There is one model but the effect of each predictor on the IPQ is graphically shown separately.*



4.5 Discussion

Accidental injuries are a critical issue with repercussions on general healthcare. The extent and characteristics of this phenomenon were described by summarizing the main findings on the topic. Specifically, the role of age, gender, cognitive and executive skills were discussed and taken into account in the present work. The objective of this experiment was to analyze self-perceived injury proneness across the lifespan with an *ad hoc* instrument (IPQ) and to verify the eventual link of such proneness to other individual variables such as age, gender and performance across different domains of cognition (e.g. intellectual, spatial and executive functions).

After calculating mean and standard deviation for the scores of all measures, Pearson's correlations were conducted with the purpose of verifying how all these variables correlated with the IPQ. In these analyses age correlated negatively with the score given in all subscales and total of the IPQ questionnaire. Therefore, older people reported a lower injury predisposition. These facts seem to be in line with those of Josef and colleagues (2016), showing more prudent behavior with age; however it remains unclear whether older people actually incur injuries less often than younger people or not. Gender was included in these correlations as a continuous variable; males gave a higher score in the IPQ Risk subscale. In contrast, the female gender correlated with the IPQ Error subscale. Omission errors correlated with IPQ Error, Risk and Total; therefore, a higher amount of omission errors was associated with lower scores given in different subscales of the IPQ. Mean reaction time at the Go/No-go task correlated negatively with the same variables as omission errors, while the Water level test correlated only with the IPQ Risk subscale. The Cattell test positively correlated with IPQ Risk and Total, while Mental rotation correlated positively with IPQ Error. This result, in particular, seems to be in contrast with some findings (e.g. Batty et al., 2009; Whitley et al., 2010) and more in line with others (e.g. Voyer & Voyer, 2015; Rowe et al., 2007), thus suggesting the idea that people with good cognitive and spatial abilities and confidence in their skills are also more likely to engage in riskier situations and underestimate danger, resulting in their greater predisposition to get hurt. It is also true that injury proneness was a self-report measure in this study; therefore no objective measure, such as injury rates, was included and further evidence is necessary to confirm this finding.

Afterwards, a linear regression model for the total and each subscale of the IPQ was considered, including age, gender and performance in the tests as predictors. With the IPQ Error subscale it revealed that age, gender and mean reaction time in the Go/No-go task were significant. Interestingly, the significant effect of gender in this regression was due to females giving a higher score in the items of this subscale. Hence, like in the previous correlation, females reported to be more likely to get hurt in situations of clumsiness, similarly to what had been found by Voyer and Voyer (2015), with female participants feeling clumsier and less confident in their abilities. Moreover, gender and mean reaction times in the Go/No-go task decreased, with higher scores in the Error subscale. This means that older people would report less injury proneness in these items than younger ones, and that people who gave themselves higher scores would have shorter reaction times when responding to the "Go" stimuli, hence responding more rapidly to relevant stimuli. When considering IPQ Risk as a dependent variable, age, gender and mean reaction times at the Go/No-go remained significant. Once again, with the increase of the score given in this subscale, age and mean reaction times would decrease, however, this time the male gender was significant. This result seems to confirm the general predisposition of males towards risk, as had already been found in the literature (e.g. Voyer & Voyer, 2015). With the IPQ Danger subscale, only age and gender emerged as significant, with a decrease in score as age increased, and a greater predisposition in males to give a higher score in this subscale. When considering the total score of the IPQ therefore, all items, age, gender and mean reaction time at the Go/No-go were significant. The total score would decrease with age and mean reaction time, but females would give a higher score than males.

This study yielded compelling results; however some limits must be acknowledged. One first limit has been mentioned, i.e. missing objective measures for injury proneness; the IPQ has proven to be a useful instrument for exploring injury predispositions in general, but objective information regarding injuries should be included, in order to have a more complete perspective on the topic. Another limit consisted in the tasks: some of which, such as the Water level test, have proven to be quite difficult to present, with participants struggling to understand the objective of the task, and therefore underperforming. Thirdly, the online format entailed many advantages (especially during the pandemic), but many disadvantages as well. Indeed, some participants had more technical issues or simply were less tech-savvy than others, and felt more nervous for this reason. Therefore, their performance could have been influenced by this ulterior pressure. Future research should consider these new administrative techniques with caution and taking its limitations into account.

5 Chapter 4: Accidental injuries in adolescents: the analysis of cognitive, attentional and behavioral factors

5.1 Introduction

The previous chapters provided a description of studies carried out across the general population, mainly composed of adults. The variables included so far were individual (age, gender and cognitive failures) and cognitive (intellectual, spatial, attentional and executive functions). A consistent part of the literature has shown that people with greater injury proneness more likely manifested better spatial skills (Voyer & Voyer, 2015), poorer executive skills (Shen et al.,2021) and poorer nonverbal reasoning (Withley et al., 2010).

Injury proneness was measured as a self-perceived modality in the previous chapters, with a new questionnaire, i.e. the Injury Proneness Questionnaire (IPQ). The profile that emerged from the results of the previous studies was the following: younger adults would self-perceive themselves as being more prone to injuries than older participants, whereas gender differences were characterized by males admitting their greater injury predisposition when getting involved in risky situations, and females when being clumsy and committing errors Moreover, participants who declared higher injury proneness had indeed experienced more injuries in their life. Poor motor coordination and good intellectual, spatial and attentional skills were risk factors for incurring injuries. However, a good portion of the younger populations remains unexplored. Youths have shown a predisposition towards risky behaviors and injuries; indeed, accidental injuries are the most common cause of pediatric death, accounting for the death of American children and adolescents (National Center for Injury Prevention and Control, NCIPC, 2008). The road environment is considered one of the most dangerous, and more than half of the victims are represented by pedestrians, cyclists and motorcyclists. In 2016, an average of 3700 deaths a day were registered, the main victims being people between 5 and 29 years of age (WHO, 2020). Therefore, even pedestrians or people without a specific driver's license are at risk in this context. Moreover, children with greater injury proneness were supervised less often by their parents (Damashek & Corlis, 2017; Kuhn & Damashek, 2015). Attentional skills play a crucial role as well; indeed, greater injury proneness was found in individuals with more persistent symptoms of inattention or hyperactivity (Rowe & Maughan, 2009; Glania et al., 2010). Following these considerations, a study focused on the characteristics of injuries in younger people was necessary, since injury proneness can be studied and detected starting from childhood. The present study will also present a comparison between self-perceived information (provided by adolescents) and that provided by other figures who are most often closely related to the participants (parents and teachers). More instruments considering spatial span and executive functions will be introduced. Executive functions, in particular, will be relevant considering the young age of the participants of the present study, and the fact that executive functions are still underdeveloped before adulthood (Zelazo & Carlson, 2012). A further aspect that was analyzed in detail in the present study consisted in spatial skills. As anticipated in chapter 1, spatial skills are categorized in different domains of spatial cognition (Linn & Petersen, 1985; Hegarty et al., 2006). Until now, the Sense of Direction and Spatial Representation scale (SDSR; navigation, chapter 2), Mental rotation (object-based rotation chapter 3) and the Water level test (spatial perception, chapter 3) have been presented. In this chapter, more spatial measures, such as the Perspective Taking task (subject-based rotation), the Embedded figures test and Minnesota Paper Form Board (both evaluating spatial visualization) and the Corsi span backward (visuospatial memory, will be introduced. The reason for this in-depth analysis on spatial skills lies in the fact that it is one of the least explored aspects in injury proneness, and even more so in self-perceived injuries. Furthermore, since spatial cognition is a heterogeneous domain with different categories different results between spatial measures could be identified. The topic of spatial cognition will also be discussed in the following chapter, when considering a meta-analysis comparing typical development and the clinical population.

5.2 Objectives

After considering the main characteristics of injury proneness provided by the literature, a series of objectives were set. Firstly, the intent was to analyze the difference between specific points of view. For this reason, separate versions of the same instrument (the IPQ) were created to test eventual differences between the self-perceived injury proneness provided by the main figure, i.e. the student, and injury proneness examined from an external point of view, in this case the parent. Secondly, injury proneness was examined in relation to other variables such as attention and hyperactivity, spatial, cognitive and executive skills, motor coordination and parental supervision. A third objective consisted in the exploration of injury proneness in relation to accidents and experience in the road environment.

5.3 Method

5.3.1 Participants. A total of 99 students (44 males, 55 females; age M = 12.77, SD = 1.28) were recruited from local middle and high schools (from 6th to 9th grade included). Adults were involved as well, i.e. the students' parents and teachers, thus providing 99 reports from parents and 92 from teachers. The inclusion criteria for students were: age between 12-16 years and sufficient knowledge of the Italian language in order to comprehend the basic instructions of all tasks. Exclusion criteria were neurological disorders or diseases capable of causing cognitive, visual or auditory impairment. Some individual differences within the group were identified: 3 students had learning disorders, whereas 15 had foreign parents.

Out of the 99 results from the parents, 79 were completed by mothers, 14 by fathers, 5 by both parents and 1 by another parental figure (e.g. caregiver). All participants were tested from February to June 2021 and recruited through word of mouth and personal connections. The Ethical Committee for Psychological Research at the University of Padova approved the study (number: 4390). The involved school boards and families were informed of the purposes of the study and gave their informed consent in accordance with the Declaration of Helsinki (World Medical

Association, 2013). Informed consent was gathered before the experiment, and minors provided the signed consent of their parents (or guardians).

5.3.2 Materials. The following instruments were presented to students, teachers and parents.

5.3.2.1 Material for students. The present material is administered to students. Test and questionnaires aimed at students evaluating self-perceived injury proneness (IPQ), cognitive skills (Cattell), memory span (Digit span and Corsi block task), spatial skills (Perspective taking, Mental rotation, Embedded figures, Minnesota Paper Form Board), inhibitory control (Go/No-go task), decision making (Iowa Gambling Task) and road experience (Road accident density).

5.3.2.1.1 IPQ Student. The following questionnaire is an adapted self-report version of the CIRB Questionnaire (Children's Injury Related Behaviour; Rowe & Maughan, 2009), which was translated from English to Italian by a native speaker and later tested and standardized in a previous study. The questionnaire was reduced to 29 items and is characterized by 3 main subscales: Error ($\alpha = 0.82$) including items from 1 to 13, Risk taking ($\alpha = 0.73$) including items from 14 to 22 and Danger evaluation ($\alpha = 0.51$) with items from 23 to 29. Overall, the IPQ has demonstrated good reliability with $\alpha = 0.84$. Participants self-report their injury proneness in different daily situations by means of a Likert scale (from "never = 0" to "very often = 4"), with a total ranging from 0 to 116. The total score consists in the sum of points in each item; thus the greater the total score, the greater the severity.

5.3.2.1.2 Cattell (Cattell & Cattell, 1954). This instrument evaluates fluid reasoning regardless of language or level of education. A series of tasks with images that the participant has to complete as accurately as possible within a specific limit of time are presented. The 2B version was used for this experiment. It is made up of 4 parts, including a set of items, and each item presents an incomplete target image: the objective of the task is to choose the option (among those presented) that best completes the target image by following its pattern in a logical sense. One point is rewarded for each correct answer. Hence the total score ranges from 0 to 48. The total raw scores were considered in the analyses.

5.3.2.1.3 Perspective taking (De Beni et al., 2014). The present instrument is an Italian adaptation of the classical test of Kozhevnikov and Hegarty (2001) which evaluates perspective taking with a specific array of introduced elements. A map is presented with a series of elements, such as a house, a tree, a car or a cat, each with its a specific position. There are 6 items, and for each item the person is invited to imagine being in a certain position (e.g. next to the car), facing another element (e.g. the house), and to indicate the direction of a third object (e.g. the tree) in relation to the current imagined position. Accuracy, i.e. the number of times the right direction was signaled and total margin of error in the task (represented by degrees) are calculated. The participant has 5 minutes to complete the task.

5.3.2.1.4 Mental rotation test (short version; De Beni et al., 2014). The present test is a shorter version of the classical Vandenberg & Kuse (1978) task, with 10 items to be completed within 4 minutes. Each item presents a target image, and the objective is to identify 2 options that coincide with the target image despite their being rotated in different positions. If the person identifies both correct options, the score is 1, whereas if none of the options are correct the score is

0. As an exception, considering the young age of the participants, partially correct answers were also considered, so if one of the identified options is correct, the score for the item is 0.5. The total score in the task ranges from 0 to 10.

5.3.2.1.5 Embedded figures test (De Beni et al., 2014). This version is an Italian adaptation of the test of Oltman and colleagues (1971). The objective in this task is to identify and trace simple geometrical figures within a more complex configuration embedding the target image. The task is composed of 3 main parts: an introductory section with 3 items and no time limits, a second part with 5 items and a time limit of 150 seconds, and a final part with 5 items and a 150 second limit. One point is rewarded for each correct answer, so the total score ranges from 0 to 13.

5.3.2.1.6 Minnesota Paper Form Board (MPFB). The present test is an Italian drafted version of the classical test of Likert and Quasha (1941), evaluating the ability to reconstruct a target stimulus by joining available pieces. The obtained image is supposed to be identical to the target one, so the parts should not overlap with one another or be rotated in other positions. For each target image there are five alternatives, listed from A to E, to choose from: each alternative contains a series of pieces that should create the target when placed together, like a puzzle. Only one alternative is correct. There are 16 items in total and the participant has 5 minutes to complete the task.

5.3.2.1.7 Digit span backward (Wechsler, 2003). This test was selected from the WISC battery. The experimenter repeats a sequence of numbers and the participant has to repeat it in the reverse order, from the most recent number to the least. As the task proceeds, the list becomes longer and more challenging by adding an extra number after completing a level of difficulty. Every level includes 2 trials and the task ends when the participant fails both trials of the same level. Span levels were considered; the span could go from 0 to 8.

5.3.2.1.8 Corsi span backward. This computerized version of the test of Corsi (1972) introduces the participant to an array of blocks. Certain blocks are illuminated for a brief second during a presentation phase; the participant has to memorize the reverse sequence of blocks that were illuminated in the presentation phase and click on the blocks in the correct order. As the task goes on, the list becomes longer, by adding an extra block to remember after each completed level. Every level includes 2 trials; the task ends when the participant fails both trials of the same level. Span levels, going from 0 to 9, were considered.

5.3.2.1.9 Iowa Gambling Task (IGT). The task is a computerized adapted version of the one used by Gianfranchi et al., 2017. The participant starts with an imaginary prize of 2,000 euro and has to increase the prize as much as possible. A series of 4 card decks are presented: 2 of these are advantageous (smaller wins but also smaller losses), while the other 2 lead to disadvantages in the long run (larger prizes but also a greater risk of losing). The task lasts about a few minutes on average and continues until both decks of the same kind are finished, or after picking 100 cards. The mean reaction time per card choice and the final prize that is obtained are the main variables considered in this study.

5.3.2.1.10 Road accident density questionnaire. The questionnaire is customized and includes a series of questions regarding driving experience and accidents as a pedestrian and/or cyclist and motorcyclist. The questionnaire is introduced by the experimenter as an interview, with questions regarding road experience as a pedestrian or a driver (in this experiment as a cyclist or motorcyclist). An initial block of 7 main questions estimates the driving and accident frequency experienced by the participant with the vehicle. The second block consists of 21 questions regarding nearly-missed accidents: each question describes a specific scenario and the participant has to say if such scenario had ever been experienced as a pedestrian and/or cyclist and motorcyclist. The total number of near misses as a specific road user (e.g. pedestrian or cyclist) is the sum of all times during which each scenario happened to the participant in each role. In this study, we focused on the number of accidents and near misses as a cyclist and pedestrian.

5.3.2.1.11 Go/No-go. The whole task lasts a few minutes (about 4 or 5), with 300 stimuli being presented one after another. The participant has to press the spacebar of a computer keyboard every time the relevant (Go) stimulus appears and do nothing whenever the irrelevant (No-go) stimulus appears. Mean reaction time (in milliseconds) and error rates are considered. Two types of errors are possible: false alarms, whenever the person clicks when it is not necessary; on the contrary, omissions when the person is supposed to click and signal the presence of the go stimulus and does not do so. The task contains a total of 200 Go stimuli and 100 No-Go stimuli, which are presented in randomized order for each participant.

5.3.2.2 Material for teachers. The teacher is invited to provide some basic details regarding the class (e.g. indicating students with intellectual disabilities, learning disorders or foreigners who are still learning Italian). The following two questionnaires are sent to the teacher, evaluating each student with the SDAI, rating symptoms of inattention and hyperactivity and the Motor Observation Questionnaire for teachers (MOQ-T), estimating the severity of motor coordination issues.

5.3.2.2.1 SDAI (Marzocchi et al., 2010). This questionnaire is the teacher version of the SDA scales from the BIA battery, which estimates the frequency of symptoms of inattention and hyperactivity manifested by the student. There are 18 items describing specific scenarios: the teacher has to rate the frequency of these scenarios by means of a Likert scale (from "never = 0" to "very often = 3"). Items: 1-3-5-7-9-11-13-15-17 evaluate situations of inattention, while items: 2-4-6-8-10-12-14-16-18 evaluate situations of hyperactivity. Thus 2 totals can be calculated, i.e. one for inattention, by adding the scores given in each item of the subscale, and one for hyperactivity, which is obtained by adding the other items. The higher the score of the subscale, the more persistent the symptomatology; each total can therefore range from 0 to 27.

5.3.2.2.2 Motor Observation questionnaire for Teachers (MOQ-T; Giofrè et al., 2015). This questionnaire is the Italian adaptation of the one proposed by Schoemaker and colleagues (2006). A series of 18 questions concerning difficulties or disabilities with gross- or fine-motor coordination are introduced: the teacher has to indicate how often the issue happens with a Liker scale (from "never true = 1" to "always true = 4"). The total is given by the sum of the scores in each item; therefore, the higher the score, the greater the severity manifested by the student. The total score can range from 18 to 72.

5.3.2.3 Material for parents. Parents are invited to complete 3 questionnaires: the IPQ for evaluating the injury proneness of their children, the SDAG questionnaire, for rating symptoms of inattention and hyperactivity manifested by their children, and the Parental Supervision Attitudes Profile Questionnaire (PSAPQ) to self-rate their supervision style and beliefs regarding danger or risk in general.

5.3.2.3.1 IPQ Parent. The following questionnaire is an adapted version of the CIRB Questionnaire (Children's Injury Related Behaviour; Rowe & Maughan, 2009) and includes the same type and amount of questions of the IPQ Student version, with the only difference that the questions are addressed to parents who evaluate their child, instead of being self-reported. There are 29 items and 3 main subscales: Error ($\alpha = 0.88$) including items from 1 to 13, Risk taking ($\alpha = 0.85$) including items from 14 to 22 and Danger evaluation ($\alpha = 0.70$) with items from 23 to 29. Overall, the IPQ has demonstrated good reliability with $\alpha = 0.90$. Parents report their child's injury proneness in different daily situations on a Likert scale (from "never = 0" to "very often = 4"), with a total from 0 to 116. The total score is given by the sum of points in each item; thus the greater the total score, the greater the severity.

5.3.2.3.2 SDAG (Marzocchi et al., 2010). This questionnaire is the parent version of the SDA scales from the BIA battery, estimating the frequency of symptoms of inattention and hyperactivity that are manifested by their child. There are 18 items describing specific scenarios: the parent has to rate the frequency of these scenarios with a Likert scale (from "never = 0" to "very often = 3"). Items: 1-3-5-7-9-11-13-15-17 evaluate situations of inattention, while items: 2-4-6-8-10-12-14-16-18 evaluate situations of hyperactivity. Thus, 2 totals can be calculated: one for inattention, by adding the scores given in each item of the subscale, and one for hyperactivity obtained by adding the other items. The higher the score of the subscale, the more persistent the symptomatology; each total can range from 0 to 27.

5.3.2.3.3 Parental Supervision Attitudes Profile Questionnaire (PSAPQ; Morrongiello & Corbett, 2006). A translated version of the questionnaire is provided to parents. A series of 29 statements regarding styles of supervision adopted by parents when looking after their child are introduced. Parents have to express how often they do whatever is described in each sentence, following a Likert scale (from “never = 1” to “always = 5). There are 4 subscales, all of which demonstrated an adequate internal consistency, considering our sample: Protectiveness ($\alpha = 0.79$) including items from 1 to 9, Supervision ($\alpha = 0.76$) with items from 10 to 18, Risk tolerance ($\alpha = 0.72$) with items from 19 to 26 and Fate ($\alpha = 0.68$) with items from 27 to 29. The whole instrument demonstrated sufficient internal consistency ($\alpha = 0.64$). The total is obtained by adding all the scores given in each item, and therefore it can range from 29 to 145.

5.3.3 Methods

The experiment was carried out with the students following a dual modality: collectively in person, and individually online through Zoom platform with the assistance of the experimenter. The collective session would usually last about 90 minutes, while the individual one would last about an hour. During the collective session, students were administered the following instruments in this specific order: Cattell test, Perspective taking task, Mental rotation test, IPQ Student version, Embedded figures test and MPFB. During the individual session students completed these tasks in the specific order: Digit span (backward), Corsi span (backward), IGT, Road accident density questionnaire and the Go/No-go task. All the material presented in the collective session was printed. Instead, the Digit span and Road accident density questionnaire were completed orally, the Corsi span and Go/No-go task were implemented using the Psytoolkit platform (Stoet 2010; Stoet, 2017) and the IGT was executed through Open Sesame, supported by the Jatos platform. The questionnaires addressed to adults (teachers and parents) were sent via email or handed out in person and collected in the same modality.

5.4 Results

Descriptive statistics and correlations were the main analyses that were considered for this research, which is still in progress. The main focus of the analysis was directed towards the IPQ questionnaire and the comparison between its two versions and other questionnaires and cognitive tasks. In particular, the points of view of students and adults regarding injury proneness and ADHD-like symptoms were considered, along with road behavior and experiences.

5.4.1 Differences between IPQ versions. The IPQ scores of both versions were analyzed (Table 10). Significant differences emerged in the scores provided by students and parents. More specifically, with a paired samples T-test the difference between the total scores was significant with $t(97) = 12.19$, $p < 0.001$, Cohen's $d = 1.23$. Significant differences in scorings were also found in all the subscales: for IPQ Error $t(97) = 6.21$, $p < 0.001$, $d = 0.63$; for IPQ Risk taking $t(97) = 11.17$, $p < 0.001$, $d = 1.13$; for IPQ Danger evaluation $t(97) = 6.83$, $p < 0.001$, $d = 0.69$.

Table 10. *M (SD) scores for each subscale and total score of the IPQ (Injury Proneness Questionnaire), according to student and parent versions.*

Error		Risk		Danger		Total	
Student	**Parent**	**Student**	**Parent**	**Student**	**Parent**	**Student**	**Parent**
19.29 (8.38)	13.13 (8.22)	12.96 (8.03)	4.79 (5.31)	9.66 (4.25)	6.31 (4.10)	41.91 (16.18)	24.23 (14.44)

Pearson's correlations were carried out comparing all subscales of the IPQ from each version (Table 11).

Table 11. *Pearson's Correlations (99 students, 99 parent reports). Significant values are flagged: * p<0.05, **p<0.01, ***p<0.001. IPQ-Error = Injury Proneness Questionnaire-Error subscale; IPQ-Risk = Injury Proneness Questionnaire-Risk taking subscale; IPQ-Danger = Injury Proneness Questionnaire-Danger evaluation subscale; IPQ-Total = Injury Proneness Questionnaire- Total score (sum of the 3 subscales).*

	1	*2*	*3*	*4*	*5*	*6*	*7*
1 Student IPQ Error							
2 Student IPQ Risk	0.44***						
3 Student IPQ Danger	0.25*	0.46***					
4 Student IPQ Total	0.80***	0.85***	0.62***				
5 Parent IPQ Error	0.29**	0.38***	0.32**	0.42***			
6 Parent IPQ Risk	0.33***	0.46***	0.24*	0.47***	0.54***		
7 Parent IPQ Danger	0.42***	0.44***	0.32**	0.52***	0.44***	0.44***	
8 Parent IPQ Total	0.41***	0.51***	0.36***	0.56***	0.89***	0.80***	0.69***

All values from the correlation were significant, so the data reported by students was in line with that reported by parents; the main differences in the versions of the IPQ consisted in the fact that students would give themselves a higher score in all the items of the questionnaire, compared to their parents.

5.4.2 IPQ students, inattention, hyperactivity, parental supervision and motor coordination. In this section, scoring given by students in the IPQ was compared to the other questionnaires in the project that were introduced to parents (SDAG for inattention and hyperactivity, PSAPQ for parental supervision) and teachers (SDAI for inattention and hyperactivity, MOQ-T for motor coordination). Therefore, self-reported injury proneness was analyzed in relation to features that had been observed by others. The PSAPQ included a total score, as well as totals for each subscale (Table 12); the total mean score in this questionnaire was M = 93.15, SD = 8.89.

Table 12. *M (SD) scores for each subscale and total score of the SDA scales (I = Inattention and H = Hyperactivity), according to student and parent version. The 4 subscales of the PSAPQ are reported (Parent Supervision Attributes Profile Questionnaire; P = Protectiveness, S = Supervision, R = Risk tolerance, F = Fate). Total score of the MOQ-T (Motor Observation Questionnaire for Teachers).*

SDAG		SDAI		PSAPQ				MOQ-T
I	H	I	H	P	S	R	F	
6.89 (4.99)	4.06 (3.72)	5.83 (7.23)	2.96 (5.54)	33.17 (5.78)	26.22 (5.16)	27.69 (4.89)	6.07 (2.39)	21.90 (9.54)

Both parents and teachers reported higher scores, hence stronger severity, in the Inattention subscale of the SDA scales. Higher scores in the PSAPQ corresponded to a higher level of agreement. The higher the score of the MOQ-T, the stronger the severity of motor coordination difficulties. Correlations were carried out to verify the relation of the total scores in these questionnaires in relation to the IPQ student version (Table 13).

Table 13. *Pearson's Correlations (99 students, 99 parent reports, 92 teacher reports). Significant values are flagged: * p<0.05, **p<0.01, ***p<0.001. IPQ-Error = Injury Proneness Questionnaire-Error subscale; IPQ-Risk = Injury Proneness Questionnaire-Risk taking subscale; IPQ-Danger = Injury Proneness Questionnaire-Danger evaluation subscale; IPQ-Total = Injury Proneness Questionnaire- Total score (sum of the 3 subscales); MOQ-T = Motor Observation Questionnaire for teachers; PSAQP = Parent Supervision Attributes Profile Questionnaire*

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1 Student IPQ Error									
2 Student IPQ Risk	0.44***								
3 Student IPQ Danger	0.25*	0.46***							
4 Student IPQ Total	0.80***	0.85***	0.62***						
5 SDAI Inattention	0.20	0.29**	0.21*	0.30**					
6 SDAI Hyperactivity	0.14	0.25*	0.09	0.22*	0.70***				
7 MOQ-T	0.02	-0.02	-0.01	-0.002	0.61***	0.27*			
8 SDAG Inattention	0.20*	0.32**	0.29**	0.34***	0.28**	0.11	0.09		
9 SDAG Hyperactivity	0.31**	0.23*	0.17	0.32**	0.15	0.14	-0.02	0.65***	
10 PSAPQ Total	0.04	-0.13	-0.24*	-0.11	-0.01	0.08	0.01	-0.004	0.13

Significant correlations were found. The IPQ representing students' point of view correlated with the SDAG and SDAI questionnaires. Therefore, a higher score of self-reported injury proneness was associated with greater inattention and hyperactivity indicated by adults (parents and teachers). Furthermore, the SDAI questionnaire correlated with another instrument presented to teachers, i.e. the MOQ-T ($r = 0.61$, $p < 0.001$ for inattention; $r = 0.27$, $p < 0.05$ for hyperactivity);

students with greater symptoms of hyperactivity and inattention in the school environment were also more prone to experience motor coordination difficulties. The total score on the PSAPQ questionnaire, an instrument addressed to parents, did not show any significant correlation with the SDAG. However, a significant correlation was found with the Danger evaluation subscale ($r = -0.24$, $p < 0.05$), therefore poorer danger evaluation of the participant was often associated with a less frequent supervision on the parent's part.

5.4.3 IPQ in relation to cognitive skills and executive functions. In this section, greater focus was offered on the tasks exclusively, with the objective of considering certain cognitive skills such as nonverbal reasoning, spatial skills, memory span (both verbal and visuospatial) and executive functions (e.g. sustained attention, impulse control and risk anticipation). More specifically, accuracy was measured in all tests, often considering the total score of correct answers as well as reaction times and error rates. Table 14 reports all the mean values that were found for each variable (Table 14).

Table 14. *Mean and standard deviation for the total scores in each task. Mean reaction times in the Iowa Gambling Task and Go/No-go task are represented in msec. The total prize obtained in the Iowa Gambling Task is expressed in euro. IGT = Iowa Gambling Task, MPFB = Minnesota Paper Form Board.*

Task variable	M (SD)
Cattell	31.35(5.19)
Digit Span	4.67(1.34)
Corsi	4.04(2.19)
Iowa mean reaction time (msec)	2054.77(898.88)
Iowa prize	2084.90(386.27)
Go/No-go false alarm	4.27(4.10)
Go/No-go omission	0.69(1.48)
Go/no-go mean reaction time (msec)	476.31(113.36)
Perspective taking accuracy	3.39(2.13)
Perspective taking error	368.23(274.69)
Mental rotation	5.76(1.99)
Embedded figures	7.43(3.38)
Minnesota paper form board	7.35(3.57)

After considering the descriptive values, Pearson's correlations were conducted. Firstly, cognitive variables were compared with the IPQ student version (Table 15). Afterwards, the same kind of comparison was made with the IPQ parent version (Table 16).

Table 15. *Pearson's Correlations (99 students). Significant values are flagged: * p<0.05, **p<0.01, ***p<0.001. The IPQ in this table is the student version. IPQ-Error = Injury Proneness Questionnaire-Error subscale; IPQ-Risk = Injury Proneness Questionnaire-Risk taking subscale; IPQ-Danger = Injury Proneness Questionnaire-Danger evaluation subscale; IPQ-Total = Injury Proneness Questionnaire- Total score (sum of the 3 subscales); IGT = Iowa Gambling Task; MPFB = Minnesota Paper Form Board*

	IPQ ERROR	*IPQ RISK*	*IPQ DANGER*	*IPQ TOTAL*
1 Cattell	-0.19	-0.15	-0.05	-0.18
2 Digit Span	0.13	0.08	0.09	0.13
3 Corsi	-0.005	-0.06	-0.11	-0.06
4 Iowa mean reaction time	-0.16	-0.08	-0.08	-0.14
5 Iowa prize	-0.08	-0.02	0.05	-0.04
6 Go/No-go false alarm	0.22*	0.05	0.21*	0.19
7 Go/No-go omission	0.003	0.06	0.11	0.06
8 Go/No-go mean reaction time	-0.04	-0.01	-0.02	-0.03
9 Perspective taking accuracy	0.03	-0.04	0.001	-0.01
10 Perspective taking error	0.003	0.14	0.003	0.07
11 Mental rotation	-0.35***	-0.22*	-0.16	-0.33***
12 Embedded figures	-0.07	-0.12	0.0001	-0.09
13 Minnesota Paper Form Board	-0.09	-0.14	-0.01	-0.12

Few significant correlations emerged. The amount of false alarm errors in the Go/No-go task reported significant values with IPQ Error ($r = 0.22$, $p < 0.05$) and IPQ Danger ($r = 0.21$, $p < 0.05$). Spatial measures reported relevant values as well, with Mental rotation being correlated with IPQ

Error ($r = -0.35$, $p < 0.001$), IPQ Risk ($r = -0.22$, $p < 0.05$) and IPQ Total ($r = -0.33$, $p < 0.001$). The same analyses were conducted with the parent version (Table 16).

Table 16. *Pearson's Correlations (99 students, 99 parent reports). Significant values are flagged: * p<0.05, **p<0.01, ***p<0.001. The IPQ in this table is the parent version. IPQ-Error = Injury Proneness Questionnaire-Error subscale; IPQ-Risk = Injury Proneness Questionnaire-Risk taking subscale; IPQ-Danger = Injury Proneness Questionnaire-Danger evaluation subscale; IPQ-Total = Injury Proneness Questionnaire- Total score (sum of the 3 subscales); IGT = Iowa Gambling Task; MPFB = Minnesota Paper Form Board*

	IPQ ERROR	*IPQ RISK*	*IPQ DANGER*	*IPQ TOTAL*
1 Cattell	-0.02	-0.01	-0.16	-0.06
2 Digit Span	0.19	0.19	0.08	0.20*
3 Corsi	-0.07	0.04	-0.02	-0.03
4 Iowa mean reaction time	-0.24*	-0.07	-0.19	-0.22*
5 Iowa prize	0.11	0.01	0.05	0.08
6 Go/No-go false alarm	0.11	-0.04	0.07	0.07
7 Go/No-go omission	-0.12	0.14	-0.005	-0.02
8 Go/No-go mean reaction time	-0.05	0.21*	0.05	0.06
9 Perspective taking accuracy	-0.09	-0.12	-0.07	-0.11
10 Perspective taking error	0.04	0.17	0.07	0.11
11 Mental rotation	-0.29**	-0.24*	-0.33**	-0.35***
12 Embedded figures	0.004	-0.04	-0.04	-0.03
13 Minnesota Paper Form Board	0.19	-0.03	-0.06	0.02

Once again, mental rotation was a measure that yielded significant values, especially with IPQ Error ($r = -0.29$, $p < 0.01$), IPQ Risk ($r = -0.24$, $p < 0.05$), IPQ Danger ($r = -0.33$, $p < 0.01$) and IPQ Total ($r = -0.35$, $p < 0.001$). Digit span correlated with IPQ Total ($r = 0.20$, $p < 0.05$). Mean reaction time in the IGT was significant with IPQ Error ($r = -0.24$, $p < 0.05$) and IPQ Total ($r = -0.22$, $p < 0.05$) and the mean reaction time in the Go/No-go task was significant with IPQ Risk ($r = 0.21$, $p < 0.05$).

5.4.4 IPQ in relation to self-reported street accidents. Questions regarding the Road accident density questionnaire were analyzed in this part. None of the participants so far reported possessing or having any experience with motorbikes or scooters, however they all had experience with bike riding. Hence questions regarding cyclists or pedestrians were ultimately considered. Mean scores of the number of accidents experienced or nearly missed when riding a bicycle or when moving as a pedestrian were reported. Near misses were calculated counting the number of times the participants reported to have experienced potential scenarios when walking or riding a bike. According to the mean scores, the number of near misses were more frequent when riding a bicycle. Moreover, the question regarding actual accidents that happened on bicycles was considered, since it was the most frequently used vehicle within the sample (Table 17).

Table 17. *Mean (standard deviation) of the Road accident density questionnaire. Number of episodes of nearly missed accidents as a biker or pedestrian and number of effective accidents as a biker.*

Road accident density questionnaire		
Near misses bicycle	**Near misses pedestrian**	**Accidents with bicycle**
4.15(2.91)	1.88(1.94)	1.38(1.10)

Correlations were taken into account with the purpose of comparing measures of self-reported injury proneness (IPQ student version) and measures of potential (near misses) and effective (accidents with bicycle) injuries (Table 18).

Table 18. *Pearson's Correlations (99 students). Significant values are flagged: * p<0.05, **p<0.01, ***p<0.001. The IPQ in this table is the student version. IPQ-Error = Injury Proneness Questionnaire-Error subscale; IPQ-Risk = Injury Proneness Questionnaire-Risk taking subscale; IPQ-Danger = Injury Proneness Questionnaire-Danger evaluation subscale; IPQ-Total = Injury Proneness Questionnaire- Total score (sum of the 3 subscales).*

	IPQ ERROR	*IPQ RISK*	*IPQ DANGER*	*IPQ TOTAL*
1 near misses bicycle	0.08	0.37*	0.20*	0.28**
2 near misses pedestrian	0.22*	0.13	-0.003	0.18
3 accidents with bicycle	0.15	0.36***	0.34***	0.34**

Missed or experienced accidents correlated with different subscales of the IPQ (Risk, Danger and Total), while near misses as a pedestrian correlated with IPQ Error ($r = 0.22$, $p < 0.05$).

5.5 Discussion

A consistent research body supports the claim that accidental injuries are a serious issue, even among children and adolescents (e.g. NCIPC, 2008). The present work focused on a target of participants aged 12-16 years while involving schools and family. A series of measures evaluating individual differences, such as spatial, cognitive and attentional skills, executive functions, motor coordination, road experience and parental supervision were included and analyzed in relation to injury proneness, which was measured with 2 versions of the IPQ questionnaire, one for students and the other for parents. A difference between the 2 IPQ versions emerged, with students rating their injury predisposition twice as much as that rated by their parents. Different plausible reasons could explain this result: the students were not probably as objective as their parents, and they might have exaggerated their situation. Another possible theory could lie in the fact that parents might not know about all of the dangerous situations experienced by their children, therefore they could have rated injury proneness considering only the events they knew or were informed of. This finding was interesting, but further evidence is needed in order to confirm it.

Self-reported injury proneness correlated with hyperactivity and inattention symptoms reported by parents (SDAG) and teachers (SDAI); this supports the fact that injury proneness tends to be greater with stronger inattention and hyperactivity symptoms (Rowe & Maughan, 2009; Glania et al., 2010). The PSAPQ correlated significantly only with the Danger evaluation subscale of the IPQ student version, hence poorer danger evaluation of the participant was often associated with less frequent supervision from the parent. When considering the IPQ student version in relation to other measures, it emerged that with the increase of self-reported injury proneness, errors in the Go/No-go task (inhibitory control) would increase, while performance in the Mental rotation tasks would decrease. These results support the claim that people with greater injury predisposition are often those who have issues with spatial (Voyer & Voyer, 2015) and attentional skills (Rowe & Maughan, 2009; Glania et al., 2010). A similar trend was found when considering the IQP parent version: once again, Mental rotation was a significant measure that strongly correlated with the questionnaire.

The student IPQ was compared with missed or experienced accidents: the amount of missed or experienced accidents (particularly as a cyclist) positively correlated with injury proneness. Despite the relevant findings that emerged, some limits must be mentioned. Firstly, not all measures, such as the general injury history of the participant and other background information, were included in these studies. Indeed, most of the information is self-reported. Secondly, the sample size was more limited than expected; a possible solution for this issue could consist in reducing the number of adopted material and simplify the administration process in order to encourage more potential participants (both students and adults). Thirdly, data regarding the clinical population is still missing. Indeed, only students with typical development were included in the study, but it has also been demonstrated that injury proneness affects other specific populations, such as Attention Deficit Hyperactivity Disorder (ADHD; Brunkorst-Kanaan et al., 2021). Therefore, a comparison between typical and atypical development could be studied in order to have a more complete perspective of the phenomenon. Lastly, information regarding injuries in the street environment was limited: this was mainly because the only adopted instrument was an interview. Hence, in future research this information should be collected with more objective measures, such as driving behavior or applications of the rules of the road, measures that could be easily assessed with virtual environment instruments or driving simulators.

6 Chapter 5: Visuospatial abilities in people with ADHD: a meta-analysis

6.1 Introduction

The present chapter analyzes a specific domain, such as spatial cognition, in relation to a specific population, in this case Attention Deficit Hyperactivity Disorder (ADHD). As anticipated in the general introduction, the reason that led towards this kind of research was to find a possible relation between aspects often linked separately to injuries. Indeed, spatial skills have demonstrated to affect injury proneness and people with ADHD are often listed as individuals who are more likely to get hurt, compared to others. Hence, further information on the ADHD profile in spatial skills was necessary in order to confirm this hypothesis.

The aim of the current meta-analysis was to systematically examine the performance of individuals with ADHD in different visuospatial abilities by specifically analyzing performance in tasks related to processing and high-order abilities.

ADHD is a neurodevelopmental disorder which often manifests during childhood and persists throughout adulthood (Frank-Briggs, 2011). It is considered one of the most common neurodevelopmental disorders (Thomas et al. 2015) and is characterized by persistent inattentive and/or hyperactive behaviors severe enough to compromise both professional and personal life (Harpin, 2005; Thurik et al., 2016; Weis, et al., 2019). ADHD is characterized by deficits in multiple domains of cognition. Executive functioning deficits usually involve working memory (WM), inhibitory control, planning and vigilance (e.g. Willcutt et al., 2005). As concerns WM, difficulties are found in both verbal and visuospatial WM (Willcutt et al., 2005), with evidence of a larger impairment in the visuospatial domain compared to the verbal one (see Martinussen et al., 2005); however, this was not confirmed in a successive meta-analysis (see Kasper et al., 2012). Difficulties in visuo-constructional (i.e. Block design) and visual memory measures (i.e. recall tests, such as the Rey figure recall task) in individuals with ADHD were also reported in the meta-analysis of Frazier and colleagues (2004). These results seem to suggest a poor profile in visuospatial abilities in individuals with ADHD. However, the visuospatial construct is broad and heterogenous, and it includes several aspects ranging from processing to high-order cognitive factors. Therefore, a clearer idea of the ADHD profile in relation to visuospatial abilities is necessary.

6.1.1 Visuospatial abilities. The visuospatial construct is quite broad; part of it was introduced in previous sections (chapters 1 and 4). One first distinction is between small-scale and large-scale categories (Hegarty et al., 2006). The former category refers to the ability to process information within a circumscribed space that is smaller than the person's body (Montello, 1993); in contrast, large-scale abilities mainly imply the management of spatial information beyond the human body and can be learned by collecting information from a plurality of points of view (Montello, 1993), as is the case of navigation learning and wayfinding (the ability to reach a destination) in an environment (Wolbers & Hegarty, 2010). As concerns the small-scale category, visuospatial abilities involve several cognitive skills used to generate, retain, and manage abstract visual images (Lohman, 1988). These include visuospatial processing abilities in terms of visuospatial working memory (VSWM), i.e. the ability to retain and process spatial information (e.g. Logie, 1995). The VSWM is also related to visuospatial large-scale (e.g. navigation), as well as to small-scale abilities, such as high-order cognitive factors (Meneghetti et al., 2014; 2016).

A well proven classification of small-scale visuospatial abilities was proposed by Linn and Petersen (1985). With a meta-analytic study, the authors described three distinct factors: spatial perception, spatial visualization and mental rotation abilities. Spatial perception refers to the ability to determine spatial positions in relation to a specific point of view. Some tasks involving this feature include the Rod and Frame Test (Witkin & Asch, 1948) or the Water level test (Piaget & Inhelder, 1956). Spatial visualization involves the manipulation of spatially represented stimuli. There are many tasks included in such a category, such as the Embedded Figures Test (Oltman et al., 1971), Paper Folding Test (Shepard & Feng, 1972), Block Design (WISC-IV, Wechsler, 2003) or Guilford-Zimmerman spatial visualization tests (Guilford & Zimmerman, 1953). Mental rotation is the ability to mentally rotate stimuli. Some examples of this kind of task are the Mental Rotations Task (Vandenberg & Kuse, 1978) and the Card Rotation Test (Ekstrom et al., 1976). Furthermore, the studies showed that rotation is not only based on object-rotation (as typically measured with the Mental Rotations Task) but also on subject-rotation tasks (Hegarty & Waller, 2004), which involve asking a person to imagine adopting a different position in space and seeing his/her surroundings from a new perspective. This ability can be measured with the Perspective-Taking Task (PTT; Hegarty & Waller, 2004), in which respondents imagine adopting new positions that are misaligned with the current physical body position within a configuration of objects. While the model suggested by Linn and Petersen is one of the most cited, other models addressing perspective taking, as well as the three previously mentioned abilities, are present in the literature (e.g. Uttal et al., 2013).

Regardless of the chosen model, another relevant visuospatial feature consists in spatial reasoning (Bednarz et al., 2022). Spatial reasoning involves visuospatial material and implies several skills such as: awareness of space, distance and dimensions, representation of spatial information (internally in the mind, and externally in graphics such as diagrams and maps), interpretation and manipulation of spatial information for problem solving and decision making (Carroll, 1993). Moreover, spatial reasoning includes different levels of visuospatial abilities ranging from the processing abilities (VSWM), to those included in higher levels (such as mental rotation); all these components can compose spatial intelligence (Martìnez et al., 2011).

The importance of studying visuospatial abilities, in a broader sense, mainly lies in their link with several domains of cognitive abilities and with everyday activities. For example, considering the latter, the relation between visuospatial abilities and academic performance in Science, Technology, Engineering and Mathematics (STEM) subjects in school (Lean & Clements, 1981;

Lowrie & Diezmann, 2007; Uttal & Cohen, 2012), and the likelihood of engagement with a STEM career (Kell et al., 2013; Wai et al., 2009) is well-demonstrated.

6.1.2 ADHD and visuospatial abilities. Visuospatial abilities in the ADHD profile have been explored considering only some of the components described above. Most studies concerning VSWM have already been synthesized in several meta-analyses (Martinussen et al., 2005; Kasper et al., 2012; Willcutt et al., 2005).

Martinussen and colleagues (2005) examined performance across all the WM components of individuals with and without ADHD. The research considered twenty-six studies, published between 1997 and 2003, involving children and adolescents. Separate analyses were conducted for each WM component according to the type of memory (verbal and spatial) and the type of function (storage component and manipulation component), and therefore leading to: verbal storage, verbal central executive, spatial storage and spatial central executive. The results illustrated various impairments of the ADHD group in different domains of memory. The dimension of the effects was large in both the spatial storage (d = 0.85) and spatial central executive (d = 1.06), and small in areas concerning verbal memory (verbal storage d = 0.47; verbal central executive (d = 0.43). However, it is noteworthy that there was from moderate to high heterogeneity for both components of VSWM and the verbal central executive component. Therefore, the studies in these three models yielded results with significant variability, whereas the results for the verbal storage component were similar. Publication bias was assessed with a statistic (Egger et al., 1997) which confirmed the presence of bias, and hence significant variability of studies, only in the spatial storage domain. The meta-analyses of Willcut and colleagues (2005; verbal WM d = 0.59; spatial WM d = 0.75) and Kasper and colleagues' (2012; verbal WM d = 0.69; spatial WM d = 0.74) however, reduced the gap between verbal and visuospatial WM by showing a similar level of impairment in the two domains.

For what concerns high-level visuospatial factors, there is some evidence from the meta-analysis of Frazier and colleagues (2004). Although the aim of their work was to summarize results on the IQ and neuropsychological profiles of individuals with ADHD, some findings are relevant for the current study. In fact, they included studies using the Weschler battery (WISC-III or WISC-R) which comprises the Block design subtest, which can be considered a measure of spatial visualization (Uttal et al., 2003). Their results showed that individuals with ADHD differed from typically developing individuals in the Block design subtest, with a small effect size (d =0.41). A recent large archive research analysis on the WISC-IV intellectual profiles of 948 children with ADHD (Toffalini et al., 2022) suggested that the higher-order aspects of the Perceptual reasoning index, which includes measures of spatial reasoning (e.g., matrix reasoning), are preserved in ADHD, while lower-level aspects, such as visual processing speed measures (coding, symbol search), are considerably impaired. The same study found that WM performance is also impaired in ADHD, although the available measures only involved verbal WM tasks.

Evidence concerning large-scale abilities, such as navigation in ADHD, is scarce. Farran et al. (2019) analyzed navigational skills, in relation to motor skills, in children with typical development (TD), ADHD and Williams syndrome (WS). Their results showed that both participants with ADHD and TD were able to learn a path (presented through a virtual environment) at a greater extent compared to the WS group. Furthermore, both the ADHD and WS groups showed motor impairment, and the latter had a significant impact on navigation performance only in participants with WS. Thus, it emerged that individuals with ADHD had evident difficulties with motor skills but this did not affect navigation learning, which was maintained.

6.2 Objectives

The main objective of this meta-analysis was to synthesize studies describing visuospatial abilities in the ADHD profile. As discussed in the previous paragraphs, findings are already available for VSWM (Kasper et al., 2012; Martinussen et al., 2005; Willcutt et al., 2005) and spatial visualization (Frazier et al., 2004), suggesting a weakness of individuals with ADHD in some aspects of visuospatial domain.

Nevertheless, a systematic analysis of visuospatial components is still lacking. In the case of VSWM, for example, the performance of individuals with ADHD was analyzed not distinguishing between the visual and spatial components of VSWM. A large body of evidence suggests the importance of differentiating between these two components. The visual component allows all details regarding the appearance of stimulus to be processed, whereas the spatial component deals with information concerning the spatial location of the stimulus (e.g. Darling et al., 2007; Mammarella et al., 2008). These distinctions proved to properly describe the multidimensional structure of WM in different ages (e.g. preschoolers, Carretti et al., 2022; children and young adults, Roberts et al., 2018; adults and older adults, Mammarella et al., 2013) and individual differences profiles (e.g. individuals with Down syndrome, Lanfranchi et al. 2009; children with nonverbal learning disabilities, Mammarella et al., 2006).

In addition, we focused on visuospatial factors, considering both small- and large-scale abilities. In the case of small-scale abilities, we followed the original model proposed by Linn and Petersen (1985) and analyzed the differences in mental rotation, spatial perception and spatial visualization. For what concerns large-scale abilities, we considered all studies requiring the learning of a large-scale environment, such as navigation, or the reproduction of space in figural (map) or symbolic (description) modalities (as is typically conducted in spatial cognition studies; Denis, 2017). Finally, spatial reasoning tasks were included in our search due to its role in academic and daily life activities (e.g. Uttal & Cohen 2012; Kell et al., 2013).

Considering the literature, we expected to replicate the results on VSWM with a weaker performance of individuals with ADHD compared to the typical developing group. The examination of different sub-components of VSWM will however permit us to extend current knowledge on VSWM functioning of ADHD. For what concerns visuospatial abilities, results in the literature are mixed, so the aim is to summarize the findings to understand the size of the differences reported (i.e. in mental rotation, spatial perception and spatial visualization). According to previous studies (e.g. Cardillo et al., 2020), we do not expect to find general impairment in visuospatial abilities.

In the case of spatial reasoning abilities, because of their close relation with WM (e.g. Kane, Hambrick & Conway, 2005), we expected to find differences between groups with a generally poorer performance in individuals with ADHD.

6.3 Method

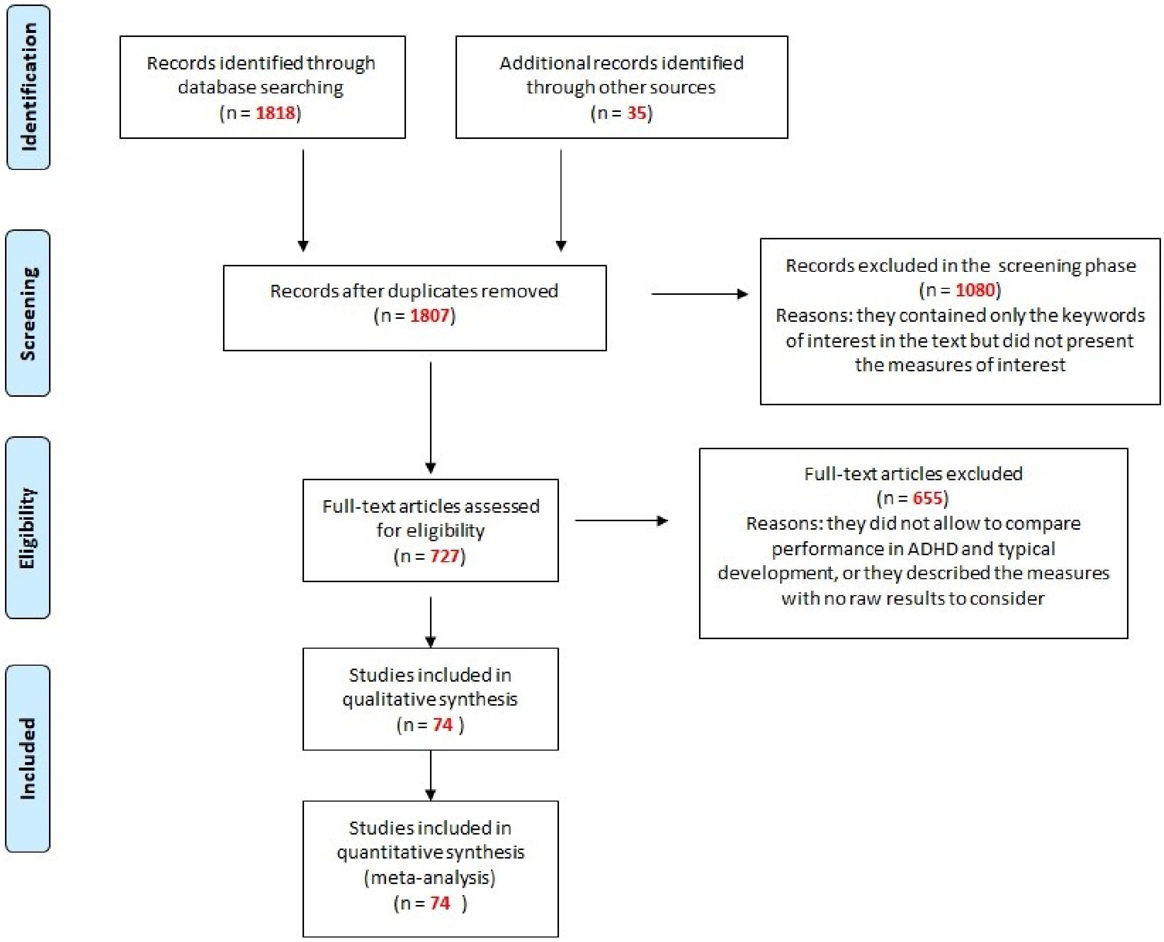
6.3.1 Study Design and Inclusion/Exclusion Criteria. We conducted a systematic review with the purpose of investigating differences in visuospatial abilities between individuals with ADHD, or reporting high ADHD-like symptomatology, according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-III, 1984; DSM-IV, 1994 or DSM-5, 2013) and typical development at any age. We included studies which considered participants with any ADHD subtype, such as the combined or inattention subtype, and eventual comorbidities such as the following: learning disabilities, anxiety, oppositional defiant disorder, conduct disorder, depressive disorder and mood disorders. Results from experiments or training programs were analyzed, as long as the latter included baseline scores for both ADHD and TD at least. The exclusion criteria were major sensory limitations and all psychiatric disorders that compromised cognitive faculties, such as severe neurological conditions, an I.Q. score below 70, substance abuse (e.g., alcohol, drugs or stimulant medication) and a history of head injuries affecting the Central Nervous System. Data was collected from published material, mostly articles and short reports. The collected papers described data from various international contexts (Europe, Asia, Oceania and America) and are written in English; some of these papers included abstracts written in Spanish or Portuguese as well.

6.3.2 Source of Data. Data were obtained from the AIRE portal considering all current and past data; the search was updated in April 2022. The portal extracted data from the following data banks: PubMed, Scopus, EBSCO, PsychINFO, Education Source and SocINDEX. Different keywords were used to search for spatial skills, tests and concepts in ADHD. More specifically, these words were queried: "ADHD" (OR "Attention Deficit Hyperactivity Disorder") AND:

"working memory" or "mental rotation" or "spatial visualization" or "spatial perception" or "perspective taking" or "Raven" or "Cattell" or "block design" or "navigation" or "route learning" or "shortcut" or "cognitive map" or "orientation" or "map learning" or "retracing" or "spatial description" or "spatial text" or "distance estimation" or "map drawing" or "direction" or "Wayfinding" or "Embedded Figures Test" or "Paper Folding Test" or "Paper Form Board" or "Surface Development" or "Differential Aptitude Test" or "Guilford-Zimmerman Spatial Visualization Test" or "Guilford-Zimmerman Spatial Orientation Test" or "Cards Rotation Test" or "mazes" or "Water Level Test" or "Rod and Frame Test" or "environment".

A gradual screening process was conducted, considering the PRISMA flowchart (Page et al., 2021; Figure 11).

Figure 11. *PRISMA flowchart, summarizing the selection process of the works for the meta-analysis. 1,818 results were initially identified; however, almost all of these works were ultimately excluded for qualitative and quantitative analyses. Thirty-five works were manually added and kept for the analyses since they were found as references in other papers (Martinussen et al., 2005; Kasper et al., 2012; Willcutt et al., 2005) and dealt with the topics of interest. The final sample of works in the synthesis included 74 studies.*



6.3.3 Study variables. The dependent variable consisted in performance in each specific domain of visuospatial abilities (Linn & Petersen, 1985), comparing individuals with ADHD (considering chronological age) and peers with typical development. Indeed, we considered the main cognitive domains, i.e. visual and spatial WM, mental rotation, spatial visualization and spatial perception (for small-scale abilities), navigation, route learning, map learning spatial description/text (for large-scale abilities) and spatial reasoning. Performance was expressed in different ways, mostly as mean raw scores in specific tasks, but also as reaction times or number of mistakes. The moderation effect of age and gender was analyzed in the present models.

6.3.4 Coding of the effects. The results were collected in a dataset containing information on the main group (individuals with ADHD, or identified by the authors as having strong ADHD-like symptoms) and the comparison group (individuals with TD or lower symptomatology). The dataset is available on Open Science Framework (OSF).

The effect sizes were Standardized Mean Differences (SMD), calculated as performance differences between the main group and the comparison group. The effects were calculated from descriptive statistics reported in works, and expressed so that negative values of effect size indicated a worse performance in spatial skills in the ADHD group compared to TD. Effect sizes were coded as nested within a group comparison, nested within a study, and ultimately nested within a domain of spatial cognition. Characteristics, such as sample size, mean age, gender percentage, testing setting, measurements involved and category of the spatial aspects involved, were collected for each group.

6.3.5 Statistical analyses. The free software R (RStudio Team, 2022) was used to conduct all analyses with the following packages: "metafor" (Viechtbauer, 2010) to fit multilevel random-effects models (with maximum likelihood estimation), "clubSandwich" (Pustejovsky, 2021) to impute covariance matrices, and "ggplot" (Wickam, 2016) for plotting.

Random-effect models were applied. A three-level random effects study structure was set, with random intercepts for both studies and effects, modeling variance given by: heterogeneity between studies, heterogeneity between effects within studies, and random sampling error. Effect sizes within the same study or comparisons shared substantial sampling error variance due to their being calculated on the same sample of participants. For such a reason, an imputed block-diagonal covariance matrix was built (Pustejovsky, 2021), assuming a constant correlation of r = .50 among effect sizes clustered within the same study. We fitted different meta-analytic models for different visuospatial aspects instead of using multivariate models. We chose to do so because we considered these aspects as different constructs, and because fitting multivariate models implies precise prior quantitative knowledge of the set of correlations among different constructs.

We were interested in assessing the effects of age and gender as moderators, so we initially fitted each model with mean age value and the percentage of females in the ADHD group (see Kasper et al., 2012). The moderation was omitted from the final model when it was not significant.

Publication bias was assessed with the PET-PEESE method, an approach based on meta-regression which has proven to be more effective than other conventional meta-analytic methods (Stanley, 2017). More specifically, a two-step meta-regression was considered: standard error (first step) and variance of the effect size (second step) were used as moderators for the effect size (Stanley & Doucouliagos, 2014). As a meta-regression, this method allows us to assess publication bias while accounting for the presence of (multilevel) dependency structures between the effect sizes, as in our case. The final estimated effect size, which is regarded as bias-free, coincided with the intercept of the model. A problem of any publication bias method based on the relationship between SMD and its variance (including funnel plots and meta-regressions) consists in the fact that the two measures are not independent from each other, so r overestimates the risk of publication bias (Zwetsloot et al., 2017). To tackle this issue, we entered alternate standard error and variance measures in the PET-PEESE meta-regression models, which were calculated after fixing the SMD term inside the variance formula to zero, thus making SMD and its variance orthogonal.

6.3.6 Potential moderators

Age. As in previous meta-analyses (see for example Kasper et al., 2012), age was included as a moderator for two reasons. On one hand, there is evidence of changes in the symptomatology of ADHD with age (e.g. Langberg et al., 2008), and these variations can differentially affect performance (and therefore the difference with peers). On the other hand, increases in age are reported in the literature for all the variables considered in the current meta-analysis (for example, in the case of WM, see van Ewijk et al., 2014), and these changes can moderate the dimension of the differences between participants with and without ADHD. Age was analyzed as a continuous moderating variable.

Gender. Gender was considered as moderator as well; in particular, following Kasper et al. (2012), the percentage of female participants in the ADHD group was included. Indeed gender differences are frequently present in the ADHD profile, with females being more likely to exhibit attention difficulties and males often demonstrating hyperactivity–impulsivity symptoms (e.g. Biederman & Faraone, 2004). In addition, gender differences are reported for some spatial abilities (e.g. Laurel, Yhang & Laurenco, 2019; Wang & Carr, 2014).

The percentage of females in the ADHD group that was included in each study was analyzed as a continuous moderating variable.

6.4 Results

6.4.1 Overview. Effect sizes from 74 studies were coded, 45 of which included multiple group comparisons. Five of these studies considered participants with no confirmed diagnosis of ADHD, but rather a strong symptomatology. Considering the sample sizes of all the studies, 3,524 participants were part of the main group, whereas 3,688 were included in the comparison group.

Individuals of different ages were included, mainly youths; the mean age for the ADHD group was 12.56 years (minimum 5 years and maximum 38 years), whereas the one for the typical development group was 12.10 (minimum 5.08 years and maximum 32.50 years).

The mean percentage of male participants in the ADHD group was 78.07%. Male participants in the comparison group formed a mean percentage of 70.24%.

Thirty-five studies included people with ADHD manifesting comorbidities, the most cited of which were: learning disorders (particularly dyslexia and dyscalculia), oppositional defiant disorder, anxiety disorders, depressive disorders, mood disorders. Other comorbidities reported by these studies, although to a lesser degree, were: conduct disorder, sleep disorder, autism, Post-Traumatic Stress Disorder, presence of tics, social communication disorder, personality disorder, eating disorders and motor disabilities.

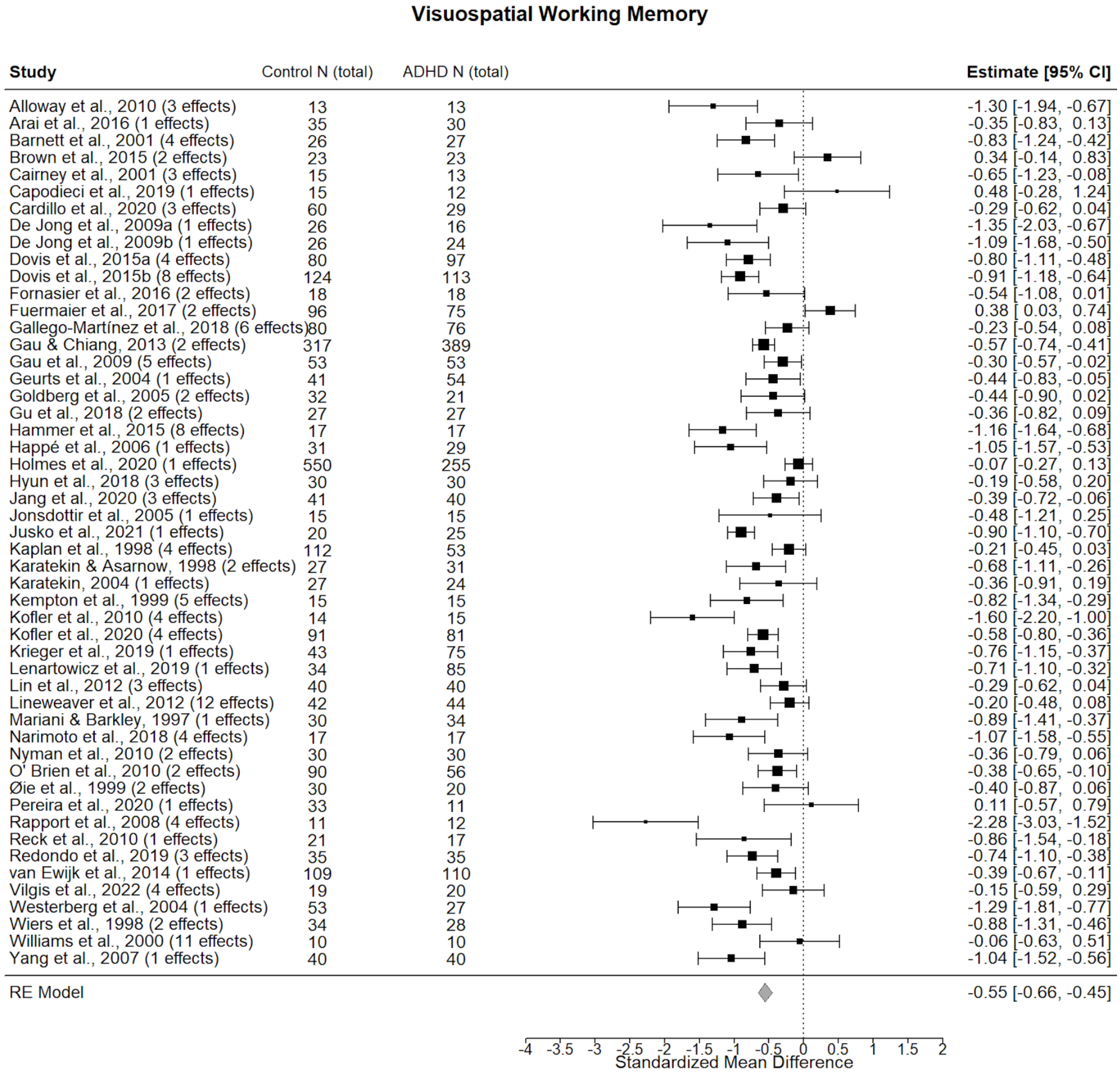
All works were categorized in the previously described main categories. A total of 146 results were part of VSWM, 16 of mental rotation, 53 of spatial visualization, and 9 of spatial reasoning. Spatial perception, as well as route learning (navigation), included only one study, therefore no specific analyses were conducted for latter measures. In the case of VSWM, an ulterior analysis was carried out separately considering results from tasks requiring the memorization of visual features from those based on predominant spatial aspects. Therefore, a first model for overall VSWM was created, followed by two separate models for results concerning predominant visual memory (24 effects) and spatial memory (122 effects). A total of 227 effect sizes were coded (Table 19, Appendix C), but 225 were ultimately considered in the analyses, since models with the age moderator automatically excluded those effects with no details regarding the mean age of the principal sample.

6.4.2 Visuospatial working memory. The estimate of the mean effect (without moderators) was d = -0.56 [95% CI: -0.68, -0.44], $p < 0.001$; with substantial overall heterogeneity, $I^2 = 75.09\%$. The between-study variance, $\tau^2_1 = 0.09$ was similar to the within-study variance, $\tau^2_2 = 0.07$. The heterogeneity of effect sizes between studies was significant ($p < 0.001$).

Effects of the moderators. The overall effect of moderation was significant, $F(2,143) = 9.22$, $p < 0.001$. Only age was a significant moderator, B = 0.03 [0.01, 0.06], p = 0.007, whereas gender was not, B = 0.01 [0.00, 0.01], $p = 0.090$. The updated estimate of the mean effect after accounting for age was $d = -0.55$ [-0.66, -0.45], $p < 0.001$, still with substantial overall heterogeneity, $I^2 = 67.40\%$. The between-study variance, $\tau^2_1 = 0.05$, was slightly smaller than the within-study variance, $\tau^2_2 = 0.08$. The heterogeneity of effect sizes between studies remained significant ($p < 0.001$).

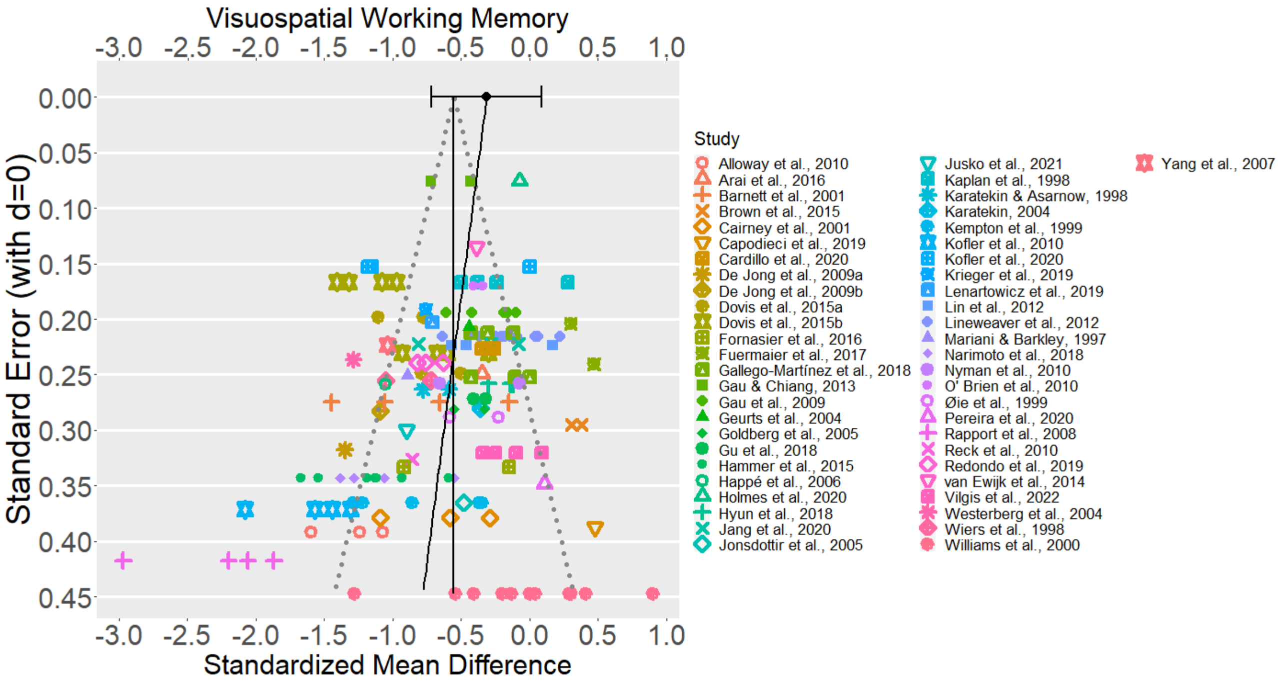
Results suggested that the difference between groups slightly decreased with the increase of age.

Figure 12. *Forest plot with 146 effect sizes (Cohen's d) for the VSWM model, aggregated by study.*



Publication bias (Figure 13) was examined through a PET-PEESE meta-regression. The first step (PET) suggested that the standard error was not a significant moderator of the effect size, B = -1.04 [-3.55, 0.46], p = 0.173, although the bias-free effect was reduced and no longer significant, d = -0.31 [-0.71, 0.09], p = 0.13, leaving us uncertain as to whether there is publication bias (in any case, there was no need to perform PEESE).

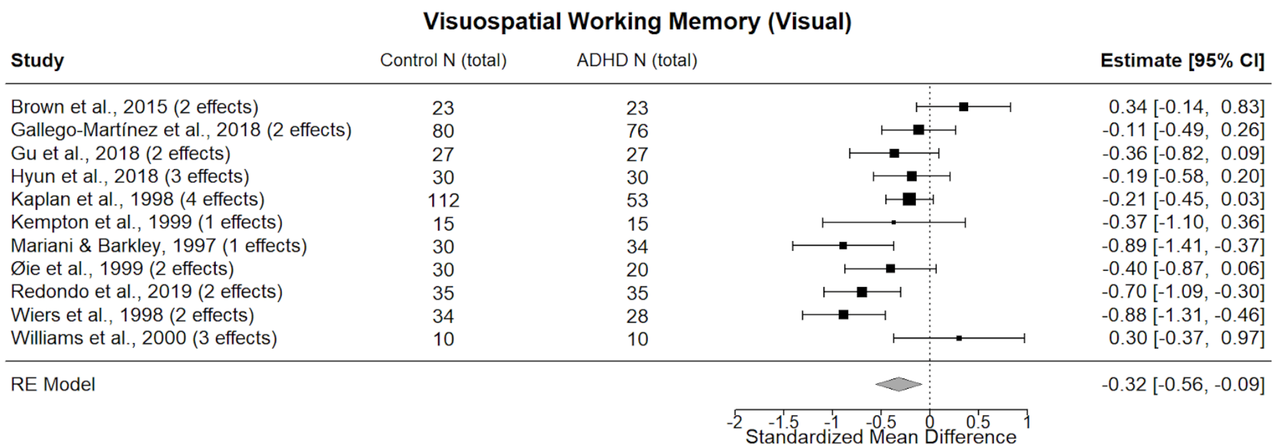
Figure 13. *Funnel plot of the effect estimates for VSWM and calculated standard error for the verification of possible publication bias. PET meta-regression and bias-free estimated effects are also shown. Each dot represents a study.*



6.4.2.1 Visual working memory. The estimate of the mean effect was d = -0.32 [-0.56, -0.09], p = 0.009, with moderate overall heterogeneity, I² = 62.06%. Individuals with ADHD performed poorly compared to the control group. The between-study variance was $\tau^2{}_1 = 0.06$, whereas the within-study variance was $\tau^2{}_2 = 0.04$. The heterogeneity of effect sizes between studies was significant ($p < 0.001$).

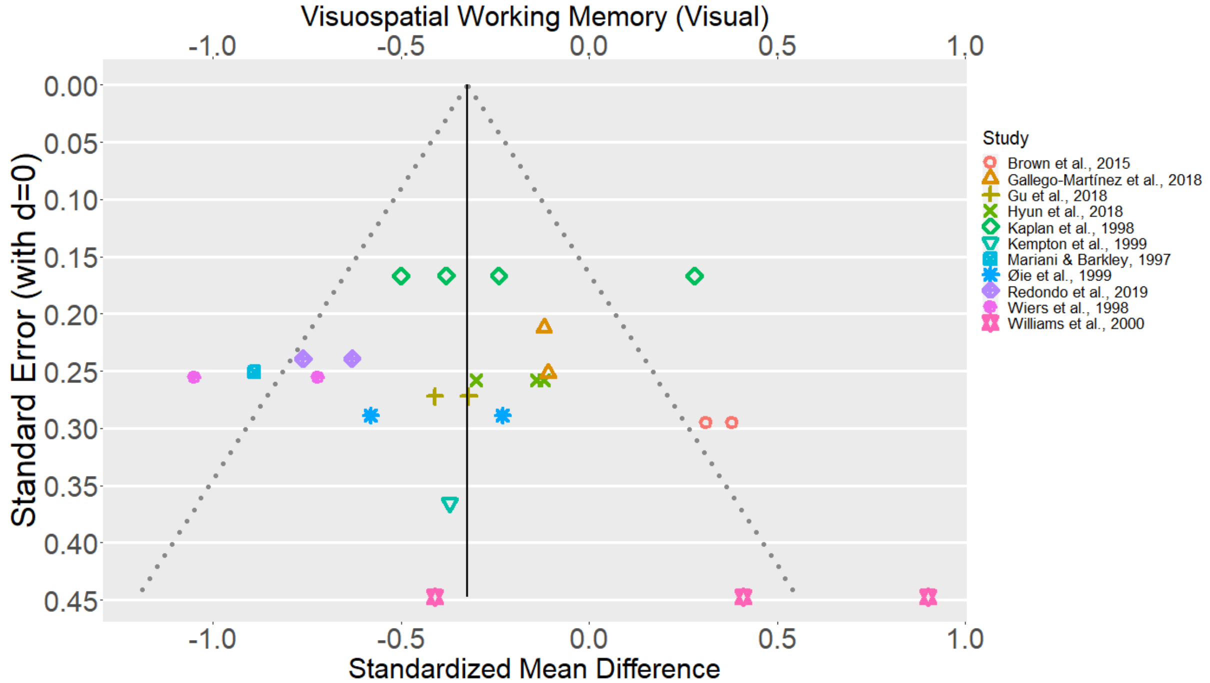
Effects of the moderators. Overall, in the case of visual WM the effect of the moderators was not significant with $F\ (2, 21) = 2.56$, $p = 0.101$.

Figure 14. *Forest plot with 24 effect sizes (Cohen's d) for the visual component of the WM model, aggregated by study.*



The first step of the PET-PEESE meta-regression did not suggest that standard error is a significant moderator of the effect size, and its parameter was even positive, B = 1.84, p = 0.30 so we did not conclude that there was relevant publication bias in this case.

Figure 15. *Funnel plot of the effect estimates for the visual component of WM and calculated standard error, for the verification of possible publication bias. Each dot represents a study.*

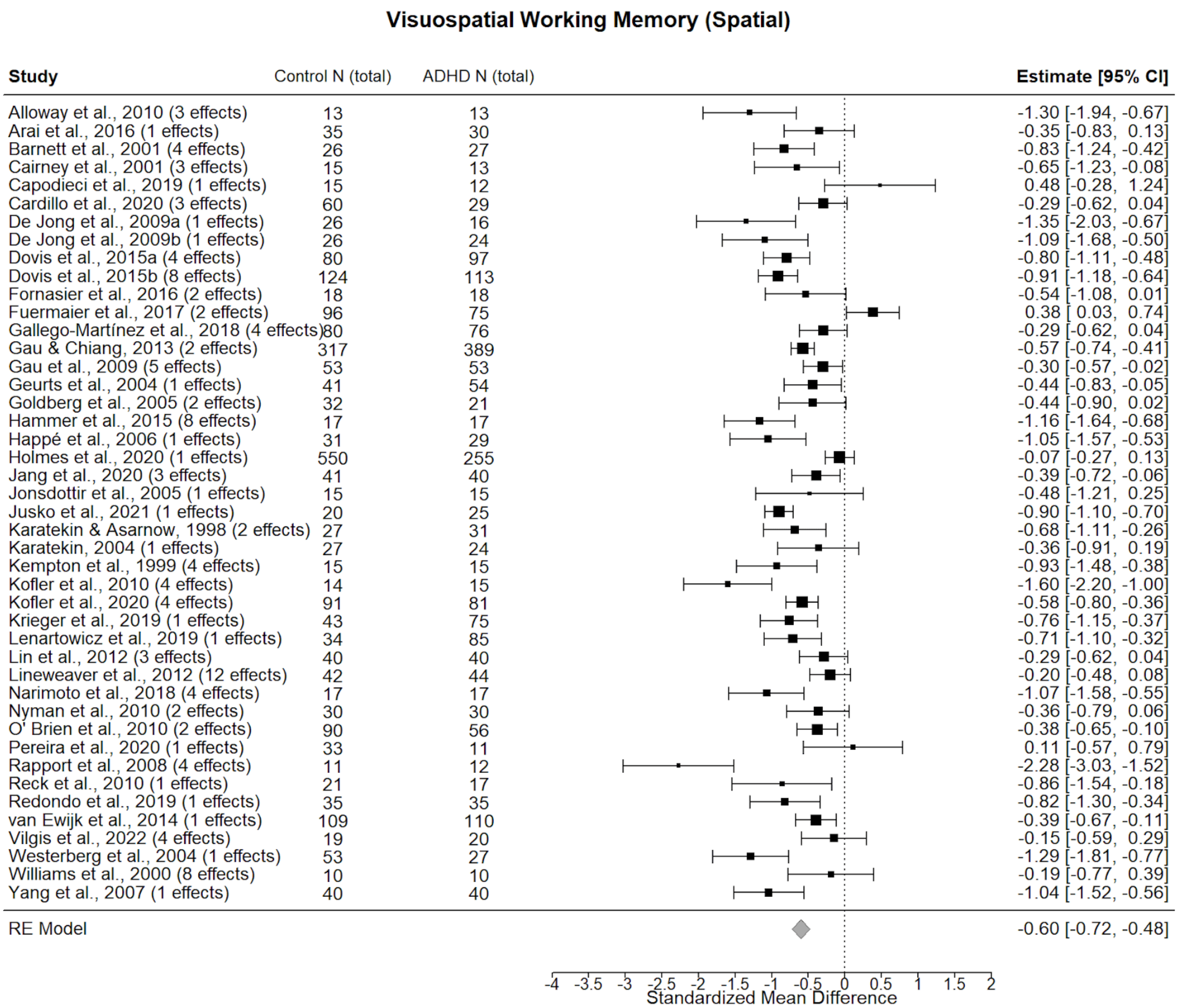


6.4.2.2 Spatial working memory. The estimate of the mean effect was d = -0.60 [-0.73, -0.47], $p < 0.001$, with substantial overall heterogeneity, $I^2 = 75.77\%$. Individuals with ADHD performed poorly compared to the control group. The between-study variance was $\tau^2{}_1 = 0.09$; the variability within study was $\tau^2{}_2 = 0.08$. The heterogeneity of effect sizes between studies was significant ($p < 0.001$).

Effects of the moderators. The overall effect of moderators was significant with F (2, 119) = 6.49, p = 0.002, but only the effect of gender reached significance, B = 0.01 [0.00, 0.01], p = 0.042, while the effect of age did not, B = 0.03 [-0.01, 0.06], p = 0.166.

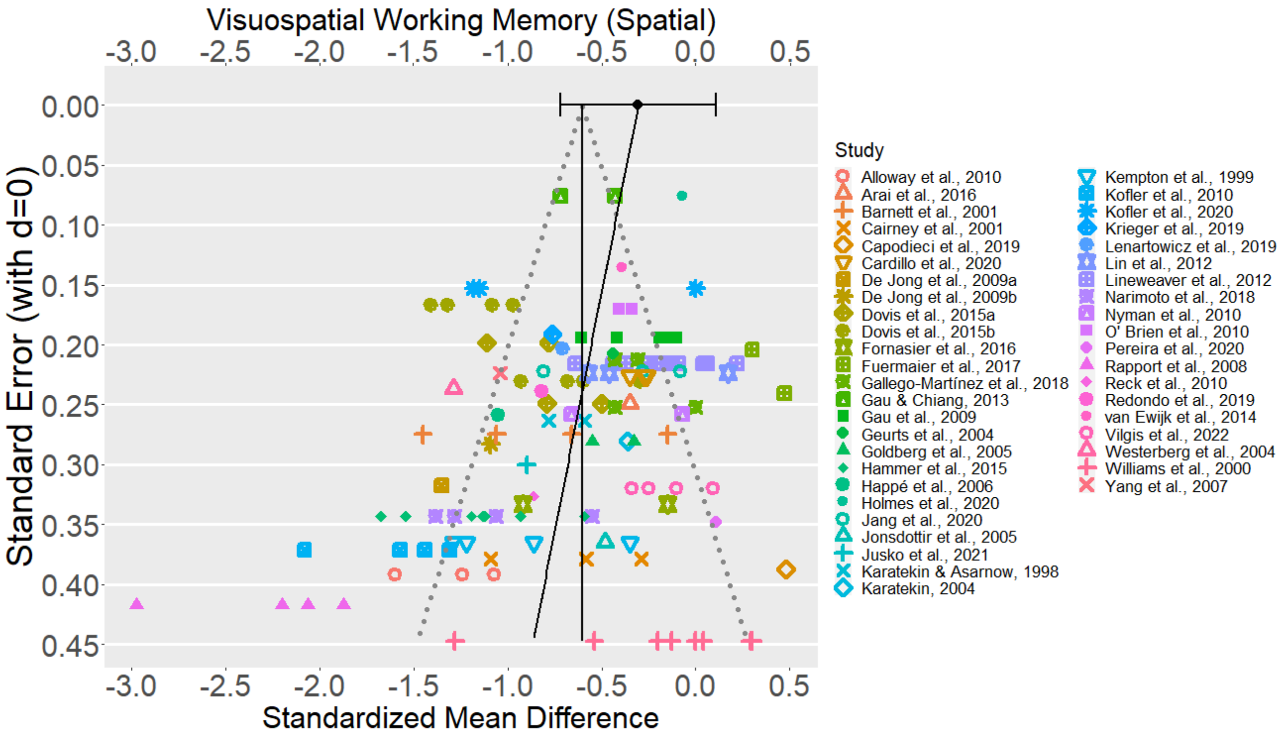
The estimate of the mean effect after controlling for gender was d = -0.60 [-0.72, -0.48], $p < 0.001$. The between-study variance was slightly reduced, $\tau^2_1 = 0.07$, while that within studies remained the same, $\tau^2_2 = 0.08$. The heterogeneity of effect sizes remained high $I^2 = 72.72\%$ and significant ($p < 0.001$).

Figure 16. *Forest plot with 122 effect sizes (Cohen's d) for the spatial component of the final WM model, aggregated by study.*



The PET-PEESE meta-regression did not suggest significant publication bias here, B = -1.25, p = 0.109, although the estimated bias-free effect was reduced and non-significant, d = -0.31 [-0.72, 0.11], p = 0.148 (due to this, we did not further perform PEESE).

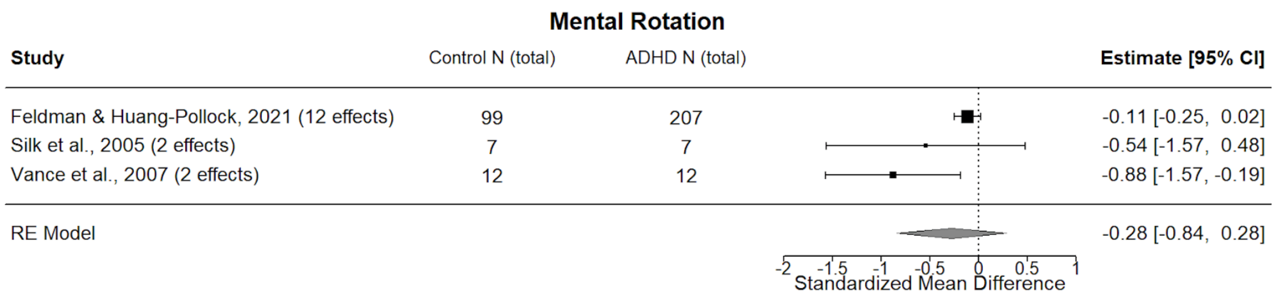
Figure 17. *Funnel plot of the effect estimates for the spatial component of WM and calculated standard error for the verification of possible publication bias. PET meta-regression and bias-free estimated effects are also shown. Each dot represents a study.*



6.4.3 Mental rotation. The estimate of the mean effect was d = -0.28 [-0.84, 0.28], p = 0.308, with considerable overall heterogeneity, I^2 = 90.24%. The between-study variance was τ^2_1 = 0.12, whereas the within-study variance was τ^2_2 = 0.02. The heterogeneity of effect sizes between studies was significant (p < 0.001).

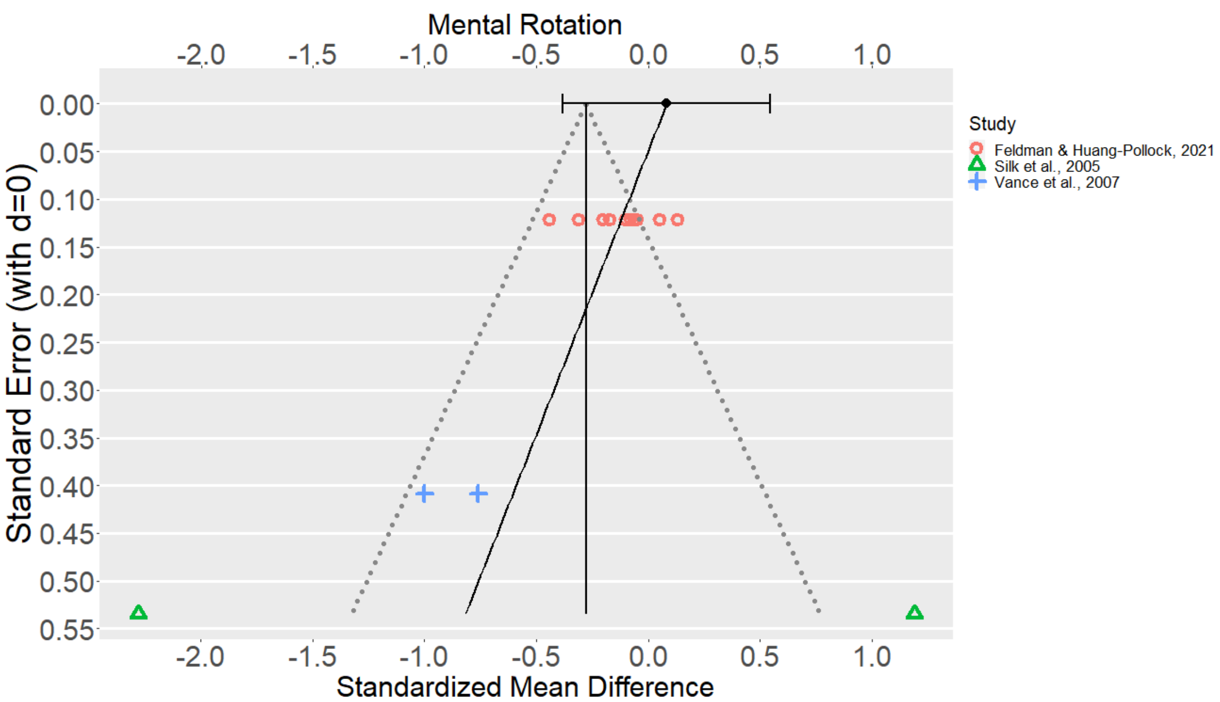
Effects of the moderators. The overall effect of moderators was not significant, F(2,13) = 0.95, p = 0.411.

Figure 18. *Forest plot with 16 effect sizes (Cohen's d) for the mental rotation model, aggregated by study.*



The PET-PEESE meta-regression did not suggest that the standard error was a significant moderator of the effect size, B = -1.68, p = 0.129, but as in previous cases, the estimated bias-free effect was reduced, here to the point of being practically zero and even changing sign, d = 0.08 [-0.38, 0.55], p = 0.727, thus signaling potential publication bias, which however is difficult to assess because only 3 studies were available.

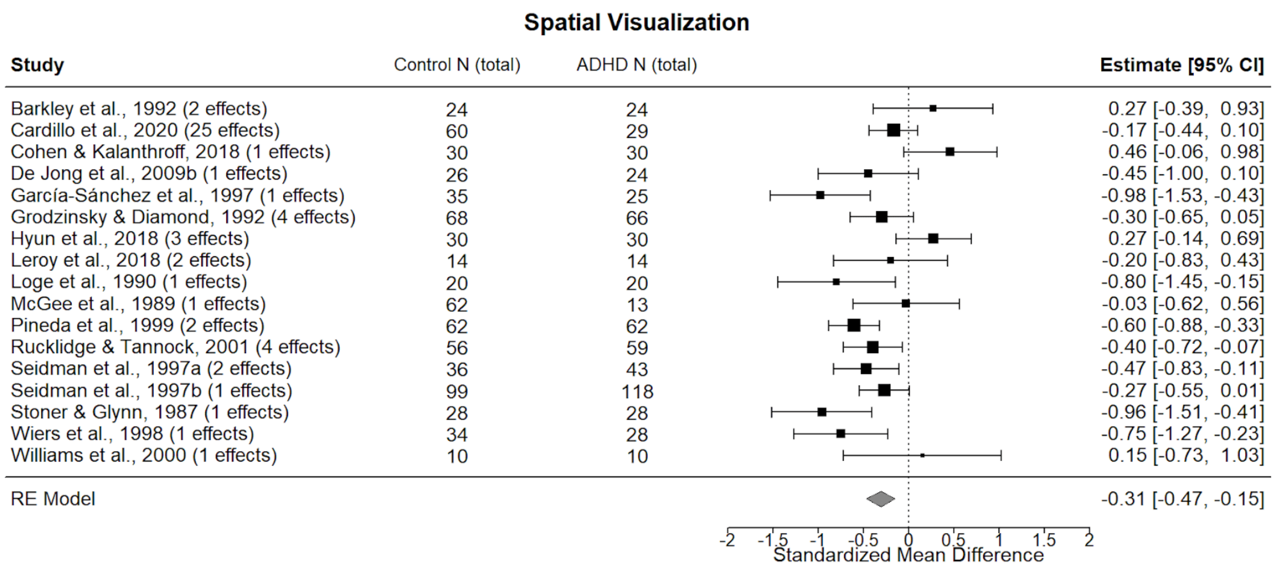
Figure 19. *Funnel plot of the effect estimates for mental rotation and calculated standard error for the verification of possible publication bias. PET meta-regression and bias-free estimated effects are also shown. Each dot represents a study.*



6.4.4 Spatial visualization. The estimate of the mean effect was d = -0.31 [-0.47, -0.15], $p < 0.001$, with considerable overall heterogeneity, $I^2 = 64.09\%$. Individuals with ADHD performed poorly compared to the control group. The between-study variance was practically null, $\tau^2_1 < 0.01$, whereas the within-study variance was $\tau^2_2 = 0.09$. The heterogeneity of effect sizes between studies was significant ($p < 0.001$).

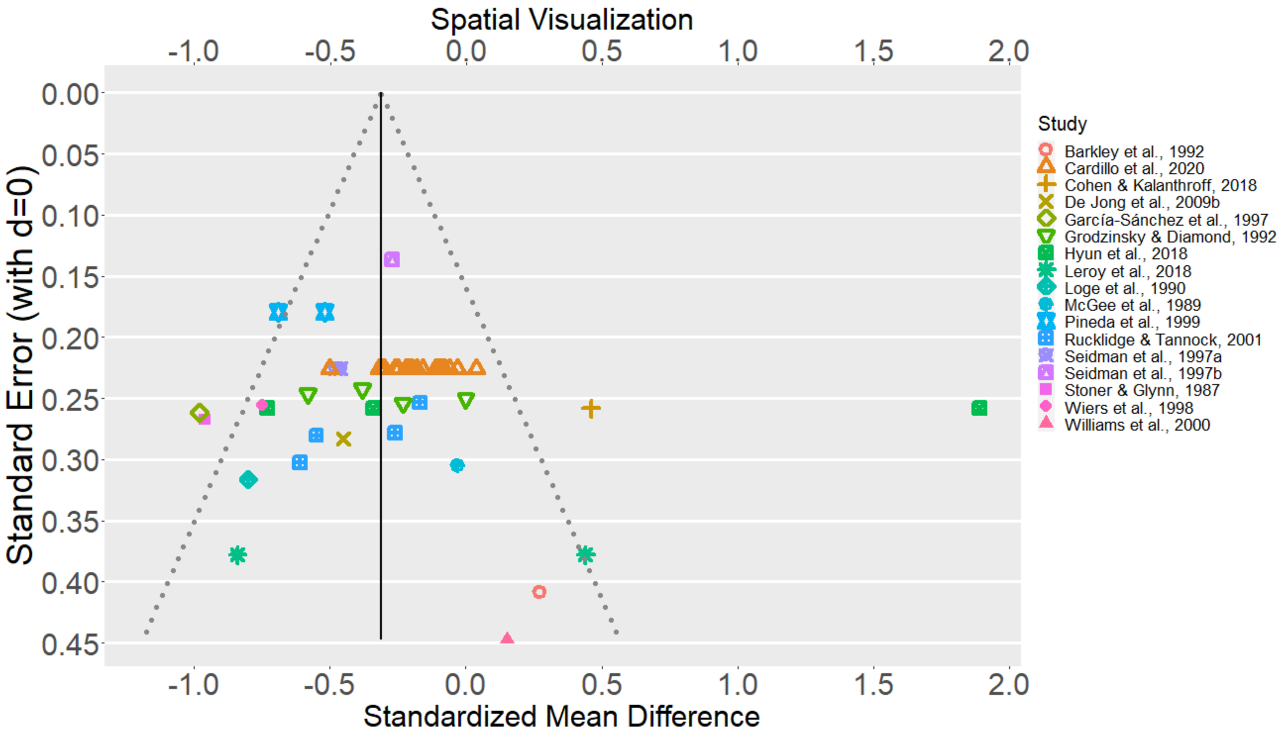
Effects of the moderators. The overall effect of moderators was not significant, $F(2,48) = 0.93$, $p = 0.402$.

Figure 20. *Forest plot with 53 effect sizes (Cohen's d) for spatial visualization model, aggregated by study.*



The PET-PEESE meta-regression did not suggest that the standard error was a significant moderator of the effect size, and it was even positive, $B = 1.37$, $p = 0.312$, so the estimated bias-free effect was inflated, albeit its uncertainty greatly increased to the point of being non-significant, $d = -0.65$, $p = 0.07$, which is probably simply due to heterogeneity. We concluded that there was no risk of publication bias here.

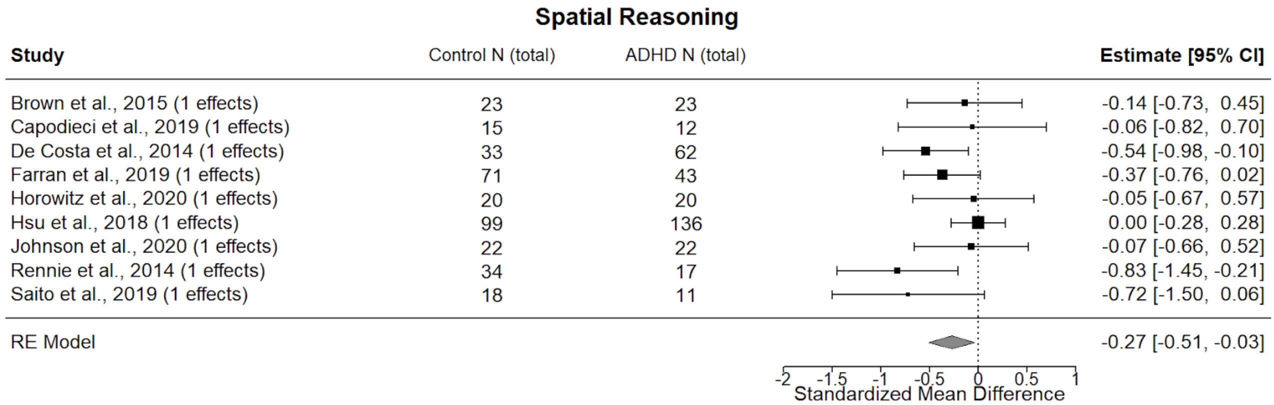
Figure 21. *Funnel plot of the effect estimates for spatial visualization and calculated standard error for the verification of possible publication bias. Each dot represents a study.*



6.4.5 Spatial reasoning. The estimate of the mean effect was small but significant $d = -0.27$ [-0.51, -0.03], p = 0.030, with heterogeneity, $I^2 = 30.14\%$. Individuals with ADHD performed poorly compared to the control group. The between-and within-study variances were both 0.01. The heterogeneity of effect sizes between studies was not significant (p = 0.200).

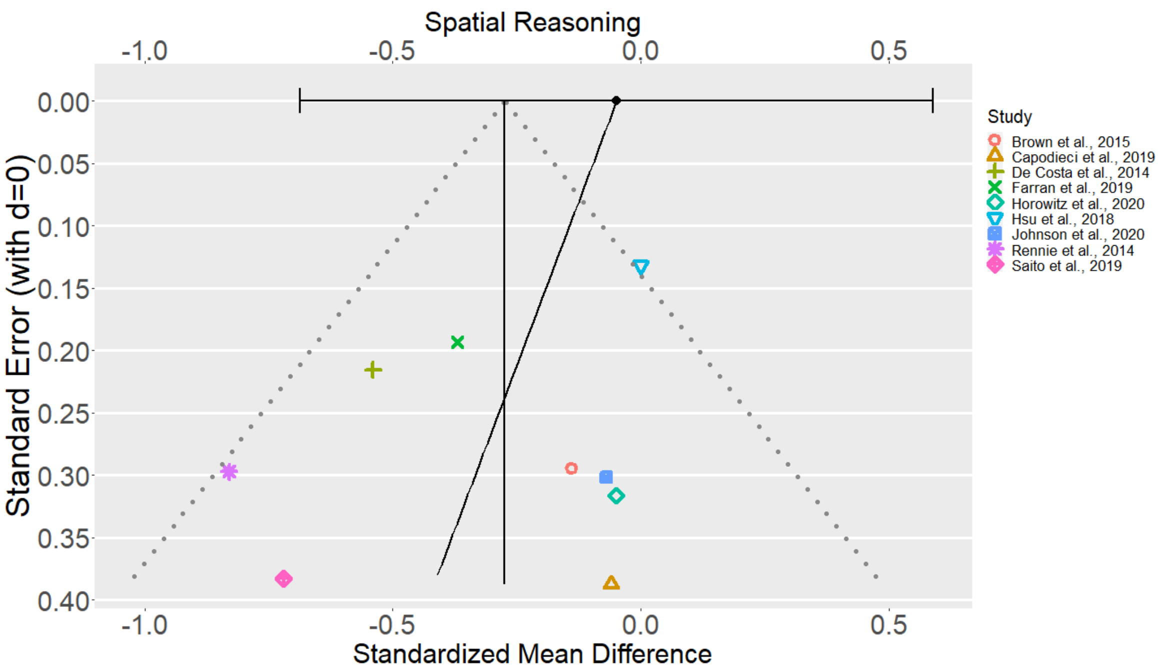
Effects of the moderators. The overall effect of moderators was not significant, F(2,6) = 1.98, p = 0.2192.

Figure 22. *Forest plot with 9 effect sizes (Cohen's d) for the spatial reasoning model, aggregated by study.*



The PET-PEESE meta-regression suggested that the standard error was not a significant moderator of the effect size, B = -0.95, p = 0.450, and yet the estimated bias-free effect became virtually null after considering it, d = -0.05 [-0.69, 0.59], p = 0.880, leaving us uncertain as to whether there is publication bias.

Figure 23. *Funnel plot of the effect estimates for spatial reasoning and calculated standard error for the verification of possible publication bias. PET meta-regression and bias-free estimated effects are also shown. Each dot represents a study.*



6.5 Discussion and conclusion

There is a broad consensus on the fact that the ADHD profile is characterized by strengths and weaknesses (Faedda et al., 2019; Reaser et al 2007). Despite well-documented difficulties in executive functions, some findings suggest that visuospatial abilities might also be impaired (Frazier et al., 2004; Kasper et al., 2012; Martinussen et al., 2005; Willcutt et al., 2005). Despite these results, visuospatial skills have been studied in ADHD up to a certain extent, and not considering the complexity of the visuospatial construct which includes several sub-abilities (Linn & Petersen, 1985; Uttal et al., 2013).

The current meta-analysis aimed to systematically examine the research body concerning visuospatial skills across distinct subfactors and specific populations, particularly performance between children and youths with ADHD compared to peers with typical development. In searching the literature, we followed the well-accepted view of spatial cognition as being characterized by different scales (Montello, 1993). In particular, we focused on basic components which support the processing of spatial information (i.e. visuospatial working memory), visuospatial abilities distinguishing between small- and large-scale components and spatial reasoning. The following abilities were considered: visuospatial WM (with the further distinction between visual and spatial WM), mental rotation, spatial visualization, spatial perception, environment learning (navigation) and spatial reasoning. However, the search of the literature highlighted a predominance of certain visuospatial abilities studied in ADHD. Indeed, most of the studies focused on VSWM, and a few on spatial reasoning, mental rotation and spatial visualization. To our knowledge, the literature does not consider perspective taking, and only one study analyzed spatial perception and navigation (route learning; a large-scale ability). We therefore focused our attention on those considered in the literature, summarizing the dimension of the differences between individuals with ADHD and typical developing peers. The role of age and gender was analyzed as moderators in each visuospatial measure. As concerns age, there are indeed data suggesting developmental changes in

ADHD, with a decrease in hyperactive/impulsive behaviors and the maintenance of inattentive ones; at the same time, increases with age are generally observed for all the measures included in the meta-analysis (e.g. for VSWM see van Ewijk et al., 2014). Instead, gender was included because the ADHD profile is frequently manifests differently in females and males, so that females are more likely to exhibit attention difficulties in the absence of hyperactivity–impulsivity symptoms, which are typically present in males with the disorder (e.g. Biederman & Faraone, 2004). In addition, gender differences are often reported in some visuospatial measures, as for example mental rotation (Lauer et al., 2019).

The results of the meta-analysis showed a significant and medium effect in VSWM: people with ADHD had a poorer performance in this kind of ability. The overall heterogeneity was equally explained by the between- and within-study level; the heterogeneity of effect sizes between the studies was significant. Publication bias was assessed with a PET-PEESE meta-regression. As for many outcomes in the present meta-analysis, no clear evidence of standard error being related with effect size emerged, yet the estimated bias-free effect was reduced to the point that it became non-significant, signaling that publication bias might be present but masked by the large overall heterogeneity. The effect of age was relevant when considering VSWM: with the increase of age, the performance of individuals with ADHD became slightly more similar to that of people with TD.

Our results showed that the effect size (d = -0.55) was lower in comparison to the results found by Martinussen and colleagues (2003), who reported larger effect sizes in VSWM tasks (d = 0.85 for spatial storage and d = 1.06 for spatial executive WM). However, the effects in their study were computed on a much lower number of studies (less than 10); therefore, differences in effect sizes may arise from a variation in tasks and characteristics of participants. In contrast, the overall effect computed in our study is similar, although slightly lower, compared to that reported by Kasper and colleagues (2012; d = 0.74) and Willcutt et al. (2005; d = 0.75).

A further distinction was made in order to analyze the visual and spatial features of VSWM separately in detail; the majority of the tasks considered by the studies evaluated the spatial component of WM. Regardless of the component, both models were in line, suggesting a poorer performance of individuals with ADHD. Gender was a significant moderator in the case of spatial WM. As in the overall model, the contribution of the moderator was marginal in changing the dimension of the effect. It is however interesting to observe the differences in effect size between the visual and spatial component: in the former, the dimension of the difference was small (d = 0.32), while in the case of the spatial component it was medium (d = 0.60). The differences in the dimension of the effect between the two components can be attributed to differences in the format of responses: visual tasks usually test memory using recognition, whereas spatial tasks often require recall. It is well-known that recall is a more resource-consuming task compared to recognition (e.g. Tulving & Watkins, 1973); therefore, the poorer performance of individuals with ADHD can depend on the way memory is tested. For exploratory purposes, we analyzed the data distinguishing between tasks requiring recognition and those requiring recall. The results suggested a significantly weaker performance of the ADHD group in recall (d = -0.56, $p < 0.001$; with significant effect of moderation, $p < 0.001$; only age was a significant moderator with d = 0.03, $p = 0.004$), and recognition tasks (d = -0.52, $p < 0.001$; no significant moderation of age and gender, $p = 0.840$) (similar results were obtained by Kasper et al., 2012). Therefore, differences in effect sizes between the visual vs spatial VSWM seem independent from the way memory is tested.

The overall effect size for the mental rotation model was negative, with a poorer performance of the group with ADHD, but not significant. The between-study variance was greater than the within-study variance; indeed, fewer studies were included in the category, but each presented more than one effect at least. As for VSWM, the PET-PEESE meta-regression did not reach significance, but the estimated bias-free effect was null, still suggesting the presence of possible publication bias. Age and gender did not moderate the effect of the model significantly. The absence of differences in mental rotation deserves further in-depth analysis: mental rotation abilities are indeed correlated with VSWM (Kaufman, 2007), therefore it is surprising that differences did not emerge. The absence of differences may partly be the consequence of the few studies which analyzed mental rotation ability in ADHD. The effect size was computed on a few studies (3) which however included multiple measures of mental rotation, and this could have overrepresented some results compared to others. In addition, the structure of the task between the studies differed, and the most represented study used concrete stimuli, varying the complexity of the task - i.e. the number of blocks (Feldman & Huang-Pollock, 2021). Participants were required to detect the correct answer between two alternatives. The other two studies (Silk et al., 2005; Vance et sl., 2007) used a single measure in which abstract elements were considered and the correct answer was detected between multiple items. In the latter cases, a poorer performance of individuals with ADHD compared to controls - with a large effect size - was reported. The difficulty of the tasks and their characteristics can therefore influence the results, and this can be an aspect to further analyze in the future.

A small effect size emerged for the spatial visualization model to the disadvantage of ADHD. The within-study variance was greater than the between-study variance. The heterogeneity of effects between studies was significant. No evidence of publication bias emerged and the moderation effect of age was not significant. Neither age nor gender moderated the effect. The effect size identified in our work was similar to the one of Frazier and colleagues (2004), who reported a small but significant effect size in the block design task (d = 0.41). It should be noted, however, that the authors calculated the effect using only results from the block design subtest, whereas our effect size referred to different tasks within the category of spatial visualization, including the block design.

As previously stated, only one study examined spatial perception in individuals with ADHD (Goulardins et al., 2013) reporting a lower performance of individuals with ADHD (d = -0.93).

Overall, our results showed that upon examining visuospatial abilities at a higher level, we found differences in spatial visualization, indicating lower performance in ADHD compared to the control, but not in mental rotation. However, as stated above, more research is needed: for example, mental rotation abilities were analyzed only in their object-based components, and no studies considered subject-based tasks (such as perspective-taking tasks).

In the case of large-scale abilities, as reported in the introduction, only Farran and colleagues (2019) examined navigation abilities in ADHD, analyzing the contribution of motor coordination skills in route learning. In general, no differences in route learning (navigation) between the group with ADHD and with TD were found, despite some difficulties in motor competencies being exhibited by some individuals with ADHD.

When considering spatial reasoning, a small and significant effect size emerged, thus indicating a poorer performance in the ADHD group. The within-study variance was absent, whereas the between-study variance explained 2% of variance. There was no significant difference of effect sizes between studies. Once again, the publication bias did not reach significance, yet the estimated bias-free was nearly zero, thus casting doubts on the size of the true effect. Age and gender did not moderate the results significantly. The findings are in line with those obtained by Brydges and colleagues (2017), who identified an association between ADHD and decreased spatial reasoning, but not with those by Toffalini et al. (2022), who found no impairment in fluid reasoning in a large sample ADHD using the WISC-IV battery. Brydges and colleagues (2017), however, specified that such a relationship could be found in individuals with combined or hyperactive type of ADHD, and only when it was mediated by WM. Hence, various elements such as VSWM and executive functions could share significant relations with other spatial domains (Miyake et al., 2001). Weaknesses in VSWM and spatial reasoning could contribute to explaining the difficulties encountered by individuals with ADHD throughout their everyday life, such as academic abilities (Re et al., 2016; Kang et al., 2009).

All these findings suggest that individuals with ADHD are more likely to struggle in some visuospatial tasks compared to their peers with typical development. In particular, differences emerged in VSWM, spatial visualization and spatial reasoning. Age and gender moderated the dimension of the differences in some cases, but their role was decisively modest. For what concerns age, it is noteworthy that the majority of reviewed studies included samples with an average age between 8–10 years. Consequently, the restriction of range may have resulted in the statistically marginal effect of age. In the case of gender, there are studies which include only males in their sample, therefore it is difficult to draw conclusions from non-balanced studies, above all in abilities in which gender differences can be expected.

In referring again to the discussion of the obtained results, the poorer performance of individuals with ADHD in VSWM is not surprising, considering the profiles of difficulties which characterized ADHD: they usually struggle with tasks which involve attentional control (Willcutt et al., 2005). However, the difference in the effect size between the visual (small) and the spatial (medium) WM components is intriguing. This result, on one hand, reiterates the importance of distinguishing between components within VSWM (as repeatedly shown in the literature, see for example, Carretti et al., 2022); on the other hand, it questions the reason for this discrepancy. One possibility relies on the features of a typical spatial WM task that requires the integration of different pieces of information, i.e. the position of the information to be recalled in relation to the spatial framework (e.g. a matrix) and the other positions of the information to be recalled. This means processing information at a local and global level, a feature that can challenge individuals with ADHD (Cardillo et al., 2020; Cohen & Kalanthroff, 2018). In analyzing this aspect in depth, Cardillo et al. (2020), for example, presented a group of children with ADHD with several tasks which required them to recognize or remember information which prompted a global vs local processing. In their study, Cardillo et al., (2020) reported that children with ADHD showed difficulties when they needed to analyze a whole picture and identify relations between its parts in order to complete the task, shifting from the global processing prompted by the stimuli to a local processing needed to perform the task correctly. This line of reasoning can also explain the results in spatial visualization measure: in that case, the majority of the papers included the Block design subtest as spatial visualization measure, for which a mixture of global and local processing is beneficial (see for example Cardillo et al., 2020).

This meta-analysis brought interesting and new results; however some limits should be acknowledged. Firstly, the analyses considered only two main groups, ADHD and typical development, regardless of further characteristics of the former group. For example, the data from the studies included in the meta-analysis did not allow us to consider if and how the specific ADHD profile, with eventual comorbidities as well, could affect the results. Secondly, as commented above, the evaluation of publication bias was often problematic due to the large heterogeneity, and these results should be considered with caution, especially in models containing few studies and with great between- and within-study variances. Finally, this study was able to identify and insert as many papers covering the topic of visuospatial abilities in ADHD as possible, but all of them were published papers. Hence, future meta-analytical research should consider further works, especially those within the gray literature, such as theses or unpublished papers.

In conclusion, these results could be considered as a starting point in tracing a more definitive description of the ADHD profile and could help explain their strengths and weaknesses in visuospatial domains involved in daily life. Indeed, with a more detailed overview of visuospatial skills (considering also less explored measured such as navigation or spatial perception), it could be possible to verify the effect of visuospatial skills altogether with other aspects related to ADHD, such as inattention, hyperactivity or risk tendency.

7 General conclusion

The objective of this dissertation was to explore the topic of injury proneness and its main characteristics. A general introduction, describing some initial data regarding the phenomenon of injuries and its incidence in the general population, was provided; moreover, the main factors of interest were mentioned and described according to the literature available.

The first chapter dove into some of the most mentioned theoretical models and provided a historical overview of the concept of accidental injuries. Cognitive and individual characteristics related to injuries, and possible hypotheses explaining their effect on injuries, were then discussed in depth.

Due to the vast nature of the topic, numerous studies were collected and presented, each describing a specific aspect of injuries. Different populations, such as adolescents, adults and elders, were included as well. The measures that were most frequently used in these studies were either self-report material allowing participants to express their feelings and concerns regarding risk taking, injuries, spatial skills and cognitive failures, or objective tasks which directly tested participants' performance in specific domains, such as cognitive, spatial or attentional skills. The inclusion of measures of different nature allows further evidence (with objective tasks) to be integrated with self-reported information, thus verifying the link between what is perceived and what is observable.

Injury proneness is measured considering either injury history (i.e. answers from interviews reporting the number of accidents and consequent injuries) or questionnaires. The second method is probably adopted less frequently than the first one; besides, many of the current questionnaires examine injuries in children and are addressed to the parents. For this reason, a more exhaustive analysis of the general population was necessary, along with a new questionnaire that anyone, regardless of age or parental status, could use. On the basis of these premises, the study in chapter 2 was carried out and a sample of 464 participants (from 14 to 86 years of age) completed a new questionnaire, the Injury Proneness Questionnaire (IPQ), with a series of other questionnaires evaluating injury history (e.g. number of episodes at the emergency room, amount of mild injuries), orientation skills and cognitive failures. The IPQ was based on the Children's Injury Related Behaviour questionnaire (CIRB; Rowe & Maughan, 2009), with the IPQ containing a more reduced number of items than those initially included in the CIRB. The reason for this reduction was that some items of the CIRB only addressed situations for children, making it hard to adapt the items to people of other ages. The validity of the new questionnaire was tested by running a series of exploratory factor analyses (EFA). From these data it emerged that 9 items did not saturate enough, and 3 clusters were defined. Afterwards, the IPQ, with its 3 clusters (Error, Risk taking and Danger evaluation) and reduced number of items, was compared with the other material introduced in the study. Gender and age differences emerged in the IPQ: older people reported lower injury proneness, males described a higher proneness in risky situations, whereas females reported greater proneness in situations of errors or clumsiness. The IPQ positively correlated with injury history, demonstrating that both methods of injury proneness were in line, so people with a greater injury history would rate themselves with higher injury tendencies. Furthermore, people who gave higher scores in the IPQ would also admit having difficulties in motor coordination and navigation skills (only if they were typically prone to injuries due to situations of errors). On the contrary, people with higher injury tendencies explained by risky situations were more confident in their spatial skills. Therefore this study demonstrated that the IPQ could be a relevant instrument for measuring injury and risk tendencies, and that it is in line with other instruments. However, this study did not include objective measures.

As a result of this, the study in chapter 3 is a continuation of the one presented in the previous chapter. Accordingly, the same sample was analyzed, and the was IPQ adapted based on the factor analyses was used. This time, the comparison was with objective tasks evaluating performance in cognitive, spatial and attentional skills, such as the Cattell test, the Mental rotation test, the Water level task and the Go/No-go task. Correlations and linear regressions were carried out: results showed that people who were more prone to get hurt in risky situations showed better cognitive skills, whereas those who reported a higher predisposition in the IPQ Error subscale performed better in the spatial task (Mental rotation). When inhibitory control was measured (Go/No-go), people with higher injury scores would respond more quickly to relevant stimuli and commit fewer errors. Considering all these facts, self-report and objective materials depicted a similar profile, i.e. people who have good cognitive skills in general are still more likely to get hurt. These findings seem to be in contrast with part of the literature described in the first chapter (Bonander & Jernbro, 2017;O'Brien & Gormley, 2013), while being more in line with studies supporting the claim that people have greater injury risks when they feel overconfident in their abilities or when they expose themselves more often in potentially dangerous situations (Voyer & Voyer, 2015; Schwebel & Gaines, 2007). However, the findings in motor coordination remained in line with the literature (Wilson & Mckenzie, 1998) supporting the fact that greater injury proneness is associated with greater issues in motor coordination.

The fourth chapter included the same variables considered in the previous studies and added others such as memory span, decision making and road experience. This time, adolescents were involved, along with people who are more likely connected to their social life, such as parents and teachers. The reason for this, beyond the involvement of younger participants and the addition of further measures, was to better analyze injury proneness and its main characteristics across adolescence. In fact, adolescence is a particularly interesting age to study since many cognitive functions, as well as social interaction outside of the domestic environment, start to develop significantly. Hence, with more exposure to the environment and potentially risky situations, paired with cognitive and individual characteristics under development, injury proneness could be significant (Johnson & Jones, 2011). A specific objective of this work was the analysis of different points of view; so students completed tests and questionnaires, while parents and teachers completed questionnaires regarding their children or pupils. On this occasion, 2 new versions of the IPQ were used: a self-report version for students and a same one addressed to parents. Injury proneness was evaluated similarly in both groups but students rated themselves with a much higher injury proneness than their parents. Generally, information from parents and teachers was in line with that provided by students: when the students admitted greater injury proneness, parents and teacher also reported higher symptoms of inattention and hyperactivity, this fact was in line with the literature suggesting a link between these aspects (Rowe & Maughan, 2009; Glania et al., 2010). Moreover, students who reported having greater injury proneness in situations where they poorly evaluated dangers were the same who were more often supervised by parents (PSAPQ). On the contrary to what happened in chapter 3, performance in inhibitory control (Go/No-go) and Mental rotation performance decreased with the increase of self-reported injury proneness. Hence, it seems that cognitive skills are still relevant and influence injury tendencies at an early age, whereas other factors, such as personality and experience, start to play a greater role with time. When considering a specifically dangerous context such as the road environment, the IPQ yielded interesting findings. Students who experienced more accidents on the road reported higher scores in the IPQ. This particular context was studied since it has been demonstrated that it presents a high injury and mortality rate, also among younger people (WHO, 2020).

Among the characteristics analyzed in this dissertation, particular interest was dedicated to spatial skills, a factor that has been explored to a lesser extent than others when dealing with injury proneness. Hence, the topic of spatial skills was mentioned in different chapters, considering a variety of measures that could evaluate performance across different domains of spatial cognition. Spatial skills have shown a connection to injuries, at least when considering the population with typical development. However, spatial abilities in atypical development, especially across populations who are known to be significantly predisposed to injuries such Attention Deficit

Hyperactivity Disorder (ADHD), were explored to a lesser extent. Therefore, a clear overview of performance in spatial skills in the typical population was necessary before going to verify its possible relationship with injuries.

The final chapter included a specific study dedicated to the exploration of spatial skills in ADHD. Different spatial measures categorized in the literature (Linn & Petersen, 1985) were analyzed, and the difference in performance between ADHD and typical development was considered. The moderation of age and gender was verified as well. Most of the available studies were based on visuospatial working memory, whereas fewer studies covered other measures such as mental rotation, spatial reasoning or large-skills measures. The results of this meta-analysis confirmed the presence of a weaker performance in ADHD just like past meta-analyses (Frazier et al., 2004; Kasper et al., 2012; Martinussen et al., 2005; Willcutt et al., 2005) in visuospatial working memory. Age showed a significant moderation, meaning that with the increase of age, the performance difference between ADHD and typical development decreased; thus, with age, people with ADHD performed better and more similarly to peers with typical development. No significant difference emerged with mental rotation, since very few results were found. Spatial visualization and spatial reasoning showed a significant difference between groups, and once again the disadvantage of the ADHD group. Overall, this study signaled the presence of possible weaknesses encountered by individuals with ADHD. This could suggest that people with ADHD, who are known to be particularly prone to injuries (Brunkhorst-Kanaan et al., 2021), could incur injuries more often because of their difficulties with spatial skills. Further evidence is necessary to confirm this eventual hypothesis.

Considering all these results, interesting implications emerge. First of all, it is possible to effectively measure injury proneness across all ages, even with a self-report instrument. Nonetheless, objective measures for injuries should still be introduced with the questionnaire in order to have a more definitive idea of participants' injury tendencies. Secondly, injury predisposition is highly related to other factors such as cognitive skills, attentional skills, individual differences and the surrounding context; so future studies should always consider these aspects when evaluating injuries. Thirdly, patterns of injury tendencies can also be identified in younger people, such as adolescents and the factors mentioned above play a relevant role once again; however, some of these factors could become less effective than others as the individual ages. For this reason, age and gender should be always taken into account, since their influence on injury characteristics is relevant. Finally, specific clinical populations and less explored factors, such as spatial skills, could bring significant evidence if studied in depth. Indeed, the current project could be a starting point for future research, especially those involving clinical populations.

Despite the promising findings, the project presents some limits that should be acknowledged; with the advent of Covid-19, many unpredicted methodological changes were made compared to previous plans. The first difficulty consisted in searching for a sample size for the studies, especially among students. A further aspect that could have influenced the results is the administration modality. Indeed, online testing has provided great benefits for the administration of tests and questionnaires, but some participants felt less comfortable than others when completing tasks remotely. This difficulty was often either due to technical reasons (e.g. unstable internet connection or frequent computer issues), or awkwardness towards technological devices in general. This issue was controlled as much as possible by providing technical assistance to the participant when necessary throughout the entire experimenting session. Another aspect to keep in mind is that most of the present work was focused on individuals with typical development but it is also important to keep in mind that even atypical development is potentially related to injuries. Some data regarding ADHD was provided but further analyses of injury proneness should be carried out, considering clinical samples. The project may therefore be considered a starting point for this kind of research. A final point to be completed in the future consists in the analysis of injuries related to the street environment: this point has been marginally considered here, but it would be interesting to evaluate self-reported road and accident experience with objective measures as well. In this case, driving simulators could be used to analyze the behavior and skills of drivers and pedestrians.

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9 APPENDIX A (Material chapter 2)

Table 4. *Descriptive statistics for the IPQ questionnaire (mean, standard deviation, skew, kurtosis and alpha values) and specific values from the factor analysis: factor loadings (labeled as MR1, MR2, MR3), percentage of variance in the item explained by the factors (H2) and residual variance (U2).*

Item	M	SD	Skew	Kurtosis	SE	Raw alpha	Std alpha	H2	U2	MR1	MR2	MR3
IPQ1	1.11	0.89	0.38	-0.40	0.04	0.86	0.86	0.49	0.051	068	0.06	0.02
IPQ2	0.69	0.75	0.78	-0.11	0.03	0.86	0.86	0.47	0.53	0.62	0.19	-0.11
IPQ3	0.98	0.83	0.64	0.17	0.04	0.86	0.87	0.45	0.55	0.68	-0.05	0.00
IPQ4	1.26	0.89	0.26	-0.33	0.04	0.86	0.87	0.25	0.75	0.50	0.00	0.00
IPQ5	1.70	1.15	0.13	-0.70	0.05	0.86	0.87	0.06	0.94	0.16	-0.01	0.17
IPQ6	0.97	0.87	0.82	0.57	0.04	0.86	0.87	0.42	0.58	0.65	0.00	0.01
IPQ7	1.43	0.90	0.16	-0.36	0.04	0.86	0.87	0.29	0.71	0.55	-0.07	0.04
IPQ8	1.29	0.88	0.30	-0.23	0.04	0.86	0.87	0.23	0.77	0.41	0.06	0.12
IPQ9	1.53	0.95	0.20	-0.36	0.04	0.86	0.86	0.33	0.67	0.45	0.20	0.07
IPQ10	0.73	0.78	0.90	0.53	0.04	0.86	0.87	0.25	0.75	0.52	-0.12	0.04
IPQ11	0.79	0.75	0.76	0.46	0.04	0.86	0.86	0.40	0.60	0.60	0.09	-0.02
IPQ12	1.27	0.89	0.42	-0.02	0.04	0.86	0.86	0.33	0.67	0.54	0.10	0.01
IPQ13	1.11	1.03	0.89	0.42	0.05	0.87	0.87	0.15	0.85	0.14	-0.31	0.31
IPQ14	0.98	0.83	0.69	0.41	0.04	0.86	0.87	0.20	0.80	0.40	0.11	-0.02
IPQ15	0.89	0.71	0.56	0.34	0.03	0.86	0.87	0.27	0.73	0.52	0.00	-0.03
IPQ16	0.74	0.89	1.03	0.35	0.04	0.86	0.86	0.46	0.54	-0.01	0.69	-0.05
IPQ17	0.56	0.83	1.32	0.68	0.04	0.86	0.86	0.53	0.47	-0.11	0.76	-0.02
IPQ18	1.08	1.20	0.79	-0.52	0.06	0.86	0.86	0.40	0.60	0.01	0.63	0.00
IPQ19	1.10	1.11	0.72	-0.43	0.05	0.86	0.86	0.36	0.64	0.25	0.50	-0.12
IPQ20	1.33	0.90	0.28	-0.34	0.04	0.86	0.86	0.45	0.55	0.18	0.61	-0.13
IPQ21	0.37	0.63	1.68	2.47	0.03	0.86	0.87	0.38	0.62	-0.04	0.63	-0.03
IPQ22	0.56	0.77	1.36	1.82	0.04	0.86	0.86	0.36	0.64	0.04	0.58	0.02
IPQ23	1.28	0.96	0.41	-0.44	0.04	0.86	0.87	0.27	0.73	0.16	0.47	-0.11
IPQ24	0.91	0.94	0.88	0.27	0.04	0.86	0.87	0.16	0.84	0.10	0.34	0.05
IPQ25	1.16	1.23	0.81	-0.39	0.06	0.86	0.87	0.06	0.94	0.04	0.21	0.05
IPQ26	1.06	1.14	1.03	0.27	0.05	0.86	0.87	0.28	0.72	-0.19	0.22	0.45
IPQ27	1.45	0.87	0.37	-0.07	0.04	0.86	0.87	0.33	0.67	0.24	-0.17	0.52
IPQ28	1.00	0.91	0.93	0.72	0.04	0.86	0.87	0.39	0.61	0.25	-0.05	0.55
IPQ29	0.78	0.89	1.18	1.30	0.04	0.86	0.87	0.19	0.81	0.00	0.42	0.03
IPQ30	0.40	0.78	2.12	4.23	0.04	0.86	0.87	0.29	0.71	0.03	0.52	0.03
IPQ31	0.37	0.77	2.33	5.03	0.04	0.86	0.87	0.10	0.90	-0.04	0.25	0.15
IPQ32	0.44	0.77	1.77	2.76	0.04	0.86	0.87	0.12	0.87	0.10	0.30	0.03
IPQ33	0.34	0.62	2.19	6.25	0.03	0.86	0.87	0.10	0.90	0.20	0.19	-0.03
IPQ34	0.45	0.90	2.11	3.92	0.04	0.87	0.87	0.05	0.95	-0.13	0.17	0.11
IPQ35	0.70	0.99	1.72	2.72	0.05	0.86	0.87	0.41	0.59	-0.13	0.13	0.61
IPQ36	1.13	1.06	0.88	0.24	0.05	0.86	0.87	0.42	0.58	-0.21	0.39	0.46

10 APPENDIX B (Material chapter 3)

Table 9. *Pearson's Correlations including all variables in the study (464 participants). Significant values are flagged: * p<0.05, **p<0.01, ***p<0.001. IPQ-Error = Injury Proneness Questionnaire-Error subscale; IPQ-Risk = Injury Proneness Questionnaire-Risk taking subscale; IPQ-Danger = Injury Proneness Questionnaire-Danger evaluation subscale; IPQ-Total = Injury Proneness Questionnaire- Total score (sum of the 3 subscales). The correlations are partialized for age, with Bonferroni correction.*

	IPQ - Error	*IPQ - Risk*	*IPQ - Danger*	*IPQ Total*
1 gender	0.22***	-0.16*	-0.07	0.08
2 Go/No-go false alarm	-0.03	0.02	0.02	-0.01
3 Go/No-go omission	-0.06	-0.04	0.05	-0.09
4 Go/No-go mean reaction time	-0.12	-0.14*	0.04	-0.18
5 Water level	-0.01	0.13	-0.08	0.10
6 Cattell	0.01	0.14	-0.10	0.12
7 Mental rotation	0.001	0.13	-0.09	0.02

11 APPENDIX C (Material chapter 5)

Table 19. *Complete list of the effect sizes identified and calculated for the meta-analysis. Category of reference, effect size (Cohen's d) and variance of the effect size are listed.*

Study	Measure	ES±Variance
Alloway et al., 2010	Visuospatial wm	-1.60±0.20
	Visuospatial wm	-1.07±0.18
	Visuospatial wm	-1.24±0.18
Arai et al., 2016	Visuospatial wm	0.35±0.06
Barkley et al., 1992	Spatial visualization	0.27±0.17
	Spatial visualization	0.27±0.17
Barnett et al., 2001	Visuospatial wm	1.45±0.10
	Visuospatial wm	0.15±0.08
	Visuospatial wm	0.66±0.08
	Visuospatial wm	-1.06±0.09
Brown et al., 2015	Spatial reasoning	-0.14±0.09
	Visuospatial wm	0.38±0.09
	Visuospatial wm	0.31±0.09
Cairney et al., 2001	Visuospatial wm	1.09±0.16
	Visuospatial wm	0.29±0.15
	Visuospatial wm	0.58±0.15
Capodieci et al., 2019	Visuospatial wm	0.48±0.15
	Spatial reasoning	-0.06±0.15
Cardillo et al., 2020	Spatial visualization	0.04±0.05
	Spatial visualization	-0.11±0.05
	Spatial visualization	-0.25±0.05
	Spatial visualization	-0.09±0.05
	Spatial visualization	-0.08±0.05
	Spatial visualization	-0.11±0.05
	Spatial visualization	-0.06±0.05
	Spatial visualization	0.26±0.05
	Spatial visualization	0.16±0.05
	Spatial visualization	0.11±0.05
	Spatial visualization	0.30±0.05
	Spatial visualization	0.18±0.05
	Spatial visualization	0.25±0.05
	Spatial visualization	-0.06±0.05
	Spatial visualization	-0.09±0.05
	Spatial visualization	-0.03±0.05
	Spatial visualization	-0.10±0.05
	Spatial visualization	-0.31±0.05
	Spatial visualization	-0.50±0.05
	Spatial visualization	0.16±0.05
	Spatial visualization	0.20±0.05
	Spatial visualization	0.09±0.05
	Spatial visualization	0.22±0.05
	Spatial visualization	0.21±0.05
	Spatial visualization	0.32±0.05
	Visuospatial wm	-0.27±0.05
	Visuospatial wm	-0.26±0.05

	Visuospatial wm	-0.35±0.05
Cohen & Kalanthroff, 2018	Spatial visualization	0.46±0.07
De Costa et al., 2014	Spatial reasoning	-0.54±0.05
De Jong et al., 2009a	Visuospatial wm	-1.35±0.12
De Jong et al., 2009b	Visuospatial wm	-1.09±0.09
	Spatial visualization	-0.45±0.08
Dovis et al., 2015a	Visuospatial wm	-0.79±0.07
	Visuospatial wm	-1.11±0.04
	Visuospatial wm	-0.50±0.06
	Visuospatial wm	-0.78±0.04
Dovis et al., 2015b	Visuospatial wm	-0.93±0.06
	Visuospatial wm	-1.41±0.03
	Visuospatial wm	-0.68±0.06
	Visuospatial wm	-1.32±0.03
	Visuospatial wm	-0.60±0.06
	Visuospatial wm	-1.08±0.03
	Visuospatial wm	-0.30±0.05
	Visuospatial wm	-0.97±0.03
Farran et al., 2019	Spatial reasoning	-0.37±0.04
Feldman & Huang-Pollock, 2021	Mental rotation	0.17±0.01
	Mental rotation	0.05±0.01
	Mental rotation	0.08±0.01
	Mental rotation	0.06±0.01
	Mental rotation	-0.13±0.01
	Mental rotation	-0.05±0.01
	Mental rotation	-0.20±0.01
	Mental rotation	-0.10±0.01
	Mental rotation	-0.06±0.01
	Mental rotation	-0.31±0.02
	Mental rotation	-0.44±0.02
	Mental rotation	-0.08±0.01
Fornasier et al., 2016	Visuospatial wm	-0.92±0.12
	Visuospatial wm	-0.15±0.11
Fuermaier et al., 2017	Visuospatial wm	0.30±0.04
	Visuospatial wm	0.47±0.06
Gallego-Martínez et al., 2018	Visuospatial wm	-0.43±0.06
	Visuospatial wm	-0.43±0.05
	Visuospatial wm	0.00±0.06
	Visuospatial wm	-0.31±0.05
	Visuospatial wm	0.11±0.06
	Visuospatial wm	0.12±0.05
García-Sánchez et al., 1997	Spatial visualization	-0.98±0.08
Gau et al., 2009	Visuospatial wm	-0.19±0.04
	Visuospatial wm	0.10±0.04
	Visuospatial wm	0.42±0.04
	Visuospatial wm	0.16±0.04
	Visuospatial wm	0.61±0.04
Gau & Chiang, 2013	Visuospatial wm	0.43±0.01
	Visuospatial wm	0.72±0.01
Geurts et al., 2004	Visuospatial wm	-0.44±0.04
Goldberg et al., 2005	Visuospatial wm	0.55±0.08
	Visuospatial wm	0.33±0.08
Goulardins et al., 2013	Spatial perception	-0.93±0.07

Grodzinsky & Diamond, 1992	Spatial visualization	0.00±0.06
	Spatial visualization	-0.38±0.06
	Spatial visualization	-0.23±0.07
	Spatial visualization	-0.58±0.06
Gu et al., 2018	Visuospatial wm	-0.41±0.08
	Visuospatial wm	-0.32±0.08
Hammer et al., 2015	Visuospatial wm	-1.54±0.15
	Visuospatial wm	-0.93±0.13
	Visuospatial wm	-1.19±0.14
	Visuospatial wm	-1.12±0.14
	Visuospatial wm	-1.67±0.16
	Visuospatial wm	-0.59±0.12
	Visuospatial wm	-1.13±0.14
	Visuospatial wm	-1.13±0.14
Happé et al., 2006	Visuospatial wm	1.05±0.07
Holmes et al., 2020	Visuospatial wm	-0.07±0.01
Horowitz et al., 2020	Spatial reasoning	-0.05±0.10
Hsu et al., 2018	Spatial reasoning	0.00±0.02
Hyun et al., 2018	Spatial visualization	1.89±0.10
	Visuospatial wm	-0.30±0.07
	Spatial visualization	0.34±0.07
	Visuospatial wm	0.14±0.07
	Spatial visualization	0.73±0.07
	Visuospatial wm	0.12±0.07
Jang et al., 2020	Visuospatial wm	0.81±0.05
	Visuospatial wm	-0.08±0.05
	Visuospatial wm	-0.28±0.05
Johnson et al., 2020	Spatial reasoning	-0.07±0.09
Jonsdottir et al., 2005	Visuospatial wm	-0.48±0.14
Jusko et al., 2021	Visuospatial wm	-0.90±0.01
Kaplan et al., 1998	Visuospatial wm	-0.24±0.03
	Visuospatial wm	0.28±0.03
	Visuospatial wm	-0.50±0.03
	Visuospatial wm	-0.38±0.03
Karatekin, 2004	Visuospatial wm	-0.36±0.08
Karatekin & Asarnow, 1998	Visuospatial wm	0.59±0.07
	Visuospatial wm	0.78±0.07
Kempton et al., 1999	Visuospatial wm	-1.22±0.16
	Visuospatial wm	1.29±0.16
	Visuospatial wm	0.35±0.14
	Visuospatial wm	-0.86±0.15
	Visuospatial wm	-0.37±0.14
Kofler et al., 2020	Visuospatial wm	-1.15±0.03
	Visuospatial wm	-1.18±0.03
	Visuospatial wm	0.00±0.02
	Visuospatial wm	0.00±0.02
Kofler et al., 2010	Visuospatial wm	-1.44±0.17
	Visuospatial wm	-1.31±0.17
	Visuospatial wm	-2.08±0.21
	Visuospatial wm	-1.57±0.18
Krieger et al., 2019	Visuospatial wm	-0.76±0.04
Lenartowicz et al., 2019	Visuospatial wm	-0.71±0.04

Leroy et al., 2018	Spatial visualization	-0.44±0.15
	Spatial visualization	-0.84±0.16
Lin et al., 2012	Visuospatial wm	-0.46±0.05
	Visuospatial wm	-0.17±0.05
	Visuospatial wm	0.57±0.05
Lineweaver et al., 2012	Visuospatial wm	-0.18±0.05
	Visuospatial wm	0.22±0.05
	Visuospatial wm	-0.37±0.05
	Visuospatial wm	-0.64±0.05
	Visuospatial wm	-0.09±0.05
	Visuospatial wm	-0.44±0.05
	Visuospatial wm	-0.37±0.05
	Visuospatial wm	0.06±0.05
	Visuospatial wm	-0.14±0.05
	Visuospatial wm	-0.21±0.05
	Visuospatial wm	-0.25±0.05
	Visuospatial wm	0.04±0.05
Loge et al., 1990	Spatial visualization	-0.8±0.11
Mariani & Barkley, 1997	Visuospatial wm	-0.89±0.07
McGee et al., 1989	Spatial visualization	-0.03±0.09
Narimoto et al., 2018	Visuospatial wm	-0.55±0.12
	Visuospatial wm	-1.28±0.14
	Visuospatial wm	-1.06±0.13
	Visuospatial wm	-1.38±0.15
Nyman et al., 2010	Visuospatial wm	-0.66±0.07
	Visuospatial wm	-0.07±0.07
O' Brien et al., 2010	Visuospatial wm	0.41±0.030
	Visuospatial wm	-0.34±0.03
Øie et al., 1999	Visuospatial wm	-0.58±0.09
	Visuospatial wm	-0.23±0.08
Pereira et al., 2020	Visuospatial wm	0.11±0.12
Pineda et al., 1999	Spatial visualization	-0.69±0.03
	Spatial visualization	-0.52±0.03
Rapport et al., 2008	Visuospatial wm	-1.87±0.25
	Visuospatial wm	-2.97±0.37
	Visuospatial wm	-2.06±0.27
	Visuospatial wm	-2.20±0.28
Reck et al., 2010	Visuospatial wm	0.86±0.12
Redondo et al., 2019	Visuospatial wm	-0.63±0.06
	Visuospatial wm	-0.76±0.06
	Visuospatial wm	-0.82±0.06
Rennie et al., 2014	Spatial reasoning	-0.83±0.10
Rucklidge & Tannock, 2001	Spatial visualization	-0.55±0.08
	Spatial visualization	-0.17±0.06
	Spatial visualization	-0.61±0.01
	Spatial visualization	-0.26±0.08
Saito et al., 2019	Spatial reasoning	-0.72±0.16
Seidman et al., 1997a	Spatial visualization	-0.46±0.05
	Spatial visualization	-0.48±0.05
Seidman et al., 1997b	Spatial visualization	-0.27±0.02
Silk et al., 2005	Mental rotation	-1.19±0.34
	Mental rotation	-2.28±0.47
Stoner & Glynn, 1987	Spatial visualization	-0.96±0.08

Vance et al., 2007	Mental rotation	1.00±0.19
	Mental rotation	-0.76±0.18
Van Ewijk et al., 2014	Visuospatial wm	-0.39±0.02
Vilgis et al., 2022	Visuospatial wm	-0.34±0.10
	Visuospatial wm	-0.25±0.10
	Visuospatial wm	0.10±0.10
	Visuospatial wm	-0.09±0.10
Westerberg et al., 2004	Visuospatial wm	-1.29±0.07
Wiers et al., 1998	Spatial visualization	-0.75±0.07
	Visuospatial wm	0.72±0.07
	Visuospatial wm	1.05±0.07
Williams et al., 2000	Spatial visualization	0.15±0.20
	Visuospatial wm	0.20±0.20
	Visuospatial wm	0.00±0.20
	Visuospatial wm	0.54±0.21
	Visuospatial wm	-0.04±0.20
	Visuospatial wm	0.29±0.20
	Visuospatial wm	-0.3±0.20
	Visuospatial wm	0.13±0.20
	Visuospatial wm	0.9±0.20
	Visuospatial wm	-0.41±0.20
	Visuospatial wm	0.41±0.20
	Visuospatial wm	-1.28±0.24
Yang et al., 2007	Visuospatial wm	-1.04±0.24