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The Interplay of Anxiety, Skills, and Performance in children and adolescents with Autism Spectrum and Specific Learning Disorders

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ABSTRACT

Children and adolescents diagnosed with Autism spectrum disorder (ASD) often face challenges with social skills, not being able to adaptively behave in social situations, which may be connected to the development of social anxiety (Spain et al., 2018; White et al., 2010). However, it is not clear the relationship between certain social skills (e.g., facial emotion recognition [FER]), and the rising of social anxiety in ASD. Moreover, social performance might be supported by specific cognitive abilities, namely executive functions (EFs), in which the majority of autistic individuals seem to experience difficulties (Hill, 2004). The large variability of findings on the topic denotes a literature gap which is incapable of establishing a clear and shared framework (for systematic reviews and meta-analyses, see Black et al., 2017; Leung et al., 2022; Lievore et al., 2023); for this reason, it is essential to increase the evidence-based results on the study of social skills in autism, by also embracing possible associated mechanisms.

Differently, children with Specific learning disorders (SLD) are characterized by severe difficulties in the acquisition of academic competences, for example in mathematics, thus experiencing distress and anxiety in relation to their educational weaknesses, such as mathematics anxiety (MA) (Cipora et al., 2022; Ma & Xu, 2004). Also in this case, mathematical performance might be upheld by executive functions, in which children diagnosed with SLD often encounter difficulties (Agostini et al., 2022). It is worth noting that the study of the emotional consequences of academic difficulties has been declined in favour of a much more extensive research on cognitive functions associated with academic performance, especially in the case of children and adolescents with SLD.

Bearing in mind that children with ASD and SLD might experience anxiety directly linked to their main diagnostic characteristics (i.e., social anxiety for ASD, mathematics

anxiety for SLD), many authors described a reciprocal interaction between social and academic functioning (see for example Caemmerer & Hajovsky, 2022; Denham & Brown, 2010). Indeed, “schools are social places, and learning is a social process” (p. 191; Zins et al., 2007), thus, it is possible that children experiencing difficulties in one of these two major areas may also fall into the other, and vice versa. For instance, children diagnosed with SLD may encounter distinct socio-emotional challenges stemming from their academic struggles (Livingston et al., 2018; Riddick, 2009; Willcutt et al., 2011). Specifically, they may grapple with social anxiety due to feelings of shame and diminished self-esteem (Elgendi et al., 2021; Kohli et al., 2005; Sahoo et al., 2015). Conversely, social skills deficits and social anxiety can affect the learning process of autistic children, as they may avoid social learning opportunities, consequently missing valuable chances for learning, as discussed by Brook & Willoughby (2015). This, in turn, may lead to the development of performance-based anxiety in a school setting.

Some studies have investigated the occurrence of social anxiety in autism (for a review see Spain et al., 2018), and MA in SLD (Lai et al., 2015; Rubinsten & Tannock, 2010). However, the majority of these have explored anxiety as a unitary construct, and/or taking just one point of view (e.g., parents). For instance, for the study of social anxiety, a public speech task has been often used (Allen et al., 2017; Buske-Kirschbaum et al., 1997), and physiological responses to this kind of social stress have also been measured (e.g., Edmiston et al., 2016), leaving aside the subjective and behavioral component of social anxiety. Conversely, many studies in the field of MA have investigated trait levels (for a meta-analysis see Namkung et al., 2019), implicitly legitimizing the idea that MA is a stable trait, whereas less has been done to investigate state mathematics anxiety (Mammarella et al., 2023).

Moreover, by comparing the study of anxiety, skills and performance across different neurodevelopmental disorders (i.e., ASD, SLD), researchers can gain a better understanding of the specific challenges and strengths associated with each condition. To the best of our knowledge, no studies have investigated performance-based anxiety, such as social and mathematics, by comparing groups of children and adolescents with ASD, SLD and non-diagnosed controls.

General aims of the present dissertation

Based on these premises, the main aims of this PhD dissertation are to increase the current understanding of social and mathematical abilities in children and adolescents with ASD, SLD compared to ND participants, by investigating the possible emotional (trait anxiety) and cognitive (executive functions) underlying factors (first part of the PhD thesis). In the second part, social and mathematics anxiety will be investigated by using a *multidimensional* approach, combining the assessment of *state* subjective, behavioral and psychophysiological responses to demanding situations. Moreover, anxiety will be assessed with a *multi-informant* methodology, by asking both parents and participants to report their perspective on *trait* anxiety symptoms in real-life contexts.

The series of studies which will be presented in this dissertation could lead to new findings allowing an in-depth analysis of different aspects of social and mathematical abilities (and associated factors) with direct clinical and educational implications. As concerns the assessment procedure, a comprehensive evaluation of both cognitive abilities and emotional aspects may be important to identify potential strengths and weaknesses when addressing social and mathematical skills. Moreover, educators and clinicians should be aware that trait and state levels of anxiety might differ, especially in children diagnosed with neurodevelopmental conditions. For this reason, assessing anxiety from a multidimensional perspective (e.g., worries, arousal, perceived competence, observable signs of discomfort) and combining reports from multiple informants, might allow to tailor individualized interventions, by understanding the influence of anxiety across different contexts, and warranting a global knowledge of all components.

Overview of the chapters

The present PhD dissertation aims at examining social and mathematical abilities by comparing children and adolescents with and without ASD and SLD, from two different perspectives. The first two studies will analyse the role of underlying factors, in particular emotional (trait anxiety) and cognitive (executive functions) aspects, in predicting social (i.e., facial emotion recognition) and mathematical (i.e., mental calculation) **abilities**. The last two studies will specifically investigate **anxiety** within social and mathematical situations, by considering *trait* levels – reported by both parents and participants, and *state* components – subjective, behavioral and autonomic responses to social and mathematical stressful tasks. A graphical representation of the main topics investigated in this PhD dissertation has been provided at the end of this section (see Figure 1).

Chapter 1 will define and describe the diagnostic criteria and main characteristics of the two neurodevelopmental conditions that will be considered in the present PhD dissertation: Autism Spectrum Disorders (ASD) and Specific Learning Disorders (SLD). Then, the chapter will introduce the topics considered in the first part of the present PhD thesis. Regarding ASD, the importance of social skills will be mentioned alongside the relationship with social anxiety and executive functions. Similarly, the significance of mathematical skills, their relationship with mathematics anxiety and executive functions will be described with reference to SLD.

Chapter 2 (Study I) will initially define social skills, specifically facial emotion recognition (FER), and the difficulties experienced by people with ASD within this realm, by pointing out the heterogeneity of findings in literature. The discussion will proceed by highlighting possible emotional (social anxiety, SA) and cognitive (executive functions, EFs) mechanisms that might influence the FER performance. The relationship between SA, EFs and FER will be discussed considering both typical development and ASD. Methodologically, children with and without ASD completed a computerized FER task, three computerized EFs (inhibition, updating and set-shifting) tests, while parents filled out a questionnaire on their children's social anxiety. In addition to significant differences between groups in FER skills, SA and EFs, our findings revealed a distinct relationship between SA and FER in children and adolescents with ASD as compared to ND participants, whereas EFs (in particular, updating skills) seem to boost socio-emotional skills in autism.

Chapter 3 (Study II) will focus on mathematical abilities, in particular mental calculation's skills, of children with and without SLD, by exploring underlying mechanisms of mathematics' achievement: mathematics anxiety (MA) and EFs. Participants were asked to complete a computerized mental calculation task, three computerized EFs (inhibition, updating and set-shifting) tests, and to fill out a self-report measure of MA. Parents filled in a questionnaire about their children's general anxiety level, useful for controlling the influence of a general trait of tension on math achievement. The present study confirmed previous findings on higher levels of MA and reduced EFs in children with SLD as compared to ND. Interestingly, our results suggest the predictive power of lower levels of MA and greater updating skills on mental calculation accuracy for ND children, though not representing supporting factors of mathematical performance for children with SLD.

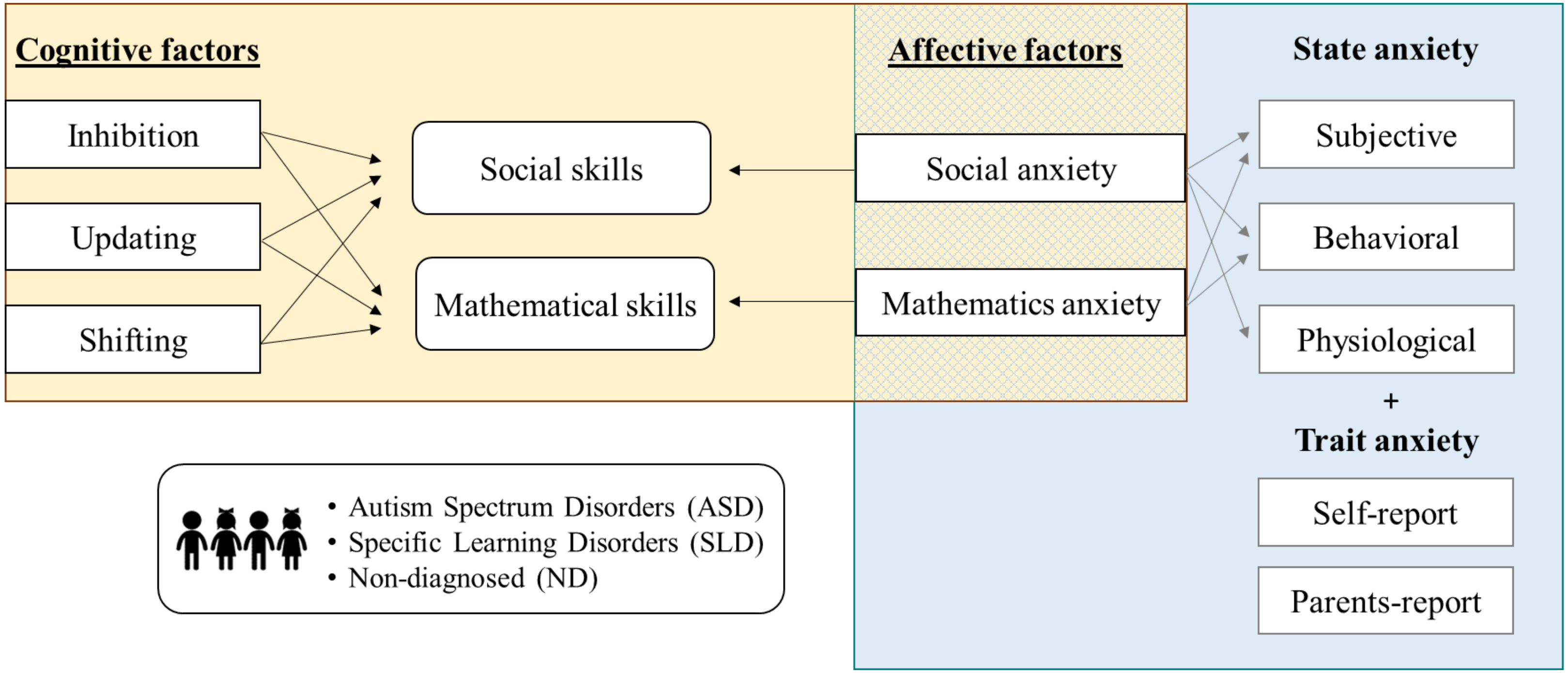
Chapter 4 will introduce the topics considered in the second part of the present PhD dissertation. Primarily, social and mathematics anxiety will be described highlighting the multidimensionality of the constructs and their experimental assessment. Moreover, the rationale of studying social anxiety in children with SLD, and mathematics anxiety in those with ASD will be explained by considering the reciprocal association between social and academic competences.

Chapter 5 (Study III) will focus on social and mathematics anxiety in children and adolescents with ASD and SLD, in comparison with non-diagnosed (ND) participants. The Introduction will go through the current knowledge about the occurrence of social and mathematics anxiety in both the clinical groups. The aim was to try to understand the single components of anxiety by using a multidimensional point of view, by considering *state* subjective and behavioral anxiety responses, to further extend the findings of the two previous studies in which we used trait-like questionnaires to assess social and mathematics anxiety. For this purpose, we asked participants to complete two stressful tasks, which were designed to elicit a laboratory-controlled stress response consistent with social and mathematical anxiety: the first was a public speech (Trier Social Stress Test, child version; Buske-Kirschbaum et al., 1997), the second a timed mental calculation task (Stressful Mathematical Test; adapted from Caviola et al., 2016; 2018). Our findings suggest that performance-based anxiety might be a common feature of children and adolescents with different neurodevelopmental conditions, such as ASD and SLD. Despite a worse performance (behavioral component) of the clinical groups in both the public speech and the mathematical test, subjective responses seem to differ between these groups depending on the task. Our results suggest that social demands might elicit greater anxiety (i.e., arousal) in children with SLD, whereas mathematical pressure could play an intensified role in those diagnosed with ASD, according to reported valence, arousal and worries. That being said, the perception of competence appears to be a constant factor between the two experimental tasks, with opposite outcomes among children with ASD (high) and SLD (low).

Chapter 6 (Study IV) will investigate social anxiety by considering the psychophysiological responses, besides subjective and behavioral components, to the Trier Social Stress Test (Buske-Kirschbaum et al., 1997) in children and adolescents with and without ASD and SLD. During the task, the electrocardiogram (ECG) was registered to measure autonomic changes across the protocol, with a focus on the reactivity of heart rate (HR) and hear rate variability (HRV). We also asked children and their parents to fill in two questionnaires to further consider trait-like symptoms of social anxiety. Our findings revealed that the fear of being evaluated might negatively influence the subjective and autonomic experience of children with SLD, but they showed to be able to adaptively regulate their emotions; instead, for children with ASD, besides a lower baseline HRV, this type of stressor might not be effective in eliciting a physiological arousal, as demonstrated by both subjective and autonomic responses.

Finally, **Chapter 7** will summarize the main findings from each study (Chapters 2-3-5-6), and describe studies strengths and limitations, by also considering open questions and suggestions for further research. Finally, both clinical and educational implications of the studies will be discussed.

Figure 1 Graphic representation of all the aspects and the relationships investigated in the present PhD dissertation: in yellow the variables considered in studies I and II; in blue those included in studies III and IV.



CHAPTER 1

Autism Spectrum Disorders and Specific Learning Disorders: Main characteristics and associated factors

1.1 Autism Spectrum Disorders (ASD): definition and main features

The term Autism spectrum disorders (ASD) refers to a lifelong neurodevelopmental disorder characterized by a set of heterogeneous symptoms with a multifactorial neurobiological aetiology. The *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5 American Psychiatric Association [APA], 2013), provides specific diagnostic criteria for ASD. Firstly, there are persistent deficits in social communication and interaction, evident in abnormalities such as atypical social approaches and a failure to engage in normal back-and-forth conversations. Nonverbal communicative behaviors, including impaired eye contact, facial expressions, and gestures, further contribute to the diagnostic criteria. Additionally, challenges in developing and maintaining relationships, characterized by difficulties in adapting behavior to different social contexts, are integral to the assessment. Secondly, the presence of restricted, repetitive patterns of behavior, interests, or activities is a crucial criterion. This includes stereotyped or repetitive motor movements, insistence on sameness, inflexible adherence to routines, and highly restricted, fixated interests that deviate from typical intensity or focus. Hyper- or hypo-reactivity to sensory input or unusual interests in sensory aspects of the environment also contribute to this category. Thirdly, symptoms must manifest in the early developmental period, although they may not become fully apparent until social demands exceed limited capacities or are masked by learned strategies in later life. Moreover, the symptoms must cause clinically significant impairment in social, occupational, or other crucial areas of current functioning. Finally, it is imperative to rule out other conditions, ensuring that the symptoms are not better explained by intellectual disability (ID) or global developmental delay. These comprehensive criteria collectively contribute to the accurate diagnosis of ASD.

The term "spectrum" denotes a range of symptoms exhibiting significant variation in both their presence and intensity, spanning from profound and widespread to a milder or higher-functioning level. To address this diversity, the DSM-5 (APA, 2013) incorporates specifiers for diagnostic purposes, assessing the severity of symptoms through a 3-level scale, ranging from "requiring support" (level 1) to "requiring very substantial support" (level 3). Furthermore, it is necessary to specify whether the disorder is accompanied by (a) intellectual disability (ID), (b) language impairment, (c) a known medical or genetic condition, or environmental factors, and (d) another neurodevelopmental or behavioral disorder (APA, 2013). In fact, comorbidities with other developmental and psychiatric disorders is high, with substantial heterogeneity, the most common being ADHD, anxiety, depressive disorders, epilepsy, ID, and sleep disorders (Bougeard et al., 2021). In the present PhD dissertation, children with ASD without ID will be included in the studies.

Epidemiology, assessment and etiology

Autism affects approximately 1 in 100 children around the world, with prevalence estimates increasing over time and varying greatly within and across sociodemographic groups (for a review see Zeidan et al., 2022). The prevalence of ASD has even been estimated 1 in 54 children in the United States (Maenner et al., 2020). About the sex ratio, a clear discrepancy has emerged from the literature with a female-to-male ratio of around 1 in 4 (Fombonne, 2009); however, the difficulty in the assessment of ASD in girls (Wood-Downie et al., 2021), for instance due to the phenomenon of camouflaging, may contribute to an under-diagnosis of ASD in these patients (Beggiato et al., 2017).

Research has indicated that the diagnosis of ASD can be consistently established before the age of two, demonstrating a high level of reliability for diagnoses made in younger siblings as early as 18–24 months of age (Ozonoff et al., 2015). Nevertheless, a significant proportion of children with ASD (38% - 46%) do not receive a diagnosis until the age of 3 or later, delaying the provision of the necessary support, especially those children without intellectual disability (Brian et al., 2016). It is important to note that an accurate diagnosis of autism is conducted within a team context involving various developmental experts and through different assessment tools, such as observation, parent interviews, and additional considerations on the everyday functioning level and necessary support.

Regarding etiology and risk factors of ASD, researchers agree on the multifactorial and complex nature, with multiple genes and environmental factors that contribute to vulnerability (Lecavalier, 2014).

In addition to the core diagnostic criteria, people with ASD may experience many other difficulties associated with cognitive, emotional and behavioral characteristics, such as abnormal sensory experience, atypical motor processing (Bradshaw et al., 2022), excessive attention to details (Happé, 2021), impaired social cognition and perception (Baron-Cohen, 1988; Frith & Frith, 2008), and challenges with cognitive skills (Pellicano, 2010). All these characteristics may have an impact on the development of social skills in ASD (Livingston et al., 2019; Pickard et al., 2020; Torske et al., 2018). In the present PhD dissertation, the focus will be given to the role played by social anxiety and cognitive abilities, in particular executive functions (EFs), on social skills in autism.

1.1.1 The importance of social skills

Social skills involve explicit and implicit processes in areas of joint attention, mentalizing, empathy, social perspective taking, social awareness, and emotion recognition (Frith & Frith, 2008; Mundy & Newell, 2007; Preckel et al., 2018). Bedell & Lennox (1996) defined social skills as *"the abilities to (a) accurately select relevant and useful information from an interpersonal context, (b) use that information to determine appropriate goal-directed behavior, and (c) execute verbal and nonverbal behaviors that maximize the likelihood of goal attainment and the maintenance of good relations with others"* (p. 9). This definition encompasses the essential elements of social skills, incorporating cognitive and interpersonal capacities necessary for adaptive social behaviours and promising interpersonal engagements. Moreover, having good social skills might be associated with successful school attainment (Denham & Brown, 2010) and career development (Morgeson et al., 2005).

People diagnosed with ASD face unique challenges related to social skills (Baron-Cohen, 1988; Constantino, 2011; Leekam, 2016), such as social communication (e.g., pragmatic deficits), social cognition (e.g., lack of theory of mind), social awareness (e.g., absence of joint attention), and social motivation (e.g., affinity for loneliness), besides all the consequences of their social difficulties, such as being subjected to discrimination and rejected by peers, and the development of anxiety and depression (Mazefsky & Herrington, 2014). The present PhD dissertation will discuss (and find evidence) on the relationship between social skills, social anxiety, and cognitive abilities by comparing children with and without ASD.

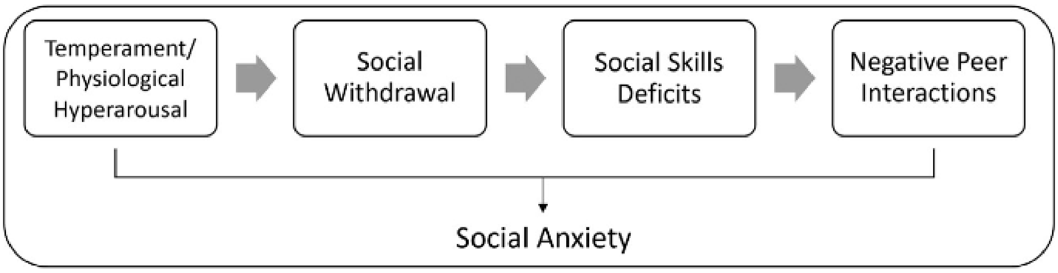
1.1.2 The relationship between social skills and social anxiety

Some researchers have proposed a bidirectional relationship between social challenges and social anxiety in autism (Bellini, 2006; Spain et al., 2018, 2020; White et al., 2010). Social anxiety is characterized by cognitive, emotional, behavioral, and physiological symptoms before and/or during social situations, concerning the fear of negative evaluation and a tendency for avoiding social interactions (APA, 2013). The specific characteristics and the assessment of social anxiety will be explained in Chapter 4, with studies III and IV specifically focusing on this construct.

Many autistic people report the onset of social anxiety in late childhood or adolescence, during which people increase awareness of their social skills, and social engagement becomes more important for an individual's well-being (Chang et al., 2012; Tantam, 2003). Some studies have reported that nearly half (49%) of autistic adolescents exceed the clinical cut-off on a measure of social anxiety (Bellini, 2004), with an estimated co-occurrence (both diagnosed and subthreshold symptoms) of 17–29.2% (Lugnegård et al., 2011; Simonoff et al., 2008).

The presence of social anxiety, together with the memory for past negative social experiences, could prevent people from engaging in social situations, reducing the opportunity to practice social skills empowering their social efficacy (White et al., 2014). Therefore, autistic individuals might have increased social worries as a consequence of the growing self-awareness of social difficulties and of rejections from others, which may result from decreased opportunity to develop these skills. Moreover, physiological and genetic factors may underpin the development of social anxiety in autistic children, for example a predisposition for physiological hyperarousal could interact with a specific social presentation to increase social anxiety (White et al., 2010). In this regard, Bellini (2006) proposed an interesting model of social anxiety in ASD beginning from predispositions (temperament and physiological arousal) to the developmental of social anxiety via social withdrawal and social skills deficits (see Figure 1.1). The arrow joining physiological arousal with negative peer interactions means that adverse peer interactions might negatively influence children with high physiological arousal more than those with low autonomic reactivity, restarting the cycle.

Figure 1.1 Developmental pathways of social anxiety in ASD according to the model of Bellini (2006) (taken from Lievore et al., 2022).



Special attention must be given to the topic of *social motivation* in ASD, which refers to the desire to engage in interpersonal activities. It is possible that autistic people do not pursue social situations because they do not gain satisfaction from them, as have challenges with establishing and maintaining relations with peers (Chevallier et al., 2012). This social motivation theory in ASD proposes that low social motivation modifies how people pay attention to social stimuli and reduces attempts at approaching social experience, consequently inducing a cascading effect of indigent social learning. However, autistic children and adolescents without intellectual disability (ID) seem to have a greater knowledge about their (dis)abilities, due to their cognitive level and preserved social motivation (Bauminger, 2002; Deckers et al., 2014; Itskovich et al., 2021; Kuusikko et al., 2008).

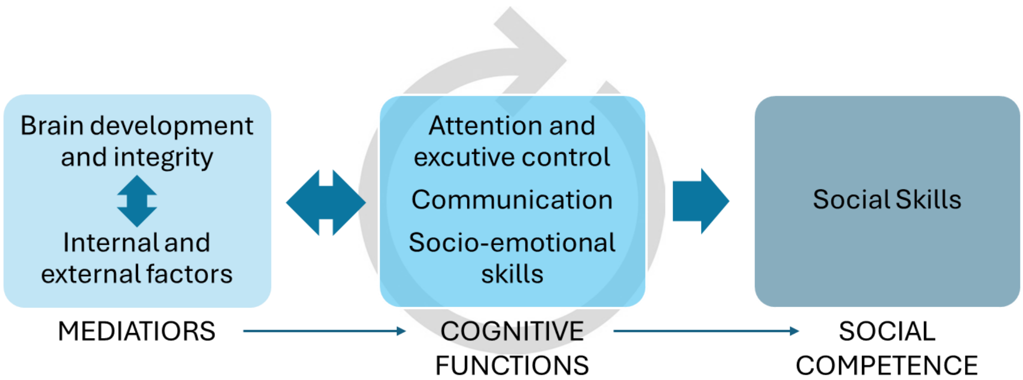
All that said, the assessment of social anxiety in autistic people requires caution because many symptoms of social phobia overlap with social features that are observed in ASD, such as social withdrawal, or not interacting in social contexts (Kuusikko et al., 2008). When assessing social anxiety in autistic children and adolescents, clinicians might encounter some difficulties with determining which condition best explains observed symptoms, such as social avoidance and failing to speak in front of an audience (APA, 2013). Evidence-based guidelines indicate that the accurate assessment of anxiety should rely on multiple informant ratings, in particular when evaluating children and adolescents (Mash & Hunsley, 2005; Silverman & Ollendick, 2005).

1.1.3 The relationship between social skills and cognitive abilities

Besides social anxiety, there is growing evidence that social development might be endorsed by higher-order cognitive skills, such as executive functions (EFs). EFs refer to an umbrella term that comprises a set of top-down mental processes, critical for controlling, monitoring and planning thoughts and behaviours, as well as problem-solving, self-controlling, considering alternatives and flexibly adjusting to new settings (Diamond, 2013; Miyake et al., 2000). According to Miyake et al. (2000), the three core processes of EFs are inhibitory control, the ability to update and monitor information in the working memory (WM), and cognitive flexibility or set shifting.

A widely-recognized model has point out the relationship between cognitive and social abilities, by defining the core areas of social skills (biological–psychological–social) and their interactions within a developmental framework based on empirical and clinical evidence (Beauchamp & Anderson, 2010). As shown in Figure 1.2, social skills first require neural systems working together in a complex functional network, from those responsible of basic social processing (e.g., face recognition) to those developing later in life and encompassing complicated social contents (e.g., moral reasoning). Besides brain and body activation, cognitive processes represent a strong foundation of social functioning, based on the classic psychological models of social skills, for instance the Social-Information Processing model (Crick & Dodge, 1996), that postulates problem-solving stages that occur within social situations: interpreting cues, clarifying goals, generating alternative responses, selecting and implementing a specific response, and evaluating the outcome. Concerning cognitive functions, EFs (namely “cold” processes) might serve for the development of emotional understanding, since attentional and inhibitory control are essential to correctly behave in social contexts, and practising with social abilities (Carlson & Wang, 2007). Self-regulation mediated by EFs facilitates the development of social interaction skills (Moriguchi, 2014; Spikman et al., 2013) and children's ability to use their understanding of mental states in a more flexible way (Lecce et al., 2017). Moreover, communication (e.g., receptive language) and socio-emotional skills, namely "hot" processes (e.g., emotion perception), are needed to appropriately respond to social cues.

Figure 1.2 The socio-cognitive integration of abilities model (SOCIAL; adapted from Beauchamp & Anderson, 2010).



The social manifestations of ASD seem to be consistent with the key dimensions of the SOCIAL model (i.e., neural, attention-executive, communication, socio-emotional dysfunction). Concerning the cognitive domain, the theory of executive dysfunction has been put forward in an attempt to explain socio-relational deficits of autistic people, with compromised planning, mental flexibility, inhibition, generativity and self-monitoring (Hill, 2004). Social and communication symptoms, but also repetitive/restrictive behaviours, appear to be linked to executive functioning in ASD (e.g., metacognitive skills, inhibition, working memory, attention), in addition to behavioral regulation (Gilotty et al., 2002; Kenworthy et al., 2008; Leung et al., 2016).

1.2 Specific Learning Disorders (SLD): definition and main features

Specific Learning Disorders (SLD) are characterized by difficulties in learning and using academic skills that significantly interfere with school achievement and/or daily living. According to the criteria outlined in the DSM-5 (APA, 2013), the diagnosis of SLD entails several key elements. First, challenges in acquiring and utilizing academic skills are identified through the presence of at least one of the following symptoms persisting for a minimum of six months, despite targeted interventions. These symptoms include inaccurate or slow word reading, difficulties in understanding the meaning of text, issues with spelling, and challenges in written expression, such as grammatical errors and organizational deficiencies. Additionally, struggles with number sense, facts, or calculations, as well as difficulties in mathematical reasoning, contribute to this set of criteria. The academic skills affected must demonstrably fall below the expected level for the individual's chronological age, resulting in significant interference with academic, occupational, or daily living activities. This discrepancy is confirmed through individually administered standardized achievement measures and a comprehensive clinical assessment. Moreover, the onset of learning difficulties occurs during the school-age years but may not fully manifest until the demands for these affected academic skills exceed the individual's limited capacities, such as in timed tests or when tackling extensive and intricate homework. Importantly, these learning difficulties are not more appropriately explained by intellectual disabilities, uncorrected visual or auditory acuity, other mental or neurological disorders, psychosocial challenges, insufficient proficiency in the language of academic instruction, or inadequate educational guidance. These criteria collectively form the basis for accurately diagnosing Specific Learning Disorders.

The severity of the SLD may be denoted by three levels: *mild, moderate,* or *severe*. Additionally, according to the DSM-5 (APA, 2013), SLD can be further specified based on certain features and associated characteristics. Here are the specifiers of SLD:

- With impairment in reading (Dyslexia): difficulties with accurate or fluent word recognition, and poor decoding abilities.
- With impairment in written expression (Dysorthography): difficulties with spelling accuracy, grammar, and punctuation; problems with clarity and organization of written expression.
- With impairment in mathematics (Dyscalculia): difficulties with number sense, memorization of arithmetic facts, accurate or fluent calculation, and accurate math reasoning.

Notwithstanding, in their Opinion Paper, Peters & Ansari (2019) explained the necessity of overcoming the problems associated with a categorical approach by considering the overlap between learning disorders, rather than entirely distinct domains of learning. As a fact, children with difficulties in one domain (e.g., reading) frequently experience challenges in at least another domain (e.g., arithmetic) (Landerl & Moll, 2010; Moll et al., 2015; Willcutt et al., 2019). Dyslexia and dyscalculia seem to be characterized by different behavioral but similar neuropsychological (Willcutt et al., 2013) and brain activity profiles (Peters et al., 2018).

Besides the higher co-occurrence of different types of SLD, comorbidities with other neurodevelopmental disorders are common, especially with ADHD, language impairment, and speech sound disorder (Pennington, 2006; Pham & Riviere, 2015), highlighting that multiple risk and protective factors influence the behavioral outcome providing evidence for the heterogeneity (and comorbidity) in neurodevelopmental disorders (Pennington et al., 2012).

Epidemiology, assessment and etiology

Approximately 5-15% of school-aged children are diagnosed with a Specific Learning Disorder (APA, 2013). Regarding dyslexia, a recent meta-analysis shows a pooled prevalence around 7% in primary school, with a higher prevalence in boys than in girls, but no significant difference was found across different writing systems (Yang et al., 2022). As concerns dyscalculia, prevalence provided by different demographic studies, estimates around 5-6%, with both genders being equally represented (Devine et al., 2013).

Likewise autism, during the assessment of academic competences, clinicians should use a combination of standardized tools, clinical interviews, and observations to be able to collect a comprehensive evidence on the student's academic achievements and related challenges, to guide appropriate interventions and support. Besides the assessment of academic achievement, the intellectual profile represents a valid and necessary measurement, since children with SLD are characterized by higher scores in verbal comprehension and perceptual reasoning, and consistent flaws in working memory and processing speed indexes (Giofrè & Cornoldi, 2015; Poletti, 2016; Toffalini et al., 2017).

Similar to the other neurodevelopmental disorders, the etiology of SLD is multifactorial, involving both genetic and environmental mechanisms. A recent meta-analysis (Georgitsi et al., 2021) posits the need to tie the knowledge gaps between all methodological strategies used so far to disentangle the possible causal factors of SLD, such as genomics, molecular pathways, cellular communication, neuronal circuits, neuroimaging data, with human cognition and brain function.

In addition to the core diagnostic criteria, people with SLD may experience many other difficulties, such as cognitive deficits (Moll et al., 2016), socio-emotional dysregulation (Eyuboglu et al., 2018; Kopelman-Rubin et al., 2020; Sarti et al., 2019), lower self-esteem and self-efficacy (Novita, 2016; Terras et al., 2009), depression and anxiety (Chieffo et al., 2023;

Haft et al., 2019; Rostami et al., 2014). All these characteristics may have an impact on the learning process and the development of academic competences in SLD. In the present PhD dissertation, the focus will be given to the role played by mathematics anxiety and cognitive abilities, in particular executive functions (EFs), on mathematical skills in SLD.

1.2.1 The importance of mathematical skills

Among all school subjects, mathematics is often associated with worries and feelings of helplessness (Hill et al., 2016; Wu et al., 2012), representing a huge societal problem given the essential role of mathematical abilities both at school and in real-life. Indeed, mathematical knowledge is required for logic reasoning and problem-solving situations, critical thinking (i.e., making connections and drawing conclusions), learning of other disciplines (e.g., science, economics, statistics), and represent a requisite for accessing higher education and personal development, by fostering cognitive functioning. Overall, mathematical skills are not only essential at school, but also contribute to cognitive growth, problem-solving abilities, and general success in various aspects of life (e.g., career development).

There is widespread consensus that the accurate learning of mathematical skills depends on a combination of domain-specific abilities and domain-general aspects (Geary et al., 2017; Gilmore et al., 2018). Domain-specific abilities include basic quantitative skills, such as numeracy, number fact knowledge, counting and calculation abilities, as well as exact numerical representations, such as digit recognition, and access to symbolic and non-symbolic magnitudes (Dowker, 2015; Sasanguie et al., 2012; Schneider et al., 2017). Instead, domain-general skills are related to a complex combination of underlying cognitive (Bull & Lee, 2014; Peng et al., 2016), affective (Barroso et al., 2021; Donolato et al., 2020), and contextual (Demirtas-Zorbaz et al., 2021; Wang et al., 2020) aspects which support mathematical learning and performance. Domain-general affective and cognitive skills will be considered in the present PhD thesis.

People diagnosed with SLD with major impairments in mathematics, face everyday challenges with understanding mathematical concepts, but also with problem-solving, planning activities, and even paying for buying things. All these difficulties experienced might be supported (or even exacerbated) by other associated emotional (Lai et al., 2015) and cognitive (Agostini et al., 2022) factors. The present PhD dissertation will discuss (and find evidence) on the relationship between mathematical skills, mathematics anxiety, and cognitive abilities by comparing children with and without SLD.

1.2.2 The relationship between mathematical skills and mathematics anxiety

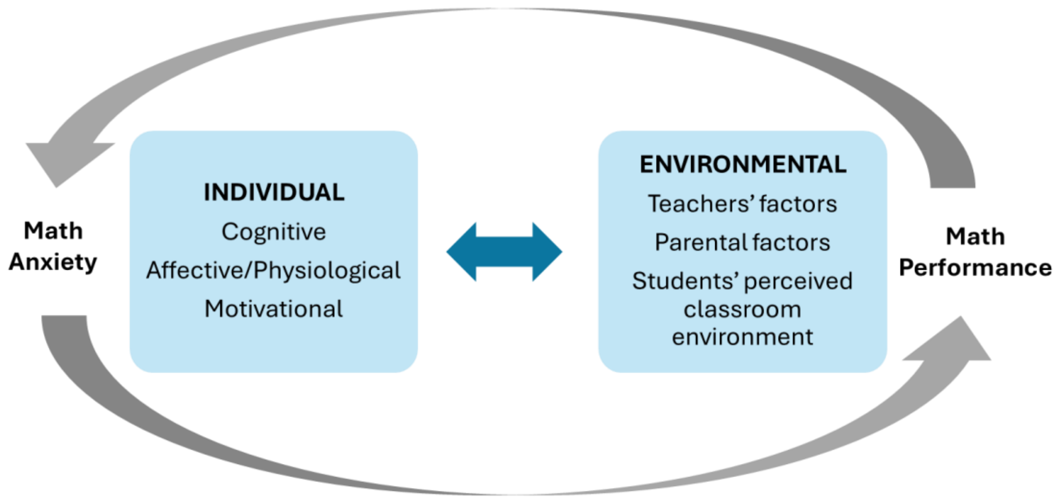
Mathematics anxiety (MA) is characterized by a pattern of negative feelings of concern, discomfort, and apprehension experienced when thinking about and performing mathematical tasks in both academic situations and everyday life (Ashcraft, 2002; Hembree, 1990; Mammarella, Caviola & Dowker, 2019). The specific characteristics and the assessment of mathematics anxiety will be explained in Chapter 4, with study III specifically focusing on this construct.

Significant small-to-moderate negative associations between MA and mathematics performance have been observed, showing that students with higher levels of MA tend to also have lower levels of mathematics achievement (for reviews and meta-analysis, see Barroso et al., 2021; Carey et al., 2016; Caviola et al., 2022; Hembree, 1990; Ma, 1999; Namkung et al., 2019). The causal relationship between mathematical performance and MA has been investigated thoroughly (Carey et al., 2016; Cipora et al., 2022), leading to the formulation of two universally recognized main models. The first one, the Deficit Theory, postulates that impairments in math performance increase the probability of developing MA, via negative prior experiences with mathematics (Hembree, 1990). The second one, the Debilitating Anxiety Model, claims that MA reduces mathematical performance by affecting the pre-processing, processing, and retrieval of information (Beilock et al., 2004; Beilock & DeCaro, 2007; Eysenck & Calvo, 1992).

However, most of the studies on this topic yield cross-sectional findings, and the direction of the relationship could not be determined from the limited number of longitudinal studies (Krinzinger et al., 2009; Ma & Xu, 2004). That's why a two-way relationship between MA and mathematical skills has been assumed (Carey et al., 2016; Cipora et al., 2022; Jansen et al., 2013), with various individual and environmental aspects accounting for the mutual association between them (see Figure 1.3).

Even less are the studies on the occurrence of MA and negative emotions related to math, in children with SLD findings higher levels of MA in this clinical group as compared to the control one (Kucian et al., 2018; Lai et al., 2015; Passolunghi, 2011; Rubinsten & Tannock, 2010), but to the best of our knowledge no previous study investigated the relationship between mathematical performance (i.e., mental calculations' skills) and MA in a group of children with established (and diagnosed) mathematical difficulties. The aim of study II of the present PhD dissertation will be to understand the association between these factors by comparing children with and without SLD with major impairments in mathematics.

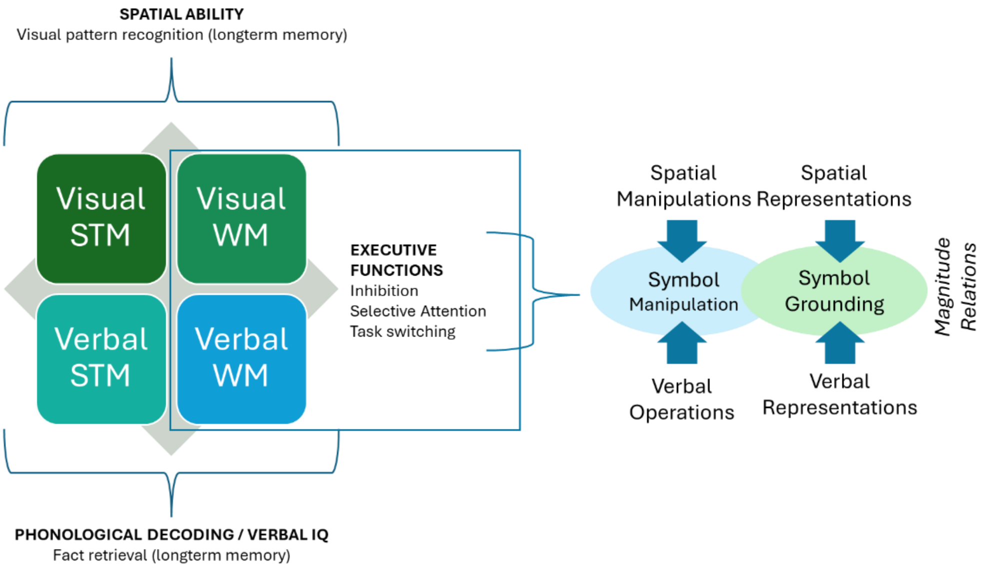
Figure 1.3 Multiple individual and environmental factors accounting for the reciprocal relation between MA and mathematical performance (adapted from Chang & Beilock, 2016).



1.2.3 The relationship between mathematical skills and cognitive abilities

Mathematical performance builds on general cognitive skills (Geary, 2011; Krajewski & Schneider, 2009), implemented by an extended brain network (Menon, 2010). Above numerical skills and knowledge, many cognitive factors contribute to individual differences in mathematical proficiency, such as the intelligence quotient (Giofrè et al., 2017), working memory (Caviola et al., 2020), language abilities (Donlan et al., 2007), visuospatial and motor skills (Simms et al., 2016), and executive functions (Cragg & Gilmore, 2014). Research in 9-year-old children (Szűcs et al., 2014) revealed an extended number processing network, with important processing nodes predicting arithmetic performance, specifically phonological processing, verbal knowledge, visuo-spatial short-term and working memory (WM), spatial ability and general executive functioning. Results from this study stretch the emphasis on the role of EFs and WM in the development of mathematical expertise (as shown in Figure 1.4), because of many studies revealing their importance in math (Bull & Lee, 2014; Cragg & Gilmore, 2014; Kolkman et al., 2013; Peng et al., 2016).

Figure 1.4 An executive memory function centric model of mathematical knowledge (adapted from Szűcs et al., 2014).



Although many studies have investigated the association between WM, EFs and mathematics in typical development, less has been done in the field of SLD. Indeed, children with mathematical difficulties have been proven to fail in WM tasks[1] including both visuospatial (for meta-analyses see Menon, 2016; Peng et al., 2016) and verbal (for a meta-analysis see Peng & Fuchs, 2016) information. Less attention (although still copious) has been given to EFs in SLD, specifically finding flaws with inhibition (Mammarella, Caviola, Giofrè, & Szűcs, 2018; Szűcs et al., 2013), and shifting (Li et al., 2023; McDonald & Berg, 2018; Van Der Sluis et al., 2004). The present PhD dissertation will focus on the impact of executive functions on mental calculations' performance in children with and without SLD with major impairments in mathematics.

[1] It is worth specifying that in literature WM has been described as an entire process of storage and processing, that also comprises (but is not reduced to) updating (Morris & Jones, 1990), as described by Baddeley and Hitch (1974; Baddeley, 2000). Although the concepts of WM and updating are not identical (see also Van der Ven et al., 2012), many authors did not distinguish between them, because of their significant correlation (St Clair-Thompson & Gathercole, 2006).

1.3 Overview of the studies I and II

The main aims of these two studies are to increase the current understanding of social and mathematical abilities in children and adolescents with ASD, SLD compared to ND participants, by investigating the possible emotional (anxiety) and cognitive (executive functions) underlying factors. Table 1.1 summarizes the main characteristics of the groups in studies I and II, the main aims and the hypotheses of each study.

Chapter 2 (study I) will initially define and describe the importance of social skills, specifically facial emotion recognition (FER), and the difficulties experienced by people with ASD within this realm, by pointing out the heterogeneity of findings in literature. The discussion will proceed by highlighting possible emotional (social anxiety, SA) and cognitive (executive functions, EFs) mechanisms that might influence the FER performance. The relationship between SA, EFs and FER will be discussed considering both typical development and ASD. Methodologically, children with and without ASD were asked to complete a computerized FER task, three computerized EFs (i.e., inhibition, updating and set-shifting) tests, and parents filled out a questionnaire on their children’s social anxiety.

Chapter 3 (study II) will focus on mathematical abilities, in particular mental calculation’s skills, of children with and without SLD, by exploring underlying mechanisms of mathematics’ achievement: mathematics anxiety (MA) and EFs. Participants were asked to complete a computerized mental calculation task, three computerized EFs (i.e., inhibition, updating and set-shifting) tests, and to fill out a self-report measure of MA. Parents filled in a questionnaire about their children's general anxiety level, useful for controlling the influence of a general state of tension on math achievement.

Table 1.1 Summary of the studies I and II: groups involved, number of participants (N), the topic examined, the main aims and hypotheses.

Study	Groups	N	Topic	Aims	Hypotheses
I	ASD ND	60 90 Total = 150	Social skills (i.e., facial emotion recognition) and related factors: • Social anxiety (SA) • Executive functions (EFs)	1. To evaluate facial emotion recognition (FER) skills in children with and without ASD, by also considering single emotions (happiness, sadness, anger, fear, surprise, disgust);	1. FER accuracy: ASD<ND (Black et al., 2017; Uljarevic & Hamilton, 2013) with more difficulties with negative emotions (i.e., fear, anger and disgust) (Ashwin et al., 2007; Economides et al., 2020; Enticott et al., 2014; Humphreys et al., 2007);
				2. To understand which factors (SA, EFs) might be associated with FER in children with and without ASD.	2. ↑SA = ↓FER in ASD (Antezana et al., 2023; Corden et al., 2008; Kleinhans et al., 2010). EFs might support FER in both groups (Martins et al., 2016; Neumann et al., 2021; Phillips et al., 2008; Sivaratnam et al., 2018; Torske et al., 2018).
II	SLD ND	39 48 Total = 87	Mathematical skills (i.e., mental calculation) and related factors: • Mathematics anxiety (MA) • Executive functions (EFs)	1. To examine levels of MA in children with and without SLD;	1. MA: SLD > ND (Lai et al., 2015; Passolunghi, 2011);
				2. To investigate EFs (inhibition, updating and set-shifting) in children with and without SLD;	2. EFs: SLD < ND (for a review see Agostini et al., 2022);
				3. To understand which factors (MA, EFs) might be associated with mental calculation accuracy in children with and without SLD.	3. ↓MA and ↑EFs = ↑mental calculations' performance both in children with (Lai et al., 2015; Szűcs et al., 2013) and without SLD (Carey et al., 2016; Caviola et al., 2022; Peng et al., 2016). However, SLD might have poor WM (Giofrè & Cornoldi, 2015; Toffalini et al., 2017), contributing to failures in the EFs (Passolunghi & Cornoldi, 2008; Passolunghi & Pazzaglia, 2005; Pelegrina et al., 2015), not further supporting mental calculations' ability.

ASD=Autism Spectrum Disorders; SLD=Specific Learning Disorders; ND=non-diagnosed matched participants.

CHAPTER 2

Facial emotion recognition in Autism Spectrum Disorders: The role of social anxiety and executive functions

2.1 Introduction

Social functioning requires the ability to recognize other people's emotional states from their facial expressions, because individuals can obtain a substantial amount of information through nonverbal facial cues giving signals to others about thoughts, feelings, attitudes, and intentions (Ekman, 1993; Ekman & Friesen, 2003). Indeed, to create worthwhile social interaction, facial emotion recognition (FER) is crucial in order to adjust one's own social actions and feedback (Fischer et al., 2019). In this sense, identifying emotional signs is a prerequisite for responding properly to other persons' presumed internal state, whether it means offering help, or simply an acknowledgement, or even a disapproval (Van Kleef, 2009).

Difficulties with FER have been associated with Autism Spectrum Disorder (ASD) (for a meta-analysis see Lozier et al., 2014), an early onset neurodevelopmental disorder characterised by deficits in social communication and social interaction alongside stereotypic, repetitive, restricted behaviours and interests (APA, 2013). Evidence suggests that social difficulties experienced by autistic individuals may be partly caused by a decrease in social reciprocity, mainly conveyed by their inability to recognise other people's emotional and mental dispositions (Baron-Cohen et al., 2009; Chiu et al., 2022). However, the large variability between the studies in tasks and participants' characteristics complicates the whole picture of FER in ASD, making findings contradictory (Black et al., 2017; Lozier et al., 2014; Uljarevic & Hamilton, 2013). Some studies have identified a generalized deficit in understanding all types of emotional facial expressions in autistic children (Lindner & Rosén, 2006; Lozier et al., 2014; Song et al., 2020; Rump et al., 2009), whereas others found a worse performance for some expressions, highlighting emotion-specific difficulties predominantly for negative emotions, for example anger, fear, disgust, sadness, and surprise (see for example, Ashwin et al., 2007; Economides et al., 2020; Enticott et al., 2014; Humphreys et al., 2007).

Some people might feel inadequate or uncomfortable when socially interacting with others, resulting in worry or anxiety (Heimberg et al., 2014). Nonetheless, anxiety is not always negative, and under certain circumstances, may be useful for facing social situations (McNeil & Randall, 2014). Nevertheless, anxiety might prevent people to maintain close social relationships by reaching the extreme level of the continuum, named *social anxiety*, characterized by cognitive, emotional, behavioral, and physiological symptoms before or during social or performance situations, concerning the fear to be negatively evaluated and a tendency for avoiding interactions (APA, 2013; Lievore et al., 2022). A recent model of childhood social anxiety development (Nikolíc, 2020) suggests the presence of cognitive biases when encoding social stimuli, such as facial emotional expressions. A face perceived as hostile or when misinterpreted can elicit feelings of perceived rejection and might consequently enhance anxiety in people for whom approval is important (for a meta-analysis see O'Toole et al., 2013). Findings are lacking consistency as regards the specific emotions linked with social anxiety. Some do support the idea that effects are not emotion-specific (Bell et al., 2011; Button et al., 2013; Silvia et al., 2006), although others have revealed that people with social anxiety are more sensitive to some emotions (Battaglia et al., 2004; Richards et al., 2002; Simonian et al., 2001; Tseng et al., 2017). Nonetheless, some children with subclinical levels of social anxiety performed well in mental state recognition of others (Nikolíc et al., 2019), and people with high trait social anxiety might better estimate others' mental states and recognize facial emotional expressions (Hunter et al., 2009; Sutterby et al., 2012; Tibi-Elhanany & Shamay-Tsoory, 2011), and in particular fear faces (Surcinelli et al., 2006).

The experience of negative emotions, such as fear or anxiety, within the social contexts is common in children and adolescents diagnosed with ASD (Spain et al., 2018; Lievore et al., 2022). A bidirectional relationship between social challenges and social anxiety in autism has been proposed (Bellini, 2006; White et al., 2010). Previous negative social experiences could prevent autistic people from engaging in social situations, reducing the opportunities to practice social skills and to empower social efficacy. Consequently, autistic individuals might have increased social worries as a consequence of the self-awareness of their social problems (internal sources of threat, e.g., making a self-identified mistake in social situations) and of rejections or negative judgement from others (external sources of threat) (Rosen & Lerner, 2018; Spain et al., 2018). In this regard, faces may be overstimulating, possibly related to higher levels of social anxiety (Kleinhans et al., 2010), but for some, faces may not be perceived as emotionally interesting causing indifference towards social interactions (Ashwin et al., 2007). The few studies on the topic revealed that social anxiety might be related to poorer facial emotion recognition in young adults and adolescents with ASD (Antezana et al., 2023; Bal et al., 2010; Joseph et al., 2008), to a greater gaze duration to social threat stimuli in adolescents with ASD (White et al., 2015), and to poorer fear recognition in autistic adults (Corden et al., 2008). Other studies found no association between behavioral ratings of social anxiety and emotion recognition performance across 7-13 years old autistic children (Wong et al., 2012) and adults (Spain et al., 2016).

Besides social anxiety, there is growing evidence that social development and emotion knowledge might be endorsed by higher-order cognitive skills, such as executive functions (EFs), already described in Chapter 1. Altogether EFs help us to reach goal-directed behaviours and are therefore essential for success in everyday living. A developing body of literature has point out the relationship between EFs and social abilities (Beauchamp & Anderson, 2010; Denham et al., 2012; Moriguchi, 2014; Spikman et al., 2013). EFs might serve for the development of emotional understanding, since attentional and inhibitory control are essential to correctly behave in social contexts, and practising with social abilities (Carlson & Wang, 2007; Lecce et al., 2017). In particular, a positive correlation between FER and inhibition skills has emerged in various populations, supporting the idea that the ability to handle with complex emotional scripts might be assisted by EFs (David et al., 2014; Lee et al., 2009; Martins et al., 2016). Moreover, working memory is important in the recognition of other persons' emotions, because of the necessity to process the emotional signal while momentarily holding it in mind in order to produce a social response (Neumann et al., 2021; Phillips et al., 2008).

Challenges with EFs have been described in autism, with the idea of an "executive dysfunction" to try to describe autistic symptoms (Hill, 2004; Hughes, 2001; Ozonoff, 1998), although the great heterogeneity within the spectrum (Dajani et al., 2016). Impairments in EFs have been proposed as a cause of not only the rigid and repetitive interests and behaviors in ASD (Cissne et al., 2022; South et al., 2007), but also of the primary challenges with reciprocal social interactions (Fong & Iarocci, 2020; Leung et al., 2016). The association between the ability to recognize others' emotions and EFs has been quite investigated in children with ASD (Joseph & Tager–Flusberg, 2004; Sivaratnam et al., 2018; Torske et al., 2018), postulating a link between the domains. Many authors in literature agree on adopting a more nuanced perspective on the difficulties in EFs in autism, due to the role of individual differences, such as intellectual functioning and age, and task characteristics (Tonizzi et al., 2022; Van Eylen et al., 2015). In this regard, sometimes autistic people display prominent challenges with EFs in everyday life, while amply performing on structured neuropsychological tests (Kenworthy et al., 2008).

Overview of the present study

To the best of our knowledge, no previous studies investigated the relationship between FER, social anxiety and executive functions, by taking into account (and comparing) groups of children with and without ASD.

Thus, the first aim of the present study was to evaluate FER skills in children with ASD without intellectual disability (ID) as compared to non-diagnosed (ND) participants, by considering both the overall performance and single emotions (happiness, sadness, anger, fear, surprise, disgust). Based on prior results (Black et al., 2017; Uljarevic & Hamilton, 2013), it is worth hypothesizing a worse general performance on the FER task in children with ASD, as compared to those without ASD. As regards single emotions, we expect that the ASD group will find more difficulties in detecting negative emotional faces, such as those expressing fear, anger and disgust than the ND group (Ashwin et al., 2007; Economides et al., 2020; Enticott et al., 2014; Humphreys et al., 2007).

The second aim was to understand which factors (social anxiety, EFs) might be associated with (and predict) FER, and whether the relationships might differ among groups (ASD, ND). We expect a statistically significant link between FER ability and the reported social anxiety in children and adolescents with ASD. It is worth assuming that higher levels of social anxiety could be consistent with a worse FER in autism, because of their widely recognized social challenges and distress within the social contexts (Antezana et al., 2023; Corden et al., 2008; Kleinhans et al., 2010). As a fact, children and adolescents with ASD with higher levels of social anxiety might avoid others' emotions which they may find hard to interpret (Bögels & Mansell, 2004; Mansell et al., 1999). Additionally, we predict that EFs might support FER skills in both groups, awaiting a positive association between these two abilities (Martins et al., 2016; Neumann et al., 2021; Phillips et al., 2008; Sivaratnam et al., 2018; Torske et al., 2018).

2.2 Method

2.2.1 Participants

The study involved 150 children and adolescents aged between 8 and 16 years old divided into two groups: 60 (M 52) with Autism Spectrum Disorders (ASD) without intellectual disability (ID), and 90 (M 71) matched non-diagnosed (ND) peers. The two groups did not statistically differ in chronological age [$F\ (1, 148) = -.79$, $p = .43$, *Cohen's* d=-.13; ASD= 11.60 (2.67), ND= 11.90 (1.99)], sex distribution [X^2=1.47, df=1, p=.22], or total IQ [$F\ (1, 148) = -1.27$, $p = .21$, *Cohen's* d =-.21; ASD= 106.63 (15.68), ND= 109.47 (11.65)].

Inclusion criterion for the current study was a standard score of 80 or more for total IQ as assessed by the Wechsler Intelligence Scales (WISC IV; Wechsler, 2003). All children and adolescents were native Italian speakers, and none had any visual or hearing impairments. Participants who were taking medication, or with other known genetic conditions, a history of neurological diseases, comorbid psychopathologies, or certified physical and intellectual disabilities were excluded.

The ND group comprised healthy children with typical development with no psychiatric, neurological, or neurodevelopmental disorders. They were engaged and examined individually at school. Participants in the clinical group were assessed at the child and adolescent psychiatric services, where they referred. All participants in the ASD group had been previously diagnosed with ASD, according to the DSM-IV-TR or the DSM-5 (APA, 2000, 2013) or ICD-10 (WHO, 1992) criteria. Diagnosis of ASD were confirmed using the Autism Diagnostic Interview - Revised (ADI-R; Rutter et al., 2005). The groups statistically differed in all subscales of ADI-R (Reciprocal social interaction: $F(1, 148)$=15.22, p<.001, *Cohen's* d=2.54; Language/communication: $F(1, 148)$=12.57, p<.001, *Cohen's* d=2.10; Repetitive behaviors/interests: $F(1, 148)$=10.51, p<.001, *Cohen's* d=1.75, with autistic participants having higher scores than those without ASD.

2.2.2 Materials

Facial emotion recognition

An ad-hoc computerized task was created to assess emotion recognition abilities. It was developed by using the EU-Emotion Stimulus Set, which was created as part of the ASC-Inclusion project within the European Community's Seventh Framework Programme (FP7/2007-2013; O'Reilly et al., 2012, 2016).

Stimuli were static images of actors, taken from dynamic video clips with a neutral white background, that expressed a facial emotion (see Figure 2.1). The frame for the static images was captured at the peak of the expressed emotion, so that the emotion appeared as close as possible to a real-life situation. A direct frontal view of each actor, featuring only their shoulders and head within the frame, was depicted. The participant was required to choose whether two actors expressed the same or different emotions by pressing distinct keys on the keyboard ("z" if "same emotion", "m" if "different emotions"). There were no time restrictions to respond. The task comprised 144 trials divided into two blocks of 72 with a small break after the first 36 trials of each block. In half of the trials the two actors showed the same emotion (n=72), in half different emotions (n=72). The six basic emotions were assessed: happiness, surprise, sadness, fear, anger, and disgust. Each of the six emotions was the correct answer 12 times during the entire task. Actors were of different ethnicity and age range 10–70 years old (ten females and nine males). The trials were counterbalanced for actors' age (adult-adult, child-child, and adult-child), and emotions' intensity (high, and low). Raw scores were calculated for total accuracy. In addition, correct responses for the single emotions (happiness, surprise, sadness, fear, anger, disgust) were considered.

Cronbach's α (total accuracy) = .83 (C.I.=.79-.86).

Figure 2.1 An example of item of the Facial emotion recognition (FER) task.

Social anxiety

The parent-report form of the Italian version (Paloscia et al., 2017) of the Multidimensional Anxiety Scale for Children (MASC-2; March 2012) was administered to evaluate the presence of social anxiety symptoms. Specifically, the Social Anxiety subscale (composed by Humiliation/Rejection, and Performance Fears) was administered. This dimension includes 9 items rated on a 4-point scale from 0 (*never*) to 3 (*often*). Raw scores were converted into T scores by using normative data that considers the child's age and sex. Cronbach's α (Social Anxiety scale) =.88 (March, 2012).

Executive functions

The tripartite model of executive functions by Miyake (Miyake et al., 2000) was employed to evaluate executive functioning in our sample. This model encompasses three components: inhibition of impulsive reactions ("Inhibition"), updating and monitoring ("Updating"), and mental set shifting or flexibility ("Set-shifting").

Inhibition

Inhibitory control was assessed with a computerized go/no-go task (adapted from Christ et al., 2007). The task included 120 trials, composed by two blocks (60+60) with a break between them. On each trial, one of four stimuli (blue, red, yellow, and green dots) was centrally displayed in a computer monitor. In the initial block, participants were asked to press the spacebar as quickly as possible when a blue dot appeared (target; go trials) and to give no response when a dot in any other colour showed (non-target; no-go trials). In the subsequent block, children were instructed to quickly press the spacebar whenever a dot of any colour except blue materialized (referred to as target; go trials), and to abstain from reacting when a blue dot was presented (classified as non-target; no-go trials). Performance on the go trials corresponds to a measure of attention, whereas errors on the no-go trials to a measure of inhibition. Within each block, stimuli were produced in a random order and targets were presented on a minority of trials (25%). After an intertrial interval of 2.000 ms, a new trial was presented. At the beginning of the task, following the delivery of instructions, eight practice trials were introduced, during which children received feedback regarding their responses ("correct", "incorrect", and "too slow" when the response was not given within 2.000 ms). Errors on the no-go trials (commission errors = number of reactions to the non-target stimuli) were considered as a measure of inhibition.

Cronbach's α (for both go and no-go trials) = .94 (C.I. = .92–.96).

Updating

This computerized task, modified from the work of Cardillo et al. (2021) and Crisci et al. (2021), was employed to evaluate the ability for visually and spatially refreshing information within the working memory system. Participants were shown a 4×4 blank matrix on the computer screen. A total of eight sequences of various shapes (i.e., triangle, circle, star, square, rhombus, pentagon) appeared in the matrix. Participants were asked to recall the last position of specific shapes in the matrix previously displayed on the screen. The quantity of shapes to be recalled varied between 2 and 5, contingent on the difficulty level of the task. Sequences of

6, 8, 10, or 12 shapes were used, and there were two trials for each sequence length. Before starting the experiment, participants were exposed to three practice trails. Accuracy was calculated as a proportion of items' last positions correctly recalled out of the total positions to remember (Giofrè & Mammarella, 2014).

Cronbach's α = .80 (C.I. = .75-.83).

Set-shifting

A computerized version of the Wisconsin Card Sort Test (WCST; Heaton et al., 1993; Lievore et al., 2024) has been designed from the original edition. Every trial consisted of four stimulus cards and one response card, with the participant's objective being to accurately associate the response card with one of the stimulus cards based on one of three grouping principles. Following each trial, participants were provided with feedback regarding the accuracy of their answers. The stimulus cards were displayed in a row at the upper part of the computer screen, while the response cards appeared one at a time at the lower section of the screen. The four stimulus cards displayed the following symbols: (a) one red triangle, (b) two green stars, (c) three yellow crosses, and (d) four blue circles. There were two decks of 64 response cards, each containing from one to four identical symbols (triangles, stars, crosses, or circles) of a particular colour (red, green, yellow, or blue). The first correct sorting principle was colour, followed by symbol and then number. The participant had to correctly match the stimulus and the response cards 10 times consecutively within each criterion. The test concluded either when the participant successfully matched the response cards according to six criteria (twice for each sorting principle), or when they employed two sets of 64 response cards (totalling 128 cards). The analysis of the present study involved using the total count of perseverative errors, which were computed as proportions relative to the total number of administered trials. A perseverative error is defined as a failure to shift category after receiving negative feedback from the previous trial.

Generalisability coefficient = .60 (from .37 to .72) (Heaton et al., 1993).

2.2.3 Procedure

The study was approved by the ethics review board of the University of Padova (Italy). After obtaining the written consent of children's parents to their participation in the study, participants were tested individually in a quiet room at specialized centers (ASD) or at school (ND) during three sessions (a screening and two experimental phases) lasting approximately 40 minutes each. In the screening phase, the IQ was calculated and only participants who scored above 80 were included; reading and math achievement was also evaluated in this initial phase. Parents were administered the ADI-R for child autistic symptoms. The first experimental phase included the emotion recognition test (first block), go-no go, and updating tasks. The second one comprised the emotion recognition task (second block) and the WCST. The tasks in the experimental sessions were presented in a counterbalanced order. At the same time, parents completed the MASC-2 for assessing the child social anxiety. The experimenter provided instructions on each task, letting the participant practice before starting the experiment. The computerized tasks (FER and EFs tasks) were created and administered using PsychoPy3 (Pierce et al., 2019), and a laptop computer with a 15-inch LCD screen.

2.2.4 Statistical approach

First, a series of univariate ANOVAs were performed to estimate differences between the two groups in the measures of interest. Effect sizes were also computed using *Cohen's d*, which expresses the effect size of the pairwise comparisons between the groups. *Cohen's d* is interpreted as the difference between means in terms of standard deviation units.

Second, a series of regression models using a hierarchical approach was developed to assess the effect of the measured variables (social anxiety, three EFs) on the dependent variable (FER). In the first model, we included the group as predictor; in the second model, we added social anxiety; in the third the EFs (inhibition, updating, and set-shifting) were included. The interactive effect of Group (i.e., ASD, ND) with social anxiety, inhibition, updating, and set-shifting was added in the fourth and last model.

The best model was selected using information-theoretic (I-T) approaches (Burnham et al., 2011), considering the Akaike information criterion (AIC), the R^2 and the R^2 adjusted. The AIC is an estimator of prediction error and therefore of the relative quality of statistical models for a given set of data. A lower AIC and a higher R^2 adjusted indicates a better model.

Data were analyzed using R version 1.3.1093 (R Core Team, 2022). The "lme4" package was used to run the regression models and the AIC (Bates et al., 2015), and the "ggplot2" package to obtain the graphical effects (Wickham, 2016).

2.3 Results

Differences between the groups

Tables 2.1 and 2.2 display descriptive statistics and statistical comparisons between the two groups in all considered measures. Effect sizes of the pairwise comparisons between the groups expressed with Cohen's d are also reported.

Facial emotion recognition

Table 2.1 concerns to the performance in the Facial emotion recognition task with respect to total accuracy (see also the distribution in Figure 2.2), and single emotions (happiness, surprise, sadness, fear, anger, disgust). The ASD group achieved an overall lower performance in recognizing emotions (total accuracy) as compared to the ND group, $F\ (1, 148) = -6.08$, $p <$

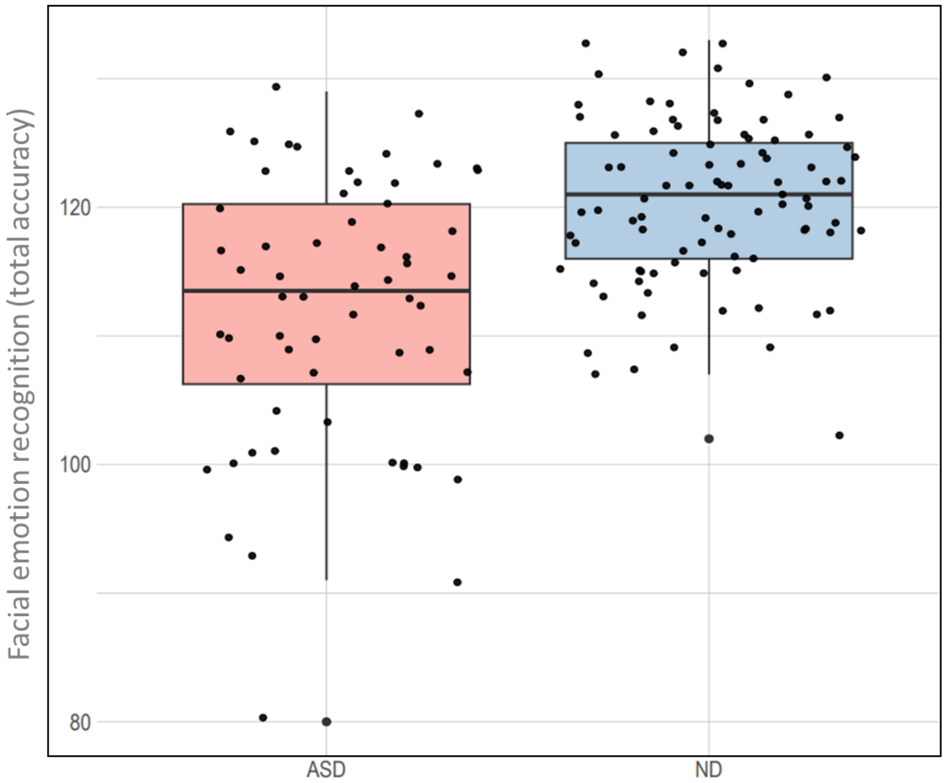
.001, *Cohen's d*= -1.01; ASD= 112.13 (10.35), ND= 120.44 (6.41). Specifically, the ASD group scored worse than the ND group in recognizing happiness, *F (1, 148)* = -2.87, *p* = .005, *Cohen's d*= -.48, surprise, *F (1, 148)* = -3.02, *p* = .003, *Cohen's d*= -.50, fear, *F (1, 148)* = -2.73, *p* = .007, *Cohen's d*= -.45, anger, *F (1, 148)* = -2.46, *p* = .007, *Cohen's d*= -.45, and disgust, *F (1, 148)* = -5.35, *p* < .001, *Cohen's d*= -.89.

Table 2.1 Descriptive statistics and statistical comparisons by group for correct responses on the Facial emotion recognition (FER) task, in children and adolescents with Autism Spectrum Disorders (ASD) and without any diagnosis (ND).

FER task		**ASD (n=60)**	**ND (n=90)**	***F* (1, 148)**	***p***	***Cohen's d***
		M (SD)	**M (SD)**			
Total accuracy		112.13 (10.35)	120.44 (6.41)	-6.08	**<.001**	-1.01
Single emotions	Happiness	11.05 (1.39)	11.56 (0.75)	-2.87	**.005**	-.48
	Surprise	8.70 (2.59)	9.74 (1.63)	-3.02	**.003**	-.50
	Sadness	10.25 (1.96)	10.72 (1.35)	-1.75	.08	-.29
	Fear	6.71 (3.12)	7.89 (2.09)	-2.73	**.007**	-.45
	Anger	6.91 (2.64)	7.90 (2.21)	-2.46	**.01**	-.41
	Disgust	7.98 (2.05)	9.64 (1.72)	-5.35	**<.001**	-.89

Note: M=mean; SD=standard deviation.

Figure 2.2 Boxplot of the distribution of performance on the Facial emotion recognition task in children and adolescents with Autism Spectrum Disorders (ASD) and without any diagnosis (ND).



Social anxiety

Concerning social anxiety (see Table 2.2), parents of children and adolescents with ASD reported greater levels of social anxiety as compared to the ND group, $F\ (1,\ 148) = 5.57$, $p < .001$, *Cohen's d*= .93.

Executive functions

As regards the executive functions' tasks (see Table 2.2), the ASD group performed significantly worse than the ND in the tasks assessing inhibition (no-go errors), $F\ (1,\ 148) = 2.17$, $p = .03$, *Cohen's d*= .36, updating (% total accuracy), $F\ (1,\ 148) = -4.18$, $p < .001$, *Cohen's d*= -.69, and set-shifting (% correct responses), $F\ (1,\ 148) = -2.12$, $p = .04$, *Cohen's d*= -.35.

Table 2.2 Descriptive statistics and statistical comparisons by group for Social anxiety and Executive functions (inhibition, updating, and set-shifting), in children and adolescents with Autism Spectrum Disorders (ASD) and non-diagnosed (ND).

Measures	Variables	ASD (n=60)	ND (n=90)	*F* (1, 148)	*p*	*Cohen's d*
		M (SD)	M (SD)			
Social anxiety	T score	66.35 (14.79)	54.93 (10.30)	5.57	**<.001**	.93
Inhibition	No-go (errors)	4.23 (3.57)	3.16 (2.52)	2.17	**.03**	.36
Updating	Total accuracy (%)	63.60 (18.58)	74.10 (12.18)	-4.18	**<.001**	-.69
Set-shifting	Correct responses (%)	69.15 (12.41)	73.19 (10.72)	-2.12	**.04**	-.35

Note: M=mean; SD=standard deviation.

Hierarchical regression analysis

A series of linear regressions (see Table 2.3) were tested in order to investigate the association between the facial emotion recognition and the hypothesized predictors (i.e., group, social anxiety, inhibition, updating and set-shifting). The interactive effect of Group with other predictors was also considered. Models' comparison (*F, p*) is shown in Table 2.4 with the AIC, R^2 and R^2 adjusted of each regression model. Before conducting the regression analysis, collinearity was verified by ensuring that correlations between predictor variables were not too high [$r_s < -.23$], confirming the robustness of the model.

As shown in Table 2.3, our model fitting procedure revealed that the best-fitting model was Model 4: Facial emotion recognition ~ Group + Social anxiety + Inhibition + Updating + Set-shifting + Group*Social anxiety + Group*Inhibition + Group*Updating + Group*Set-shifting (*AIC* = 1030.10, Δ°AIC = 31.07, R^2=.41, *Adj* R^2 =.38). Taken together, our variables in the best fitting model accounted for 41% of the variance calculated using the R-squared (*Adj*

R-squared = 38%), adding around 22% of variance to the first model which included only Group. Regarding the main effects, Group, *t*= 3.35, *p* = .001, Inhibition, , *t*= -3.78 *p* < .001, and Updating, *t*= 3.48, *p* < .001, were significantly associated with Facial emotion recognition: membership in the ND group, lower errors in the inhibition task, higher scores in the updating task were related to better performance in the FER task. Two interaction effects were found to be statistically significant: between Group and Social anxiety, *t*= -2.29, *p* = .02; and between Group and Updating skills, *t*= -2.09, *p* = .04. More specifically, as shown in Figure 2.3, higher levels of social anxiety coincided with better FER abilities in the ASD group, and the contrary was true for the ND group. Instead, as depicted in Figure 2.4, higher scores in the updating task was consistent with better FER task in the ASD group, but not in the ND group. No other statistically significant main or interactive effects emerged.

Table 2.3 Hierarchical regression models with Facial emotion recognition (total accuracy) as dependent variable, and all the other measured variables and their interactions with group as predictors.

Regression models	***Estimate coefficient***	***SE***	***t***	***p***
Model 1				
Group	**8.31**	**1.37**	**6.07**	**<.001**
Model 2				
Group	**9.19**	**1.49**	**6.13**	**<.001**
Social anxiety	.08	.05	1.42	.16
Model 3				
Group	**6.36**	**1.50**	**4.23**	**<.001**
Social anxiety	.03	.05	.52	.61
Inhibition	**-.82**	**.21**	**-3.91**	**<.001**
Updating	**.14**	**.04**	**3.25**	**.001**
Set-shifting	-.02	.05	-.37	.71
Model 4				
Group	**36.03**	**10.74**	**3.35**	**.001**
Social anxiety	.11	-07	1.60	.11
Inhibition	**-1.04**	**.27**	**-3.78**	**<.001**
Updating	**.19**	**.05**	**3.48**	**<.001**
Set-shifting	.01	.08	.14	.88
Social anxiety * Group	**-.23**	**.10**	**-2.29**	**.02**
Inhibition * Group	.52	.41	1.25	.21
Updating * Group	**-.17**	**.08**	**-2.09**	**.04**
Set-shifting * Group	-.08	.11	-.72	.47

Table 2.4 Results of the comparisons between the regression models.

Model 1 was compared to a null model (lm = Facial emotion recognition ~ 1).

Model	***F***	***p***	**AIC**	**R^2**	**R^2 adjusted**
Model 1	36.92	**<.001**	1061.17	.20	.19
Model 2	2.02	.16	1061.13	.21	.20
Model 3	10.31	**<.001**	1037.93	.35	.33
Model 4	3.89	**.005**	1030.10	.41	.38

Note: AIC, Akaike Information Criterion.

Figure 2.3 Significant interaction effect of the group with Social anxiety (T score), with Facial emotion recognition (total accuracy) as a dependent variable. Error bands represent 95% confidence intervals.

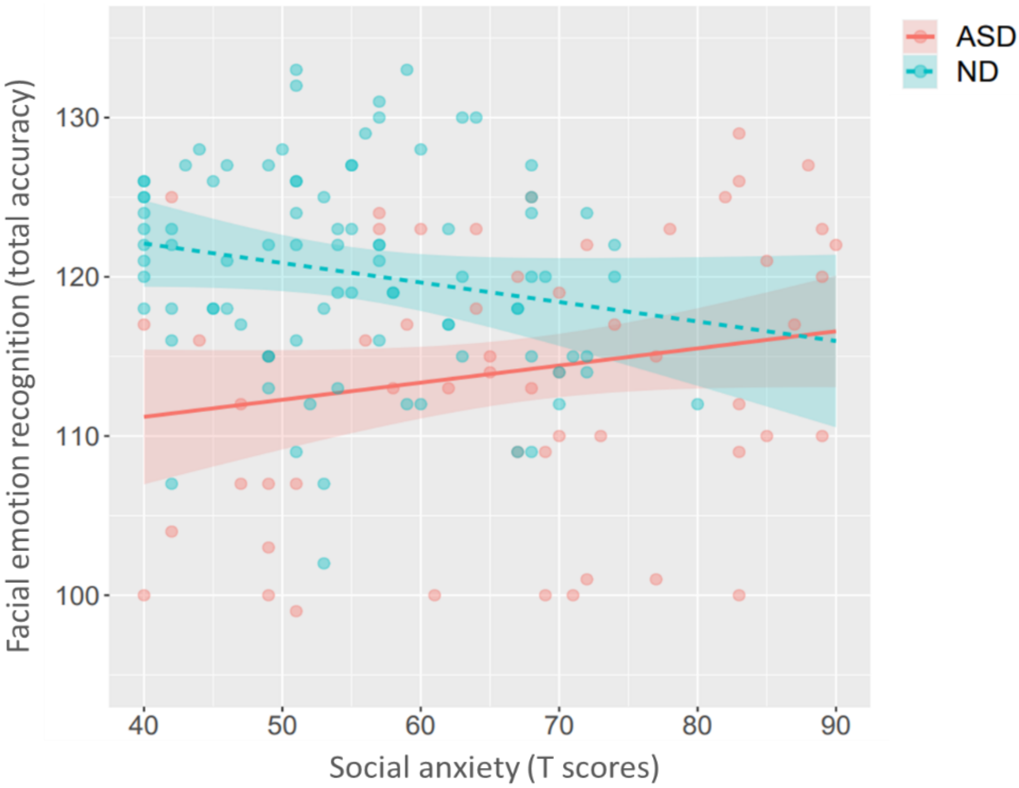
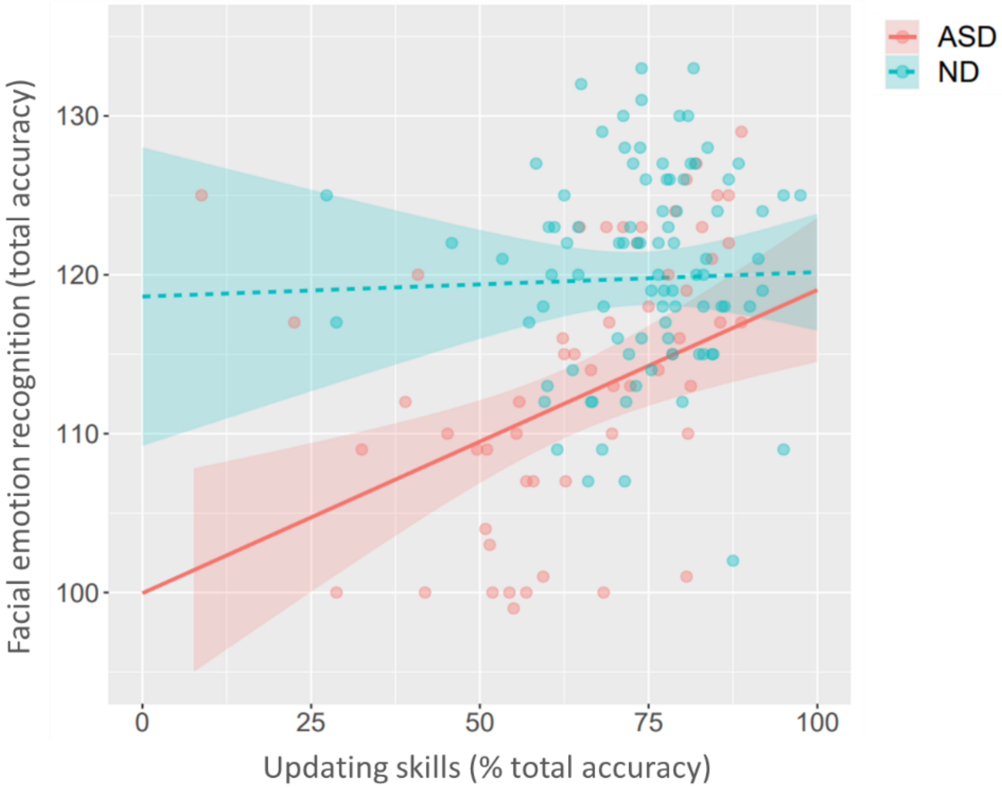


Figure 2.4 Significant interaction effect of the group with Updating (% accuracy), with Facial emotion recognition (total accuracy) as a dependent variable. Error bands represent 95% confidence intervals.



2.4 Discussion

The present study aimed to investigate the abilities to recognize facial emotion expressions in children and adolescents with and without ASD, by also studying how different emotions are identified. A second aim was to examine whether social anxiety and executive functioning (inhibition, updating and set-shifting) might lie behind FER skills in these two groups (ASD, ND).

Consistent with previous data in literature (Black et al., 2017; Uljarevic & Hamilton, 2013), overall performance on the FER task was statistically lower in the ASD group as compared to the ND group. Recognizing other people's emotions from faces denotes a foundation for adaptive social functioning (Fischer et al., 2019; Van Kleef, 2009), so autistic children and adolescents might find difficult to navigate the social world because of their efforts in decoding facial emotions, which explicit requests, intentions, and feedback in dyadic social exchanges. As regards specific emotions, our results do not confirm our previous hypothesis. In fact, participants with ASD seem to experience difficulties in recognizing all basic emotions included in our task (Ekman, 1993), except for sadness, as compared to the ND group, giving support to the hypothesis of a generalized face-emotion recognition deficit in ASD (Lindner & Rosén, 2006; Lozier et al., 2014; Rump et al., 2009). A lack of global expertise in social skills like FER may underlie extreme challenges in social reciprocity, particularly whether contemplating primary basic emotions (Høyland et al., 2017).

To further explore associated mechanisms useful to understand FER challenges, it is worth investigating whether internalizing symptoms such as social anxiety might be a factor. In our study, parents of children and adolescents with ASD reported higher levels of social anxiety in their sons and daughters as compared to ND participants, in agreement with previous literature (Bellini, 2006; White et al., 2010). Therefore, youth with ASD might experience concerns and emotional activation when acting in front of other people, and this could prevent them from being involved in social situations, by generating a cascade effect which could lower the possibility of practising with social skills to appropriately socially behave (Spain et al., 2018). What is substantial in our research is the relationship between social anxiety and FER abilities depending on the group of membership. In fact, a statistically significant interaction emerged between social anxiety and group in predicting FER ability. In contrast with our initial hypotheses, a better FER was consistent with higher levels of social anxiety reported by parents of autistic participants. It is possible that better FER skills might trigger social anxiety in children and adolescents with ASD, because of the discomfort with social interactions, which may increase when they are more aware, as found by research on socially anxious individuals (Hunter et al., 2009; Nikolíc et al., 2019; Tibi-Elhanany & Shamay-Tsoory, 2011). On the other hand, autistic children with higher levels of social anxiety may have heightened attentional resources (hypervigilance) towards external stimuli (Schultz & Heimberg, 2008) when executing a socially-based test. Emotional faces might be identified as threatening for people with ASD because of the awareness of their own social challenges (Brewer et al., 2022), producing a biased attentive processing (Koster et al., 2006). An interesting study conducted by Livingston and colleagues (2019) stated that autistic adolescents who show better social skills than others, usually display higher levels of anxiety. In this sense, compensation may come at a cost, promoting anxiety for trying to meet social demands. Higher attentional levels could have resulted in a better performance, because of the increased focus on the FER task: anxiety may not damage the performance when it supports the use of compensatory strategies (Eysenck et al., 2007).

In accordance with the literature, not only social anxiety, but also cognitive processes are involved in the processing of others' emotions. As regards the role of EFs, the main effect of inhibition was significant in predicting FER in the total sample. The capacity to inhibit impulsive behaviors is significantly related to the ability to detect others' emotions, but also with the ability to complete a computerized task that entails to give the correct answer as rapidly as possible (Martins et al., 2016; Neumann et al., 2021). What is more noteworthy, a statistically significant interaction appeared between updating and group membership in predicting FER ability. Updating skills seem to be predictive of social abilities in ASD children and adolescents (Philipps et al., 2008; Sivaratnam et al., 2018; Torske et al., 2018), supporting the idea that EFs are required to appropriately respond to social cues (Denham et al., 2012; Moriguchi, 2014; Spikman et al., 2013). As a fact, higher order cognitive abilities may support social engagement, acting as a compensatory mechanism (Johnson et al., 2015; Livingston et al., 2019). In line with these previous studies, our findings demonstrated that ASD-diagnosed children with the highest performance on the updating task, equal the performance on the FER task of non-ASD subjects, as if this EF might have a booster underlying impact on social skills in autism.

Limitations, future directions and potential implications

Despite the novelty and significance of our results, the present study had some limitations.

First, the FER task is composed by static images of faces, and though previous research testified the reliability of this type of stimuli, also other kind of stimuli should be used to properly examine emotion recognition skills. For example, dynamic cues (e.g., morphing from neutral to angry) and videos of social interactions could be more ecologically valid, because they resemble more which can be observed in the real world (Ekman & Friesen, 2003; Cardillo, et al. 2023). Moreover, the FER task required a matching condition, in which participants had to recognize whether two faces displayed the same emotion; it would be interesting to implement a labelling condition, in which children should detect the correct emotion and verbalize it. Likewise, only the six basic emotions have been investigated (Ekman, 1993), but more complex emotions, especially the "social" emotions (e.g., shame, guilt), could be more related to the development of social anxiety and internalizing problems. In addition, a ceiling effect might have occurred in the performance on the FER of happiness, which may lead to loss of information in the observed data (Liu & Wang, 2021). Future studies should consider a revision of the instrument, or larger sample size to verify the ceiling effect. A final limitation can be detected in the absence of the assessment of child general anxiety (besides social anxiety), which may play a role in the prediction of FER; thus, future research should control for general trait anxiety.

Clinical implications of the present study may be drawn on social skills' treatment in autism. From our findings, higher awareness of others' emotions is associated with higher levels of social anxiety in ASD, possibly underlying how autistic children could experience negative feelings when they encounter socially-driven stimuli. From this point of view, social motivation and social kills should be empowered to prevent worries, tension and anxiety associated with socio-emotional reciprocity. Instead, a key factor for preventing the rising of social anxiety might be improving self-efficacy and lowering worries towards others' negative judgement, enhancing the occasions of social skills' practise and the interactions with peers. Lastly, training aimed at developing executive functions should also be addressed to support social learning in the case of ASD-diagnosed children and adolescents.

To conclude, findings from the present study shows new understandings into the association between facial emotion recognition, social anxiety, and executive functioning in children and adolescents with and without ASD. Remarkable, a distinct relationship was found between social anxiety and FER in children and adolescents with ASD as compared to ND participants, whereas executive functioning appears to boost socio-emotional skills in autism.

CHAPTER 3

Mental calculation in Specific Learning Disorders:

The role of mathematics anxiety and executive functions

3.1 Introduction[2]

Among mathematical skills, mental calculation has been extensively examined due to its fundamental importance in different academic and everyday situations (e.g., making payments, playing games). Mental calculation has been closely linked to specific affective components, such as mathematics anxiety (Barroso et al., 2021; Caviola et al., 2022), and general cognitive abilities, for instance, executive functions (EFs) (Bull & Lee, 2014; Cragg & Gilmore, 2014). In the current study, the ability of mental calculation has been considered with the aim of investigating the role of both affective and cognitive domain-general abilities in typical and atypical mathematical learning.

Regarding affective domain-general factors, a specific type of anxiety has been linked to mathematics and is referred to as mathematics anxiety (MA). Alike other forms of anxiety, MA encompasses a combination of negative emotions such as tension, discomfort, and fear that individuals experience only when facing or thinking about mathematical tasks, both in academic settings and in daily life (Ashcraft, 2002; Hembree, 1990; Ma & Xu, 2004). Significant small-to-moderate negative associations between MA and mathematics performance have been observed, showing that students with higher levels of MA tend to also have lower levels of mathematics achievement (for reviews and meta-analysis, see Barroso et al., 2021; Carey et al., 2016; Caviola et al., 2022; Hembree, 1990; Ma, 1999; Namkung et al., 2019). However, most of the studies on this topic yield cross-sectional findings, and the

[2] The present study is under review: Lievore, R., Caviola, S., & Mammarella, I.C. Children with and without dyscalculia: How mathematics anxiety and executive functions may (or may not) affect mental calculation. *Learning and Individual Difference.*

direction of the relationship could not be determined from the limited number of longitudinal studies. Some involve a pre-post testing design (Cargnelutti et al., 2017; Gunderson et al., 2018; Vukovic et al., 2013), and even fewer include more than two-time points (Krinzinger et al., 2009; Ma & Xu, 2004). Hence a two-way relationship between MA and mathematical skills has been hypothesized (Carey et al., 2016; Cipora et al., 2022; Jansen et al., 2013).

Developmental dyscalculia (DD), also known as Mathematical Learning Disability, is defined by severe impairments in the acquisition of mathematical skills. As declared by the international classification systems DSM-5 (APA, 2013) and ICD-10 (WHO, 1992), individuals with DD specifically show a persistent pattern of mathematics performance significantly below the expected level for their age, educational background, and intellectual ability on standardized assessments, and these challenges often have a detrimental impact on their academic and daily life. Approximately 5-15% of school-aged children are diagnosed with a Specific Learning Disorder (SLD) (APA, 2013), with a mean estimate of 5-6% provided by different demographic studies, of children with mathematical learning difficulties (Devine et al., 2013). Regarding domain-general affective aspects, it is worth noting that some aversive emotional aspects, such as MA, might be intensified in students with established mathematical impairments. Compared to domain-specific and cognitive general aspects, affective factors have been understudied within the context of SLD. The few studies on the topic suggest higher levels of MA in children with mathematical difficulties as compared to those without (Kucian et al., 2018; Lai et al., 2015; Passolunghi, 2011; Rubinsten & Tannock, 2010), given that DD and math anxiety may also be dissociated aspects (Devine et al., 2018). Moreover, individual differences in children’s self-reports about their MA could be further negatively shaped by repetitive experiences of failure and adverse emotional dispositions towards mathematical settings (Hunt & Maloney, 2022; Pekrun, 2006).

Among domain-general abilities, performance on mental calculation tasks has been found to rely on higher-order cognitive skills, specifically EFs (Bull & Lee, 2014; Cragg & Gilmore, 2014), already described in Chapter 1. Although many studies have investigated the relationship between WM and mathematics (for reviews see Allen et al., 2019; Friso-van den Bos et al., 2013; Menon, 2016; Peng et al., 2016; Raghubar et al., 2010), there is a knowledge gap on the specific association between WM updating and mathematics (Hu et al., 2023; Lechuga et al., 2016; Lee & Bull, 2016; Passolunghi & Pazzaglia, 2005; Pelegrina et al., 2020; St Clair-Thompson & Gathercole, 2006). Even less has been done to understand the role of inhibitory control and switching. Both inhibition (Bull & Scerif, 2001; Gilmore et al., 2013; St Clair-Thompson & Gathercole, 2006) and shifting ability (Bull & Scerif, 2001; Vosniadou et al., 2018; Živković et al., 2022) seem to predict mathematics outcomes, though set-shifting has found to be strongly associated with intelligence, this latter accounting for a stronger variability on mathematics (effect size: $r = .47$, $85\% \ CI = .41–.52$) (for a meta-analysis Yeniad et al., 2013). Regarding the crucial role of WM instead, a significant amount of traction has been given to the positive association with mathematical achievement (Caviola et al., 2020; Szücs et al, 2014), with a particular emphasis on its visuospatial component (Geary et al., 2017; Mammarella, Caviola, Giofrè, & Szűcs, 2018; Menon, 2016), regardless the type of mathematical task considered (for a review, see Allen et al., 2019). However, as mentioned earlier, only a relatively limited number of studies examining the relation between WM and mathematics have specifically measured WM updating (Hu et al., 2023; Lechuga et al., 2016; Lee & Bull, 2016; Passolunghi & Pazzaglia, 2005; Pelegrina et al., 2020; St Clair-Thompson & Gathercole, 2006). Even fewer are the studies which attempted to show the interplay of both affective and cognitive factors in explaining mathematic attainment (Justicia-Galiano et al., 2017; Mammarella, Caviola, Giofrè & Borella, 2018; Orbach et al., 2020; Passolunghi et al., 2019; Pellizzoni et al., 2022; Živković et al., 2022). To the best of our knowledge, none of them considered these domains within the realm of mathematical difficulties, given the clinical relevance of this phenomenon.

An extensive body of literature shows that specific domain-general cognitive skills, especially EFs, are impaired in children with SLD (for recent reviews, see Agostini et al., 2022; Mishra & Khan, 2023). Challenges in retaining and simultaneously manipulating verbal, visual and spatial information in WM have been proven in people with SLD (Keeler & Swanson, 2001; Kuhn et al., 2016; Mammarella et al., 2015; McDonald & Berg, 2018; Passolunghi & Mammarella, 2012; Szűcs et al., 2013; Szűcs, 2016). Mixed findings have been found when considering EFs in children with SLD, especially inhibition ability (Agostini et al., 2022; Censabella & Noël, 2007; Mammarella, Caviola, Giofrè, & Borella, 2018; Szűcs et al., 2013). Most studies have shown that children with mathematical difficulties struggle to flexibly adapt their responses based on contextual demands (McDonald & Berg, 2018; Van Der Sluis et al., 2004; Willcutt et al., 2013), potentially impacting their capacity to perform complex mathematical calculations that require transitioning between conceptual and procedural knowledge. Although the assessment of cognitive abilities is already advised as part of the diagnostic process, there is no consensus on which of those skills should be prioritized (Mammarella et al., 2021).

Overview of the present study

In the current study, we assessed mathematics' performance using a mental calculation task in children and adolescents with SLD aged between 8 and 15 years old in comparison to non-diagnosed (ND) children, matched for age, gender and IQ. To be included in the study, children and adolescents in the SLD group had previously received a formal diagnosis of Specific Learning Disorder, with major impairments in mathematics. Additionally, to explore underlying mechanisms of mathematics' achievement, we asked participants to fill out a self-report measure of MA, as a domain-general affective factor. Parents filled in a questionnaire about their children's general anxiety level, useful for controlling the influence of a general state of tension. To assess domain-general cognitive abilities, we asked participants to complete three EFs tasks specifically evaluating inhibition, updating and set-shifting abilities.

Moreover, our first aim was to examine levels of MA in children and adolescents with and without SLD. It was assumed that children and adolescents with SLD could report higher levels of MA than those without SLD (Lai et al., 2015; Passolunghi, 2011), due to the well-established negative relationship between MA and mathematical performance (Barroso et al., 2021; Carey et al., 2016; Caviola et al., 2022; Namkung et al., 2019).

The second aim of the present study was to investigate EFs (inhibition, updating and set-shifting) in an actual sample of children and adolescents with SLD compared to ND participants. Based on the literature, it seemed reasonable to hypothesize poorer performance in all the tasks assessing EFs in participants with SLD as compared to ND participants (for a review see Agostini et al., 2022).

The third aim was to understand whether MA and EFs might be associated with mathematics' performance (specifically mental calculation), and how these relationships might differ among the groups with and without SLD. It was worth hypothesizing that, after controlling for general anxiety, low levels of MA and good EFs could contribute to improve mental calculations' performance both in children with (Lai et al., 2015; Szűcs et al., 2013) and without SLD (Allen et al., 2019; Carey et al., 2016; Caviola et al., 2022; Peng et al., 2016). Nevertheless, we assumed children with SLD to have poor WM skills (Giofrè & Cornoldi, 2015; Toffalini et al., 2017), and this specific weakness might contribute to failures in the proposed updating task (Passolunghi & Cornoldi, 2008; Passolunghi & Pazzaglia, 2005; Pelegrina et al., 2015), not further supporting mental calculations' ability. From this perspective, the relationship between EFs and mathematics' performance may not be statistically significant for the SLD group.

3.2 Method

3.2.1 Participants

The study involved 87 children and adolescents aged between 8 and 15 years old divided into two groups: 39 (17 M) with Specific Learning Disorders (SLD), and 48 (24 M) matched non-diagnosed (ND) participants. The two groups did not differ statistically in chronological age [$F(1, 85) = -.80$, $p = .42$, *Cohen's* $d = -.17$], gender distribution [$X^2 = .35$, $df = 1$, $p = .55$], or total IQ [$F(1, 85) = -.95$, $p = .34$, *Cohen's* $d = -.20$]. A summary of the participants' characteristics is shown in Table 3.1.

The clinical group was assessed at the child and adolescent psychiatric service centers to which they had been referred. All participants in the clinical group had been previously diagnosed with a Specific Learning Disorder with major impairments in mathematics, according to the DSM-5 (APA, 2013) or the ICD-10 (WHO, 1992) criteria. Children and adolescents with SLD were identified by assessing their mathematical achievement using standardized batteries (AC-MT-3, Cornoldi et al., 2020; MT-Avanzate-3, Cornoldi et al., 2017), in which they obtained scores more than 1 SD lower than average (<16th percentile) in at least half of the proposed subtests (e.g., mental calculation, written calculation, transcoding, fact retrieval) (Istituto Superiore di Sanità [ISS], 2022).

The control group was comprised of healthy children and adolescents without any diagnosis (SLD) with no psychiatric, neurological, or neurodevelopmental disorders. They were engaged and examined individually at their respective schools.

Participants who were taking medication, or who had other known genetic conditions, a history of neurological diseases, comorbid autism and ADHD, or certified physical and intellectual disabilities were excluded. All children and adolescents were native Italian speakers, and none had any visual or hearing impairments. Participants of both groups were included in this study only if they achieved a standard score of 80 or more for the abbreviated version of IQ on the Wechsler Intelligence Scales (WISC IV; Wechsler, 2003).

Table 3.1 Descriptive statistics and statistical comparisons in children and adolescents with a Specific Learning Disorder (SLD) and without any diagnosis (ND).

Screening variables	**SLD (n=39)**		**ND (n=48)**				
Gender M:F	**17:22**		**24:24**		***F*** **(1, 85)**	***p***	***Cohen's d***
	M	**SD**	**M**	**SD**			
Age (years)	11.28	1.79	11.62	2.12	-.80	.42	-.17
IQ	102.92	10.14	104.94	9.52	-.95	.34	-.20

Note: M=mean; SD=standard deviation; IQ=intelligence quotient.

3.2.2 Materials

Mental calculation

This task, adapted from Caviola et al. (2016, 2018), consisted of 60 multiple-choices trials divided into two blocks of 30 trials each: the first block included two-digit additions without carrying, the second two-digit subtractions without borrowing. Participants had to choose the correct answer between the three alternative choices (the correct answer, the correct answer plus or minus 1, and the correct answer plus or minus 10). The operations to be solved appeared at the top of the screen with the three answer options placed horizontally underneath. The order of the possible answers was counterbalanced to prevent children to spot the pattern of responses. Participants had to press a keyboard key based on the position on the screen of the answer they wanted to select ("z" for the left choice, "v" for the one in the middle, and "m" for the right one). Participants had to solve each operation within the time limit of 10 seconds, as shown by the presence of a count-down clock on the screen. Before starting the real task, participants had the chance to solve three practise trials with feedback. The total accuracy was considered in the statistical analyses of the present study. Cronbach's α = .98.

Questionnaires

General anxiety

The parents' version of the Multidimensional Anxiety Scale for Children (MASC-2; March 2012; Italian version, Paloscia et al., 2017) was administered. It is a 50-item questionnaire that evaluates the presence of anxiety on a rating scale that goes from 0 ("never") to 3 ("often"). It includes a total score, and six subscales (i.e., separation anxiety, generalized anxiety disorder, social anxiety, obsessions and compulsions, physical symptoms, and harm avoidance). Raw scores are converted into T scores by using normative data that considers the child's age and gender. This tool also features an Inconsistency Index that identifies possible unreliable ratings by comparing scores on eight item-pairs with the highest bivariate inter-item correlations from the development sample. In this study, the total T score has been considered.

Cronbach's α =.89 (C.I. = .88–.90).

Mathematics anxiety

Children and adolescents were requested to fill in the Abbreviated Math Anxiety Scale (AMAS; Hopko et al., 2003), which involves nine Likert-type items ranging from 1 ("No bad feelings") to 5 ("Very bad feelings") related to feelings and level of fear towards mathematics. Examples of items are: "Having to solve many difficult math problems for homework due the next class lesson" or "Starting a new topic in mathematics". Higher scores on the scale indicate higher levels of MA. In this study, the total raw score was considered. We administered the Italian version of the AMAS (Caviola, Primi, et al., 2017).

Cronbach's α = .86 (C.I. = .83–.88).

Executive functions

The tripartite model of executive functions by Miyake (Miyake et al., 2000) was employed to evaluate executive functioning in our sample. This model encompasses three components: inhibition of impulsive reactions ("Inhibition"), updating and monitoring ("Updating"), and mental set shifting or flexibility ("Set-shifting"). The three tasks were already described in the previous study (Chapter 2).

3.2.3 Procedure

The study was approved by the ethics review board of the University of Padova (Italy), and adheres to APA ethical standards. After obtaining the written consent of children's parents to their participation in the study, participants were tested individually in a quiet room at specialized centers (SLD) or at school (ND) during three sessions (a screening and two experimental phases) lasting approximately 30 minutes each. In the screening phase, the IQ was calculated and only participants who scored above 80 were included. The first experimental phase included the mental calculation task, the inhibition task, and the AMAS. The second one comprised the set-shifting and the updating tasks. The tasks in the experimental sessions were presented in a counterbalanced order. The experimenter provided instructions on each task, letting the participant practice before starting the experiment. The computerized tasks (mental calculation and executive functions' tasks) were created and administered using PsychoPy3 (Pierce et al., 2019), and a laptop computer with a 15-inch LCD screen. At the same time, parents completed the MASC-2 for assessing the child general anxiety.

3.2.4 Statistical approach

First, a series of univariate ANOVAs were performed to estimate differences between the two groups in the measures of interest. Effect sizes were also computed using *Cohen's d*, which expresses the effect size of the pairwise comparisons between the groups. *Cohen's d* is interpreted as the difference between means in terms of standard deviation units.

Second, a series of regression models using a hierarchical approach was performed to assess the effect of the measured variables (general anxiety, MA, inhibition, updating, set-shifting) on the dependent variable (total accuracy on the mental calculation task). In the first model, we included the general anxiety as a control variable; in the second model, we added the group; in the third, the MA; in the fourth, the EFs (inhibition, updating, and set-shifting) measures were included. The interactive effect of Group (i.e., SLD, ND) with MA, inhibition, updating, and set-shifting was added in the fifth and last model.

The best model was selected using information-theoretic (I-T) approaches (Burnham et al., 2011), considering the Akaike information criterion (AIC) and the adjusted R^2 (Adj R^2). The AIC is an estimator of prediction error and therefore of the relative quality of statistical models for a given set of data. The Adj R^2 represents the proportion of variance in the outcome variable which is explained by the predictor variables in the sample. The Adj R^2 is a modified version of R^2 that adjusts for the number of predictors in a regression model and allows for comparing models with a different number of predictors (Miles, 2005). A lower AIC and a higher Adj R^2 indicates a better model.

Data were analyzed using R version 1.3.1093 (R Core Team, 2022). The "lme4" package was used to run the regression models and the AIC (Bates et al., 2015), and the "ggplot2" package to obtain the graphical effects (Wickham, 2016).

3.3 Results

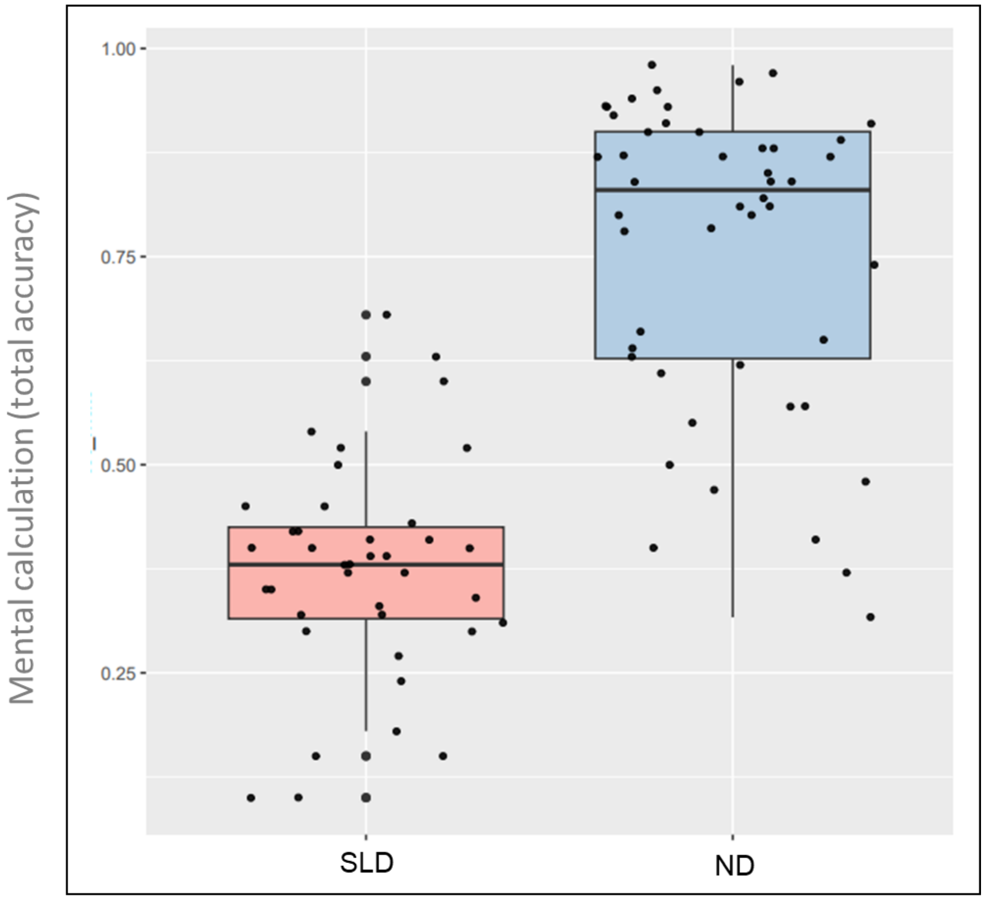
Differences between the groups

Table 3.2 displays descriptive statistics and statistical comparisons between the two groups in all considered measures. Effect sizes of the pairwise comparisons between the groups expressed with *Cohen's d* are also reported.

Mental calculation

The SLD group achieved an overall lower performance in the mental calculation task (total accuracy) as compared to the ND group, $F(1, 85) = -11.02$, $p < .001$, *Cohen's d*= -2.38; SLD= .37 (.13), ND= .76 (.18). Figure 3.1 shows the distribution of the accuracy scores on the mental calculation task divided per group (SLD, ND) with individual observations.

Figure 3.1 Boxplot of the distribution of performance with individual observations on the mental calculation task (total accuracy), in children and adolescents with a Specific Learning Disorder (SLD) and without any diagnosis (ND).



Questionnaires

Concerning the questionnaires, participants with SLD had greater levels of general anxiety (as reported by their parents), $F(1, 85)$=3.08, p=.003, *Cohen's d*=.66, and of self-reported mathematics anxiety, $F(1, 85)$=2.36, p=.02, *Cohen's d*=.51, than the ND group.

Executive functions

As regards the executive functions' tasks, the SLD group performed significantly worse than the ND group in all tasks. Statistically, participants with SLD made more errors in the inhibition task (no-go condition), $F(1, 85)=4.92$, $p<.001$, *Cohen's* $d=1.06$, performed worse in the updating task (total accuracy), $F(1, 85)=-3.78$, $p<.001$, *Cohen's* $d=-.81$, and made more perseverative errors in the set-shifting task (WCST), $F(1, 85)=2.13$, $p=.04$, *Cohen's* $d=.46$, than the ND group.

Table 3.2 Descriptive statistics and statistical comparisons by group for all considered measures in children and adolescents with a Specific Learning Disorder (SLD) and without any diagnosis (ND).

Measures	**SLD (n=39)**		**ND (n=48)**		***F* (1, 85)**	***p***	***Cohen's d***
	M	**SD**	**M**	**SD**			
Mental calculation							
Total accuracy	.37	.13	.76	.18	-11.02	**<.001**	-2.38
Questionnaires							
General anxiety	62.72	12.00	55.21	10.69	3.08	**.003**	.66
Mathematics anxiety	25.92	7.27	22.67	5.58	2.36	**.02**	.51
Executive functions							
Inhibition	5.00	3.43	2.12	1.94	4.92	**<.001**	1.06
Updating	.57	.24	.73	.15	-3.78	**<.001**	-.81
Set-shifting	15.95	6.73	12.78	6.88	2.13	**.04**	.46

Note: M=mean; SD=standard deviation; General anxiety=T score on the total scale of the MASC-2; Mathematics anxiety=total raw score on the AMAS; Inhibition=total errors on the no-go trials; Updating=proportion of correct responses; Set-shifting=percentage of perseverative errors on the WCST task.

Hierarchical regression analysis

A series of linear regressions (see Table 3.3) were tested to investigate the association between the performance on the mental calculation task and the hypothesized predictors (i.e., general anxiety, mathematics anxiety, inhibition, updating and set-shifting). The interactive effect of Group with other predictors was also considered. Models' comparison is also shown in Table 3.3 with the AIC and the adjusted R^2 of each regression model. Before conducting the regression analysis, collinearity was verified by ensuring that correlations between predictor variables were not too high [r_s < -.29], confirming the robustness of the model.

As shown in Table 3.3, our model fitting procedure revealed that the best-fitting model was Model 5: Mental calculation (total accuracy) ~ General anxiety + Group + Mathematics anxiety + Inhibition + Updating + Set-shifting + Group*Mathematics anxiety + Group*Inhibition + Group*Updating + Group*Set-shifting (F = 19.01, p<.001; AIC = -78.48, $\Delta°AIC$ = 81.89, *adjusted* R^2 =.68). Two interaction effects were found to be statistically significant: between Group and Mathematics anxiety, t= -2.20, p = .03; and between Group and Updating, t= 2.30, p = .02. More specifically, as shown in Figures 3.2 and 3.3, lower levels of mathematics anxiety and higher scores in the updating task coincided with a better performance in the mental calculation task in the ND group, but not in the SLD group. No other statistically significant main or interactive effects emerged in the best-fitting model.

Table 3.3 Hierarchical regression analysis with mental calculation (total accuracy) as dependent variable, and all the other measured variables and their interactions with group (SLD, ND) as predictors.

Regression models	*Estimate coefficient*	*SE*	*t*	*p*	*F*	*p*	AIC	Adj R^2
Model 1					8.36	.005	3.41	.08
General anxiety	**-.006**	**.002**	**-2.89**	**.005**				
Model 2					60.80	<.001	-64.29	.58
General anxiety	-.001	.001	-.85	.39				
Group	**.37**	**.04**	**10.16**	**<.001**				
Model 3					44.83	<.001	-68.23	.60
General anxiety	-.001	.001	-.33	.74				
Group	**.36**	**.04**	**9.86**	**<.001**				
Mathematics anxiety	**-.007**	**.003**	**-2.42**	**.02**				
Model 4					26.51	<.001	-72.83	.65
General anxiety	-.001	.001	-1.05	.32				
Group	**.33**	**.04**	**8.04**	**<.001**				
Mathematics anxiety	**-.005**	**.003**	**-2.19**	**.03**				
Inhibition	.001	.006	.23	.81				
Updating	**.18**	**.09**	**2.02**	**.04**				
Set-shifting	-.001	.002	-.40	.69				
Model 5					19.01	<.001	-78.48	.68
General anxiety	-.001	.001	-.92	.36				
Group	.25	.22	1.14	.26				
Mathematics anxiety	-.001	.003	-.18	.86				
Inhibition	.06	.10	.57	.57				
Updating	.001	.007	.04	.97				
Set-shifting	-.004	.003	-1.31	.19				
Group * Mathematics anxiety	**-.01**	**.005**	**-2.20**	**.03**				
Group * Inhibition	.002	.01	.16	.87				
Group * Updating	**.43**	**.19**	**2.30**	**.02**				
Group * Set-shifting	.003	.005	.73	.46				

Note: AIC, Akaike Information Criterion. The lower the AIC and the higher the adj R^2, the better the model.

Figure 3.2 Significant interaction effect of the Group*Mathematics anxiety, with Mental calculation (total accuracy) as dependent variable. Error bands represent 95% confidence intervals.

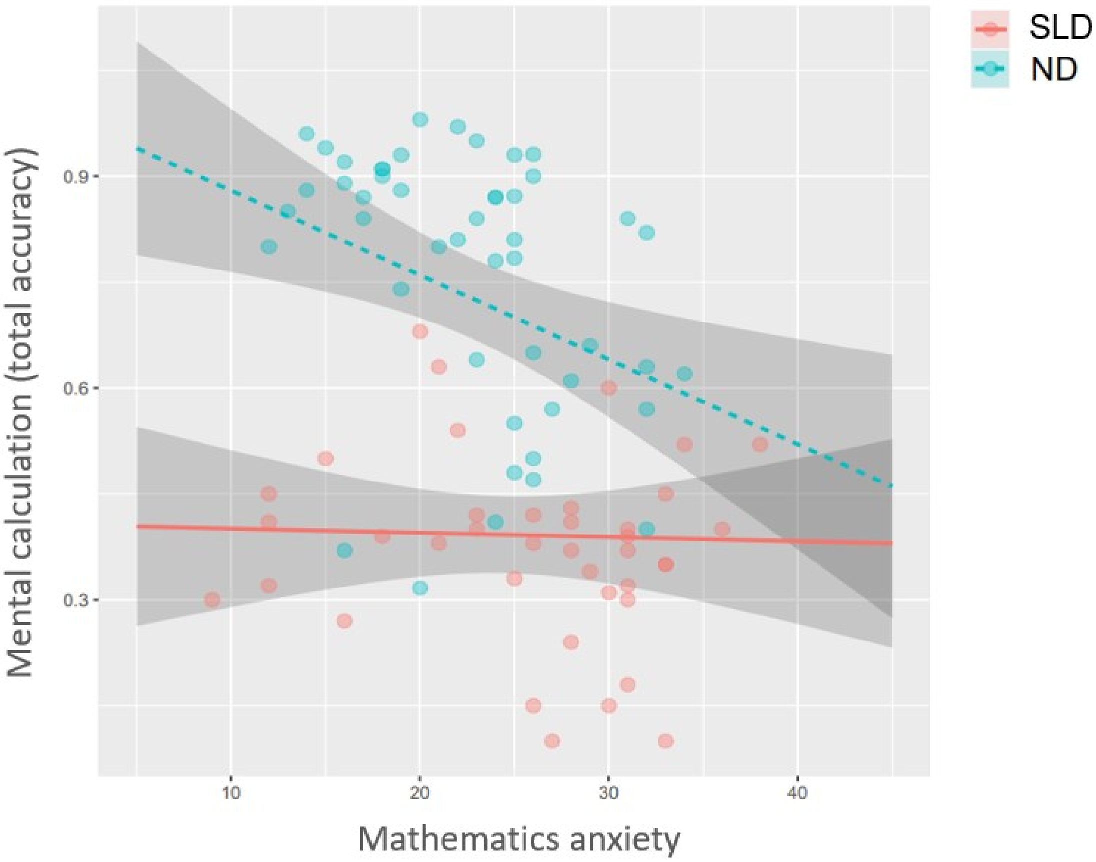
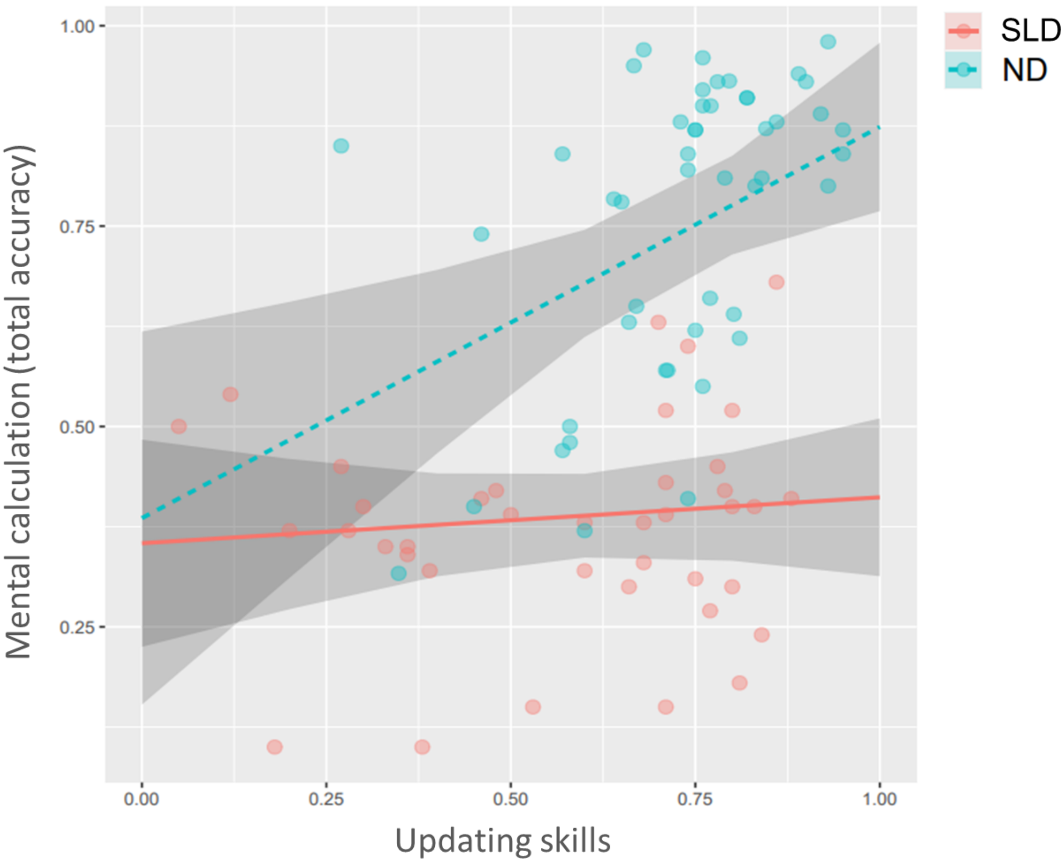


Figure 3.3 Significant interaction effect of the Group*Updating, with Mental calculation (total accuracy) as dependent variable. Error bands represent 95% confidence intervals.



3.4 Discussion

The main aim of the current study was to evaluate factors associated with mathematical skills, specifically mental calculation, of children and adolescents with SLD in comparison to ND peers, matched for age, gender and IQ. In particular, we investigated the role of affective and cognitive domain-general abilities, respectively mathematics anxiety (MA) and executive functions (EFs), in predicting mathematical skills of children with and without SLD.

The strengths of the present study are multiple. First, we implemented a case-control study design to identify condition-specific characteristics, by comparing a group of children and adolescents meeting criteria for a standard SLD diagnosis, with a control ND group. In fact, children and adolescents in the SLD group had previously received a formal clinical diagnosis, following the criteria of the DSM-5 (APA, 2013) or ICD-10 (WHO, 1992), with major impairments in mathematics. Second, computerized tasks (i.e., mental calculation and EFs) provide a higher reliability of the objective performance than traditional assessments, because they allow for precise control over task presentation, minimizing potential sources of bias and variability in the data. Third, executive functioning has been investigated as a multicomponent psychological process (Diamond, 2013; Miyake et al., 2000) to study the role of each single component in determining children's mental calculation skills. Moreover, the specific contribution of WM updating, rather than working memory, on mathematics has been investigated. Finally, another strength of the study is that we considered the child general anxiety as a covariate by adding it in the first step of the regression model, to ensure that a constant state of tension would not represent a confounding variable in the relationship between the primary predictors and the dependent variable (Carey et al., 2017).

Our findings show that our first hypothesis on levels of MA in children and adolescents with and without SLD has been confirmed. As previously observed (Kucian et al., 2018; Lai et al., 2015; Passolunghi, 2011; Rubinsten & Tannock, 2010), the SLD group reported higher mean levels of MA in comparison to the ND group, highlighting how affective domain-general factors could contribute to the discomfort experienced at school by diagnosed children. Indeed, repetitive failures in mathematical tasks might be a risk factor for the development of negative emotions, thoughts and worries (Carey et al., 2017; Hunt & Maloney, 2022; Pekrun, 2006), which could culminate with the avoidance of math-related activities, also in real-life contexts.

Also, our second hypothesis regarding EFs in children with and without SLD has been confirmed. Statistical comparisons show significant differences between the two groups in terms of inhibition, updating and set-shifting. Concerning inhibitory mechanisms, children and adolescents with SLD made a greater number of commission errors in the go-no go task, showing a higher probability of failure to inhibit a response that should be withheld. In this regard, inhibitory control allows students to stop unsuccessful problem-solving strategies and choose more efficient ones, by also preventing impulsive errors, thus children with SLD might be disadvantaged by weak inhibitory mechanisms (Agostini et al., 2022; Mammarella, Caviola, Giofrè, & Borella, 2018; Szűcs et al., 2013). As regards updating skills, children and adolescents with SLD seem to be characterized by the inability to maintaining, manipulating and/or updating the visual and spatial information in WM (Keeler & Swanson, 2001; Kuhn et al., 2016; Mammarella et al., 2015; Mammarella, Caviola, Giofrè, & Szűcs, 2018; McDonald & Berg, 2018; Passolunghi & Mammarella, 2012; Szűcs et al., 2013; Szűcs, 2016), which represents a critical skill in academic learning, especially in mathematics (Passolunghi & Pazzaglia, 2005; St Clair-Thompson & Gathercole, 2006). Children and adolescents with SLD also made a significant higher number of perseverative errors in the WCST, as an indicator of difficulties with mental flexibility, set-shifting and planning (McDonald & Berg, 2018; Van Der Sluis et al., 2004; Willcutt et al., 2013), which could contribute to worse scholastic learning and achievement (Bull & Scerif, 2001).

Besides the differences between the two groups in the measures of interest, our third (and main) goal was to investigate whether MA and EFs might be associated with mathematics' performance (specifically mental calculation accuracy), and how these relationships might differ among the groups with and without SLD. After controlling for general anxiety, our best-fitting model revealed two significant interaction effects, predicting the mental calculation performance: the first between group and mathematics anxiety, and the second between group and updating skills. Results indicated that the relationship between these two predictors and mental calculation seems to vary depending on the group membership (SLD, ND).

In agreement with our initial hypotheses, a negative relationship between the level of MA and mental calculation accuracy occurred in the ND group. Statistical comparisons showed that ND children and adolescents reported lower levels of MA as compared to those who experience mathematical challenges: this could suggest a good affective disposition towards mathematics, probably as a consequence of the lack of difficulties in solving operations. Therefore, lower levels of MA might be a supporting factor for mathematical achievement in ND children (Carey et al., 2016; Caviola et al., 2022). Instead, no linear relationship has been found between MA and mental calculation skills in children diagnosed with SLD. Indeed, though the significant difference with the ND group, children with SLD exhibited greater variability in the levels of reported mathematics anxiety. On one hand, there are individuals with SLD who experience MA and emotional problems, but on the other hand, there are also students with SLD not suffering from MA. This confirms that MA and SLD can be dissociated, as proposed by Devine and colleagues (2018). In fact, children with SLD might be characterized by secondary symptoms, such as a reduced motivation towards mathematics, low perception of competence and self-efficacy (Novita, 2016; Riddick, 2009; Terras et al., 2009), not caring of their mathematical flaws, thus feeling little MA. Similarly, children with SLD might report high levels of MA regardless of their ability of solving mental calculations, and despite the possible improvements, possibly because of learned helplessness (Peard, 2010; Rubinsten & Tannock, 2010). All things considered, the large variability of MA levels in SLD may prevent the linear relationship between MA and calculation abilities found in the ND group.

In addition, a positive relationship between updating skills and mental calculation accuracy appeared in the ND group. In particular, our regression analysis suggests that updating skills, among all the EFs considered, might be protective and supportive of mental calculation performance in the ND group (Hu et al., 2023; Lee & Bull, 2016; Passolunghi & Pazzaglia, 2005). As a fact, mental calculation often requires students to retain information in their memory and to update partial results to reach the final one. Intact cognitive abilities might strengthen mathematical achievement, thus children without mathematical impairments could perform more adaptively due to these sustaining characteristics (Friso-van den Bos et al., 2013). Likewise the previous result, no linear relationship has been found between updating and mental calculation skills in children diagnosed with SLD. It is worth saying that children with SLD obtained a lower average performance in both tasks, possibly preventing a distribution of scores capable of allowing a significant correlation. In addition, we assumed children with SLD to have a poor WM profile (Giofrè & Cornoldi, 2015; Toffalini et al., 2017). Thus, the diminished WM functioning (including updating) of children diagnosed with SLD might be incapable of providing performance support. On the other hand, it could be possible that preserved updating skills, whether present, are not enough to overcome the core mathematics difficulties experienced by participants with SLD.

The present study is not without limitations, which could help to detect future directions of our study. First, mathematics anxiety has been investigated by asking children and adolescents to fill out a trait-like self-report measure, implicitly legitimizing the idea that MA is a permanent trait. However, questionnaires could be influenced by subjective beliefs and reappraisal thoughts related to past experiences, thus it could be important to assess state MA in real-time assessments (Mammarella et al., 2023). Second, we considered MA as a unitary construct, setting aside its multicomponent nature, since it comprises a combination of negative worries, arousing emotions, and unpleasant self-beliefs. Future studies should assess the concordance between state and trait MA, and its different cognitive, emotional, and physiological components (Ashcraft, 2019; Cipora et al., 2022; Ho et al., 2000). Third, regarding domain-general cognitive abilities, our study focused on the tripartite model of EFs (Miyake et al., 2000), not considering other crucial skills of the mathematical processing network that may play a role in mathematical achievement, for example phonological and spatial abilities (Szűcs et al., 2014). Lastly, future research should also consider achievement emotions, values, and perceived control towards mathematics (Forsblom et al., 2022), to gain a comprehensive idea of underlying (and supporting) mechanisms of mathematical achievement in children with and without SLD.

Even with the above-mentioned limitations, our findings could have important clinical and educational implications. Educators and clinicians should bear in mind that underlying domain-general affective and cognitive factors could contribute to influence the mathematical performance of children and adolescents with and without SLD. Consequently, a global assessment of both abilities and emotional aspects may be important to identify potential strengths and weaknesses of children profile. For example, the identification and modification of MA, especially of negative thoughts and self-beliefs, could represent a starting point for addressing learning difficulties, even before working on the use of compensatory strategies to reinforce mathematical concepts. Similarly, the assessment of executive functions and WM could represent a valuable source of information useful to tailor the interventions based on the individual characteristics.

In conclusion, the present study confirmed previous findings on higher levels of MA and reduced EFs in children and adolescents with SLD as compared to those without the diagnosis. More interestingly, our results suggest the predictive power of lower levels of MA and greater updating skills on mental calculation accuracy for children and adolescents without SLD, though not representing supporting factors of mathematical performance for those with SLD.

CHAPTER 4

The other side of the coin:

Beyond the core features of ASD and SLD

In the previous two studies, the relationship between social and mathematical skills with anxiety (besides executive functions), has been investigated by considering separately groups of children and adolescents with specific difficulties in these areas, respectively those diagnosed with ASD and SLD. Indeed, experiencing difficulties in certain domains might often generate symptoms of anxiety, and vice versa anxiety might negatively impact the execution of an activity. Taken together, anxiety and skill deficits are two factors that negatively affect performance (Hopko et al., 2001). This is true especially when considering contexts in which the performance might be evaluated by other people, for example social and mathematical settings. Actually, performance-based anxieties can be considered a distinct but functionally similar types of anxiety that include conditions such as social phobia (Beidel et al., 1985; Rapee & Heimberg, 1997), and mathematics anxiety (Ashcraft & Faust, 1994; Carey et al., 2016). These forms of anxiety are marked by tension, inadequacy, and worries that occur either in anticipation and/or in a performance-based situation, combined with the fear of receiving negative evaluations for one's actions.

The risk of developing social and mathematics anxiety in vulnerable populations, such as ASD and SLD, will be briefly discussed, considering “the other side of the coin” in which children with ASD might face challenges at school, and those with SLD with social relationships. This topic will be further addressed in detail in the Introduction of Study III (Chapter 5). Moreover, social and mathematics anxiety will be described in details in the next paragraphs, alongside their experimental assessment.

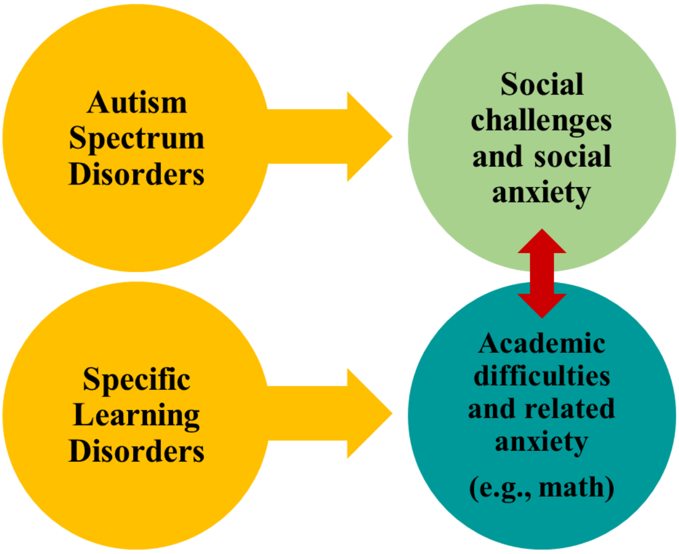
4.1 The reciprocal link between social and academic functioning

The intent to study social anxiety in autism and mathematics anxiety in SLD is justified by the close relationship between the specific symptoms of anxiety and the characteristics of the diagnosis, as previously described in the first part (Chapter 1, and Studies 1-2) of the current PhD dissertation. However, which is the rationale of studying social anxiety in children with SLD, and mathematics anxiety in those with ASD, given the different nature of the clinical manifestations of the two conditions?

The extensive literature on the relation between social and academic skills, can help explaining the logic behind it, by showing two different general perspectives. The first one is about poor social skills affecting academic failures (Sung & Chang, 2010), and the second one suggests that academic functioning may impact future peer relationships and social skills (Caemmerer & Keith, 2015). However, based on the dynamic systems perspective (Yoshikawa & Hsueh, 2001), a reciprocal association between social and academic skills has been proposed (Caemmerer & Hajovsky, 2022; Denham & Brown, 2010; Welsh et al., 2001). As mentioned by Zins et al. (2007) “schools are social places, and learning is a social process” (p. 191). Concerning specific social abilities, previous studies revealed that prosocial behaviours (Caprara et al., 2000), social acceptance (Elias & Haynes, 2008), emotion knowledge and regulation (Harrington et al., 2020), were closely associated with academic success. Given these findings, particular attention should be given to those students who struggle socially and academically.

As already described, performance difficulties might be associated with the development of anxiety, specially related to the situation in which children need specific skills that they have not been properly developed. Indeed, as shown in Figure 4.1, children with ASD might experience social anxiety as a consequence of their social challenges (Bellini, 2006; Spain et al., 2018; White et al., 2010), and those with SLD might feel inadequacy and anxiety linked to academic (e.g., mathematical) impairments (Kucian et al., 2018; Passolunghi, 2011). However, children with SLD might also face a unique set of socio-emotional challenges as a consequence of their academic difficulties (Livingston et al., 2018; Riddick, 2009; Willcutt et al., 2011). In particular, they could experience anxiety within social situations because of feelings of shame and lower self-esteem (Elgendi et al., 2021; Kohli et al., 2005; Sahoo et al., 2015). On the other hand, difficulties with social skills and social anxiety may impact the learning process of children with ASD, since they may not seek out social learning opportunities, thus missing chances to learn (Brook & Willoughby, 2015; Ricketts et al., 2013), and possibly developing performance-based anxiety at school.

Figure 4.1 The relationship between Autism Spectrum Disorders, Specific Learning Disorders, social challenges and academic difficulties.



All things considered, the study of anxiety responses to performance tasks, could be of particular interest with children and adolescents who experience social and academic difficulties, such as Autism Spectrum Disorders and Specific Learning Disorders. For these reasons, Study III and IV aim at understanding social and mathematics anxiety by considering all their state components (subjective, behavioural and physiological) in these clinical groups, in comparison to non-diagnosed children and adolescents.

4.2 Social anxiety: components and experimental assessment

People who experience social anxiety may have concerns about looking foolish or acting in an inappropriate way in front of other individuals, thus preventing them from being involved in social situations. Besides the fear of social judgment, there is the worry about the possibility that others could notice their anxiety from their bodily symptoms (e.g., blushing, sweating) (Siess et al., 2014). People who experience social anxiety report discrete impairments in daily living, most of all in the areas of employment, education, family, and social relationships, contributing to a general decrease of the quality of life (Schneier et al., 1994). Social anxiety could be experienced in many social situations, such as interacting with other people, public speaking, and eating in public. Social anxiety is characterized by subjective (emotional, cognitive), behavioral, and physiological symptoms (APA, 2013), that are three domains bi-directionally influencing one another (Clark & Wells, 1995; McNeil & Randall, 2014). A brief overview of the components of social anxiety, is provided in Table 4.1.

At a *subjective* level, social anxiety is characterized by negative emotions, adverse thoughts, and cognitive biases, which may prevent people from seeing social interactions as they really are, but much more frightening (Riskind et al., 2006), and causing them to act in ways that provide the maintenance of fears (e.g., ruminating) (Hirsch & Clark, 2004). Besides the fear of social judgment, there is the worry about the possibility that others could notice their anxiety from their bodily symptoms (e.g., blushing, sweating) (Siess et al., 2014). Moreover, a lower perception of competence, due to the awareness about one's own difficulties within the social domain, might cause (and maintain) social anxiety (Tantam, 2003).

At a *behavioral* level, the most common responses to socially demanding situations are avoidance, behavioral inhibition, social withdrawal, and safety behaviours (e.g., avoiding eye contact, not participating actively in a group conversation, excessive self-monitoring, mental rehearsal of sentences to avoid stumbling over words) (Bögels & Mansell, 2004; Rubin et al., 2009).

At a *physiological* level, the activation of sympathetic and/or withdrawal of parasympathetic autonomic nervous system might result in changes in electrodermal activity, respiratory activity, and heart rate (Krämer et al., 2012; Schmitz et al., 2013). Indeed, people who experience social anxiety exhibit physiological arousal when facing socially threatening situations (e.g., blushing, sweating, trembling).

Table 4.1 Components of social anxiety (adapted from Lievore et al., 2022).

Component	**Definition**	**Examples**
Subjective (e.g., cognitive)	Psychological anxiety, negative thoughts related to social situations, cognitive biases	Fear of negative evaluation, looming cognitive style, hypervigilance and self-focused attention
Behavioral	Behavioral manifestations	Avoidance, safety behaviours, social withdrawal
Physiological	Physiological arousal and/or psychological reactivity due to social situations	Blushing, sweating, trembling, altered heart rate

Considering the *multidimensionality* of social anxiety, besides the use of *trait*-like questionnaires, research often applies experimental tests to investigate this complex psychological construct. The most common experimental tasks designed to evaluate *state* stress responses to social demands in children and adolescents are social performance tasks. For instance, the Trier Social Stress Test (TSST) was originally developed to evaluate the effects of social stress on physiological responses in adults' samples (Kirschbaum et al., 1993), but then it was adapted and applied to groups composed by children and adolescents (TSST-C; Buske-Kirschbaum et al., 1997; Seddon et al., 2020). The original protocol is composed of a preparation phase, a public speech, and a mental arithmetic task. For the speaking task, children are asked to give a speech about their most recent birthday (Poole et al., 2018) or to complete a story in an interesting way (Buske-Kirschbaum et al., 1997), better than that provided by other participants, in front of a panel of 'committee members' who are trained not to provide feedback or social engagement. Sometimes, authors have used a videorecording as an alternative to a panel of judges (Cartwright-Hatton et al., 2003). Regarding the mental arithmetic task, researchers have replaced it with a serial subtraction task (Krishnaveni et al., 2014), or even removed it from the paradigm (Seddon et al., 2020). Several adaptations of the original paradigm have been published (Allen et al., 2017; Narvaez Linares et al., 2020) considering different populations, such as social anxiety disorder (Grace et al., 2022), eating disorders (Monteleone et al., 2020), psychosis (Lee, Kang, et al., 2023), and women with negative childhood experiences (Riem et al., 2020). Moreover, online versions of the TSST have been developed during the last years (Eagle et al., 2021; Gunnar et al., 2021). Nevertheless, adaptations of the paradigm have never been administered to compare different neurodevelopmental disorders, such as ASD and SLD.

4.3 Mathematics anxiety: components and experimental assessment

Besides social anxiety, another common type of performance-related anxiety has been described in academic contexts, and called mathematics anxiety (MA). MA is a combination of negative feelings of tension, discomfort, and fear experienced when thinking about and performing mathematical tasks in both academic situations and everyday life (Ashcraft, 2002; Hembree, 1990; Mammarella, Caviola & Dowker, 2019). Although MA cannot be reduced to other constructs (i.e., text anxiety; Caviola et al., 2022), it is multidimensional like some other types of anxiety, and it can be described as having cognitive, emotional, and psychophysiological components (Ashcraft, 2019; Cipora et al., 2019; Mammarella et al., 2023).

There is wide-ranging consensus recognizing two main components of MA (Dowker et al., 2016; Ho et al., 2000): an affective component ("arousal"), which refers to tension, frustration and physiological excitement felt in evaluative settings; and a cognitive component ("worries"), which includes worries about performance and the perceived risk of failure resulting in disapproval by people who are evaluating the performance in comparison to a standard of achievement. According to well-established theories (e.g., Eysenck & Calvo, 1992), worries might cause distracting thoughts that interfere with cognitive resources at different levels, thus reducing the mental assets available and consequently impairing mathematical performance (Pellizzoni et al., 2022; Živković et al., 2022). Instead, emotionality refers to individual perception of the physiological-affective aspects of anxiety, that is, signs of autonomic arousal and unpleasant feeling states (Morris et al., 1978).

Besides worries and emotionality, perceived competence and the expectancy of success (or failure) might also play an important role in defining math performance and related (Pekrun, 2006; Wigfield & Eccles, 2000). The correlation between MA and individuals' perception of their own competency, seems to encourage the idea of self-perception and self-efficacy as key determinants of math achievement (Jansen et al., 2013; Malanchini et al., 2020), but repetitive failures might lower the perception of competence (Ganley & Lubienski, 2016; Justicia-Galiano et al., 2017; Lee, 2009). The combination of affective state, worries, and perceived competence might produce undesirable feelings surrounding math and adverse consequences on both math performance and the confidence to learn and perform math.

It is worth noting that MA has frequently been evaluated using trait-like self-report questionnaires, implicitly legitimizing the idea that MA is a permanent trait, whereas less has been done to investigate state mathematics anxiety (Mammarella et al., 2023). Nonetheless, it is necessary to differentiate between *trait* and *state* mathematics anxiety (Cipora et al., 2022; Mammarella et al., 2023): the former refers to the idea of an enduring, non-modifiable, generalized personality feature usually assessed with self-report questionnaires; the latter refers to the emotional and cognitive responses individuals implement when facing a stressful math situation and which can only be appraised with state measures. A clear discrepancy between retrospective self-reports and real-time assessments (Sorvo et al., 2017) has advanced the idea that trait-like questionnaires, influenced by subjective beliefs and reappraisal thoughts related to past experiences (Goetz et al., 2013; Robinson & Clore, 2002; Roos et al., 2015), cannot be considered a comprehensive evaluation of the actual emotional states experienced during math situations. Instead, real-time assessments might be more suitable to study state MA, classified as a temporary and math-situation-related anxiety reaction linked to increased arousal of the autonomic nervous system (Orbach et al., 2020; Roos et al., 2015). MA should be assessed using a more explicit/direct approach, pulling together experimental manipulations (e.g., time constraint paradigms), state-like questionnaires and autonomic measures related to a specific task. Indeed, increasing time pressure during a mathematical task makes it more difficult to perform, thus prompting an anxiety state that allows truthful analysis of how anxiety can interfere with task execution (Kellogg et al., 1999; Rieskamp & Hoffrage, 2008; Tsui & Mazzocco, 2006).

4.4 Overview of the studies III and IV

In the second part of the present PhD dissertation, social and mathematical anxiety will be investigated by using a *multidimensional* and *multi-informant* approach, combining the assessment of *state* subjective experiences, behavioural manifestations and physiological responses towards stressful conditions, and the analysis of both parents- and self-reports on the occurrence of *trait* symptoms. The sample will be composed of children and adolescents with ASD, SLD, and ND.

The main aims of Studies III and IV are to assess social and mathematics anxiety in children and adolescents with ASD, SLD compared to ND participants, by investigating the subjective (emotional, cognitive), behavioral and psychophysiological components of anxiety in response to two demanding tasks. Table 4.2 summarizes the main characteristics of the groups in studies III and IV, the main aims and the hypotheses of each study.

Chapter 5 (study III) will focus on social and mathematics anxiety in children and adolescents with ASD and SLD, in comparison with non-diagnosed (ND) participants. The aim was to try to understand the single components of anxiety by using a multidimensional point of view, by considering subjective and behavioral anxiety responses. For this purpose, we asked participants to complete two stressful tasks, which were designed to elicit a laboratory-controlled stress response consistent with social and mathematical anxiety: the first was a public speech (Trier Social Stress Test, child version; Buske-Kirschbaum et al., 1997), the second a timed mental calculation task (Stressful Mathematical Test; adapted from Caviola et al., 2016; 2018). In this study, particular importance was given to the *state* components of anxiety, to further extend the findings of the two previous studies in which we used trait-like questionnaires to assess social and mathematics anxiety. Participants were asked to report state subjective experiences (valence, arousal, perception of competence, worries) before and after the two tasks, and their performance was evaluated by considering the quality of the public speech (Trier Social Stress Test) and the total response accuracy (Stressful Mathematical Test). For completeness, *trait* levels of anxiety were reported by children's parents, with a focus on the fear of being humiliated and rejected by others (consistent with SA), and of being negatively evaluated for their performance (more related to MA).

Chapter 6 (study IV) will investigate social anxiety by considering the psychophysiological responses, besides subjective and behavioral components, to the Trier Social Stress Test (Buske-Kirschbaum et al., 1997) in children and adolescents with and without ASD and SLD. During the task, the electrocardiogram (ECG) was registered to measure autonomic changes across the protocol, with a focus on the reactivity of heart rate (HR) and hear rate variability (HRV). We also asked children and their parents to fill in two questionnaires to further consider trait-like symptoms of social anxiety.

Table 4.2 Summary of the studies III and IV: groups involved, number of participants (N), the topic examined, the main aims and hypotheses.

Study	Groups	N	Topic	Aims	Hypotheses
III	ASD SLD ND	60 70 150 Total = 280	Social and mathematics anxiety: • Behavioral components • Subjective components	1. To evaluate the (trait) levels of SA reported by the participants' parents;	1. Trait SA: ASD, SLD > ND (Sukhodolsky et al., 2008; Thaler et al., 2010);
				2. To assess the (state) **behavioral** components of anxiety, by analysing the quality of the public speech (Trier Social Stress Test) and the mathematical performance accuracy (Stressful Mathematical Test);	2. **Trier Social Stress Test** ASD < ND (Edmiston et al., 2017; Kumazaki et al., 2020) **Stressful Mathematical Test** SLD < ND (Kucian et al., 2018; Rubinsten & Tannock, 2010);
				3. To evaluate the (state) **subjective** responses towards the two stressful tasks by considering baseline and task-related self-reports.	3. **Trier Social Stress Test** **ASD:** ↑ arousal and worries, ↓ valence and perception of competence (Bellini, 2006; Jansen et al., 2006), or low awareness of one's own internal emotional states (Barnhill et al., 2000; Huggins et al., 2021). **SLD:** ↑ arousal ↓ perception of competence, due to the fear of being negatively judged, and low self-esteem (Livingston et al., 2018; Novita, 2016; Rostami et al., 2014). **Stressful Mathematical Test** **SLD:** ↑ arousal and worries, ↓ valence and perception of competence, due to well-established difficulties (Passolunghi, 2011; Rubinsten & Tannock, 2010). **ASD:** ↑ worries towards the timed test (Ashcraft & Kirk, 2001; Beilock, 2008; Beilock et al., 2004), overestimation of their mathematical performance (Furlano & Kelley, 2020).

IV	ASD SLD ND	15 15 25 Total = 55	Social anxiety: • Psychophysiological components	To evaluate autonomic responses, registered with an electrocardiogram (ECG), to a social stress task (Trier Social Stress Test - child version, TSST-C).	Activation of the ANS due to social evaluative threat and unpredictability (Allen et al., 2019). **ASD:** Lower heart rate (HR) and heart rate variability (HRV) reactivity in response to social stress (for a meta-analysis see Cheng et al., 2020), and a lower baseline HRV (Bal et al., 2010; Edmiston et al., 2016); **SLD:** Higher HR and HRV reactivity to social stress, because of a marked fear of negative evaluation and anxiety (Riddick, 2009; Rostami et al., 2014), and a higher baseline HRV (Palser et al., 2021; Sturm et al., 2021).

ASD=Autism Spectrum Disorders; SLD=Specific Learning Disorders; ND=non-diagnosed matched participants.

CHAPTER 5

Social and mathematics anxiety in ASD and SLD:

Behavioural and subjective components

5.1 Introduction

The study of performance-based anxiety might be of particular interest in the field of neurodevelopmental disorders, for instance Autism Spectrum Disorders (ASD) and Specific Learning Disorders (SLD), because of the challenges experienced respectively (and not only) within the social domain and the academic contexts (APA, 2013). In the next sections, the occurrence of social and mathematical anxiety in children and adolescents with ASD and SLD, will be described.

Social anxiety in Autism and Specific Learning Disorders

As already discussed in Chapters 1 and 2 (Study I), children diagnosed with autism might feel inadequacy and tension when facing social challenges as a consequence of their inability to interact properly with other people. Actually, some researchers have proposed a bidirectional relationship between social impairments and social anxiety in this clinical group (Bellini, 2006; Spain et al., 2018; White et al., 2010). Some studies have reported that nearly half (49%) of autistic adolescents exceed the clinical cut-off on a measure of social anxiety (Bellini, 2004), with an estimated co-occurrence (both diagnosed and subthreshold symptoms) between 17 and 29% (Simonoff et al., 2008). Although many studies have examined the presence of social anxiety in ASD, little attention has been given to the assessment of the multiple components (subjective, behavioral, physiological) of the construct by focusing on state anxiety responses, which will be the main aim of the present study.

Regarding children with learning disorders, it is worth saying that academic achievement has been discovered to be intimately linked to social adaptive functioning (Brigman et al., 2007; Sung & Chang, 2010). In particular, the model of social-emotional learning emphasizes that learning in school is a profoundly social process (Denham & Brown, 2010). Considering the association between school performance and social functioning, children with SLD might face a unique set of socio-emotional challenges as a result of their academic difficulties (Livingston et al., 2018; Riddick, 2009; Willcutt et al., 2011). Specifically, regarding social anxiety, different studies have revealed a higher rate in children and adults with SLD compared to non-diagnosed (Carroll & Iles, 2006; Mammarella et al., 2016; Rostami et al., 2014; Terras et al., 2009). Consequently, to school challenges and negative experiences, children with SLD might experience feelings of anxiety, shame and inadequacy (Elgendi et al., 2021), and any negative feedback from school may affect their socio-emotional functioning furthering internalizing problems (Donolato et al., 2022; Sahoo et al., 2015; Thaler et al., 2010). Multiple experiences of these feelings can result in lowering self-esteem, social skills deficits with peers, causing loneliness and troubles finding friends or relationships, and resulting in higher levels of social anxiety (Kohli et al., 2005). Though, the association between social skills and social anxiety in children and adolescents with SLD has not been systematically examined yet.

Mathematics anxiety in Specific Learning Disorders and Autism

As previously mentioned in Chapter 3, youth with specific learning disorders (SLD) might experience anxiety when navigating the school context, due to their academic impairments, especially when mathematical skills are required. Besides heterogeneous cognitive profiles, children with SLD show low self-concept as a secondary reaction to experienced academic difficulties or as a result of school challenges (Haft et al., 2019; Novita, 2016). Regarding MA, the few studies suggest higher levels of MA in SLD (Kucian et al., 2018; Lai et al., 2015; Passolunghi, 2011; Rubinsten & Tannock, 2010). However, no studies employed an experimental task to assess the multiple components of MA in children with SLD, thus further research is still needed to disentangle which aspects have greater impact on math performance.

Understanding the academic strengths and weaknesses should be important not only for students with learning disorders, but also for those with established social difficulties, such as those with a diagnosis of ASD (Fleury et al., 2014). Indeed, social challenges (e.g., restricted social initiation) and social anxiety might have negative effects on the learning processes, since students with ASD may not seek out social learning opportunities, thus missing chances to learn (Brook & Willoughby, 2015; Ricketts et al., 2013). The few studies on mathematical abilities in autism yield mixed results, with some studies revealing exceptional mathematical abilities in ASD (Baron-Cohen et al., 2007; Heavey, 2003; Soulières et al., 2010), other studies showing mathematical difficulties (Aagten-Murphy et al., 2015; Bullen et al., 2022), and other findings demonstrating similar math performance when compared to typically developing peers (Chiang & Lin, 2007; Mayes & Calhoun, 2008). Nonetheless, a recent meta-analysis reveals that mathematical performance in studies on ASD, is significantly affected by sample-related characteristics (Tonizzi & Usai, 2023). Even less are the studies on the effect of mathematical challenges, for instance mathematics anxiety, in ASD, yielding mixed results (Georgiou et al., 2018; Oswald et al., 2016). A systematic review reported some evidence of non-specific school anxiety in autism, but research on the field remains very limited (Adams et al., 2019). To our knowledge, there are no systematic studies that explore MA in children and adolescents with ASD with an experimental task assessing subjective and behavioural responses to math-related demands.

Overview of the study

To the best of our knowledge, no previous studies have examined the characteristics of social and mathematics anxiety by considering (and comparing) children and adolescents with ASD and SLD, with a control group with no diagnosis (ND). The three groups were also matched for age (ranging between 8 and 16 years old), sex and IQ. For this purpose, we asked participants to complete two stressful tasks, which were designed to elicit a temporary and laboratory-controlled stress response consistent with social and mathematical anxiety. Overall, a stress response may be triggered by an actual or perceived threat, commonly referred to as a *stressor*. It can be characterized as the condition of an organism reacting to adverse circumstances that have the potential to induce state anxiety (Endler & Parker, 1990). For social anxiety, we used a public speaking task (adapted from the Trier Social Stress test, child version; Buske-Kirschbaum et al., 1997) and, for mathematics anxiety, a mental calculation test with time restrictions (adapted from Caviola et al., 2016, 2018). Behavioral (i.e., quality of the performance) and subjective (i.e., valence, arousal, perception of competence, worries) components of anxiety towards the two stressful tasks have been examined. In fact, participants were asked to report state subjective experiences before and after the two tasks. We also asked participants' parents to fill in a questionnaire on their children social anxiety, to further consider trait symptoms of social anxiety observed by parents in real-life settings.

The first aim was to evaluate the trait levels of social anxiety reported by the participants' parents. We expected parents of children with ASD (e.g., Sukhodolsky et al., 2008) and SLD (e.g., Thaler et al., 2010) to report higher levels of social anxiety compared to the ND group, as described in literature. In particular, we assumed children with ASD would obtain higher levels on the subscale assessing *the fear of humiliation and rejection*, which is more closely associated with social anxiety, and those with SLD higher levels on the *performance fears* subscale, which is more associated with mathematics anxiety.

However, our primary interest was on the state components of social and mathematical anxiety provoked by the presence of social and mathematical pressure in the two experimental tasks. Thus, the second aim of the present study was to assess the state *behavioral* components of anxiety, by analysing the quality of the public speech and the mathematical performance accuracy. In comparison to the ND group, it is worth hypothesising a worse quality of the public speech in the ASD group (Edmiston et al., 2017; Kumazaki et al., 2020), and a lower accuracy in the stressful mathematical task in the SLD group (Kucian et al., 2018; Rubinsten & Tannock, 2010). However, the two experimental tasks are both characterized by performance-related pressure: in one case it is the presence of an audience (TSST-C), in the other one it is the time constraint for solving the operations (stressful mathematic task), therefore we assumed an overall worse performance in both tasks of the clinical groups compared to the control group.

Finally, the third aim was to evaluate state *subjective* responses towards the two stressful tasks by considering baseline and task-related self-reports, and comparing their change across the two time-points between the three groups (ASD, SLD, ND). Exploratory hypotheses will be described, because of the lack of similar studies in literature.

Consistent with findings on social anxiety in ASD, it seems reasonable to hypothesize that autistic participants would report increased arousal and worries, and lower valence and perception of competence after executing the public speaking task (Bellini, 2006; Jansen et al., 2006). However, a decent body of research reveals low awareness of one's own internal emotional states in autism (for a meta-analysis see Huggins et al., 2021), besides an overestimation of one's own social skills (Barnhill et al., 2000; Scheeren et al., 2010). For these reasons, the ASD group might also report state subjective responses characterized by absent arousal and worries towards the social stressor (Dijkhuis et al., 2019; Simon & Corbett, 2013). Concerning children with SLD, the fear of being negatively judged by others might play a role as well in the enhancement of the state anxiety during the public speaking task (Livingston et al., 2018; Novita, 2016; Rostami et al., 2014).

In respect to the stressful mathematical task, we assume to observe the same pattern of state subjective responses (previously described in ASD for the TSST-C) with higher arousal/worries and lower valence/perceived competence, in the group with SLD (Passolunghi, 2011; Rubinsten & Tannock, 2010), especially as a consequence of reduced self-esteem in school (Terras et al., 2009). Similarly, the presence of time constraints during the mathematical task, could produce a performance-based anxiety response also in children with ASD, by enhancing perceived concern towards the timed test, and lowering cognitive resources allocated for that task (Ashcraft & Kirk, 2001; Beilock, 2008; Beilock et al., 2004). However, children with ASD might also overestimate their mathematical performance, because they seem to be unaware of their academic competences (Furlano & Kelley, 2020).

5.2 Method

5.2.1 Participants

The study involved 280 children and adolescents aged between 8 and 16 years old divided into three groups: 60 (52 boys, 8 girls) with Autism Spectrum Disorders (ASD), 70 (55 boys, 15 girls) with Specific Learning Disorders (SLD), and 150 (114 boys, 36 girls) matched non-diagnosed (ND) peers. The three groups did not statistically differ in chronological age [$F(2, 277) = 1.35$, $p = .26$, $Adj\ R^2=.002$], sex distribution [$X^2=2.94$, $df=2$, $p=.23$], or total IQ [$F(2, 277) = .86$, $p = .42$, $Adj\ R^2=-.001$].

Inclusion criterion for the current study was a standard score of 80 or more for total IQ as assessed by the Wechsler Intelligence Scales (WISC IV; Wechsler, 2003). All children and adolescents were native Italian speakers, and none had any visual or hearing impairments. Participants who were taking medication, or with other known genetic conditions, a history of neurological diseases, comorbid psychopathologies, or certified physical and intellectual disabilities were excluded.

The ND group comprised healthy children with typical development with no psychiatric, neurological, or neurodevelopmental disorders. They were engaged and examined individually at school. The clinical groups (ASD, SLD) were assessed at the child and adolescent psychiatric services, where they referred. All participants in the clinical groups had been previously diagnosed with ASD or SLD, according to the DSM-IV-TR or the DSM-5 (APA, 2000, 2013) or ICD-10 (WHO, 1992) criteria.

To confirm their diagnosis, an experimenter, blind to the group membership of the participants, was responsible for testing all the children using specific clinical assessment materials. Diagnosis of ASD were confirmed using the Autism Diagnostic Interview - Revised (ADI-R; Rutter et al., 2005). The groups statistically differed in all subscales of ADI-R (Reciprocal social interaction: $F(2, 277)=134.14$, $p<.001$, $Adj\ R^2=.50$; Language/communication: $F(2, 277)=97.44$, $p<.001$, $Adj\ R^2=.42$; Repetitive behaviors/interests: $F(2, 277)=81.61$, $p<.001$, $Adj\ R^2=.38$), with autistic participants having higher scores than those with SLD and ND. Diagnosis of SLD was also confirmed by implementing some age-appropriate subtests which evaluated reading and math competencies (AC-MT-3 6-14, Cornoldi et al., 2020; DDE-2, Sartori et al., 2007; MT-Avanzate-3-Clinica, Cornoldi et al., 2017). In both reading (words - errors: $F(2, 277)=65.76$, $p<.001$, $Adj\ R^2=.45$; words - time $F(2, 277)=66.80$, $p<.001$, $Adj\ R^2=.45$; pseudo-words - errors: $F(2, 277)=27.97$, $p<.001$, $Adj\ R^2=.26$; pseudo-words - time $F(2, 277)=42.29$, $p<.001$, $Adj\ R^2=.34$) and math (mental calculation - accuracy: $F(2, 277)=24{,}22$, $p<.001$, $Adj\ R^2=.23$; mental calculation - time $F(2, 277)=15.38$, $p<.001$, $Adj\ R^2=.15$) subtests, the SLD group was more impaired than the ASD and ND groups.

Table 5.1 includes a summary of the participants' characteristics and of the screening measures with groups' comparison.

Table 5.1 Descriptive statistics and statistical comparisons on the screening measures in the ASD, SLD and non-diagnosed (ND) groups: means (M), standard deviations (SD) and results of ANOVAs.

Screening measures	**ASD (n=60)**	**SLD (n=70)**	**ND (n=150)**	**ANOVAs**			
Gender (M:F)	52:8	55:15	114:36	***F*** **(2, 277)**	***p***	***Adj R²***	***Post-hoc***
	M (SD)	**M (SD)**	**M (SD)**				
Age (in months)	146.25 (31.60)	152.76 (23.06)	146.88 (26.39)	1.35	.26	.002	-
IQ	106.97 (15.88)	106.24 (12.02)	108.49 (11.22)	.86	.42	-.001	-
ADI-R							
Reciprocal social interaction	15.12 (5.68)	4.49 (3.61)	5.19 (3.69)	134.14	**<.001**	.50	ASD > SLD, ND
Language/ communication	11.33 (4.50)	3.96 (3.21)	4.43 (2.94)	97.44	**<.001**	.42	ASD > SLD, ND
Repetitive behaviors/interests	5.47 (3.38)	1.36 (2.03)	1.30 (1.53)	81.61	**<.001**	.38	ASD > SLD, ND
Reading							
Words (errors)	.08 (1.25)	2.14 (1.17)	.15 (.95)	65.76	**<.001**	.45	SLD > ASD, ND
Words (sec)	.006 (.86)	2.18 (1.16)	.34 (1.00)	66.80	**<.001**	.45	SLD > ASD, ND
Pseudo-words (errors)	-.16 (.90)	1.31 (1.28)	-.02 (1.09)	27.97	**<.001**	.26	SLD > ASD, ND
Pseudo-words (sec)	.06 (1.00)	1.93 (1.19)	.38 (1.09)	42.29	**<.001**	.34	SLD > ASD, ND
Mathematics							
Mental calculation (accuracy)	-.06 (1.21)	-1.02 (1.10)	.32 (1.11)	24.22	**<.001**	.23	SLD < ASD, ND
Mental calculation (sec)	.55 (1.25)	1.37 (1.42)	.16 (1.16)	15.38	**<.001**	.15	SLD > ASD, ND

Note: M=mean; SD=standard deviation; No gender differences between the three groups ($X^2 = 2.94; p=.23$); IQ: intelligence quotient. All reading and mathematics subtests are expressed in standardized z scores.

5.2.2 Materials

Questionnaires

Social anxiety

The parent-report form of the Italian version (Paloscia et al., 2017) of the Multidimensional Anxiety Scale for Children (MASC-2; March, 2012) was administered to evaluate the presence of social anxiety symptoms. Specifically, the Social Anxiety subscale (composed by Humiliation/Rejection, and Performance Fears) was administered. This dimension includes 9 items rated on a 4-point scale from 0 (*never*) to 3 (*often*). Raw scores were converted into T scores by using normative data that considers the child's age and sex.

Cronbach's α (Social Anxiety scale) =.88.

Experimental tasks

Trier Social Stress Test

A computerized version of the Trier Social Stress test – child version (TSST-C, Buske-Kirschbaum et al., 1997; adults' version, Kirschbaum et al., 1993) was applied with the aim of eliciting a laboratory-controlled and socially-driven temporary stress reaction. Indeed, the TSST-C combines the key elements of social-evaluative threat and uncontrollability to produce a consistent psychophysiological stress response (Allen et al., 2017).

In the original version of the TSST-C, children are asked to perform a public speaking task and an arithmetic task in front of a jury. However, a different version of the TSST-C was developed and adapted due to the COVID-19 restrictions which limited personal contacts and movements, thus a videorecording was used as an alternative to a panel of judges (e.g., Cartwright-Hatton et al., 2003). Participants were asked to prepare a speech about their ideal birthday party (Poole et al., 2018) for three minutes, and then to "publicly" perform it in front of the video-recorded panel committee (a man and a woman) for five minutes. The following instructions were given: "*In this test, you will have to give a speech in front of some unknown people. They don't know you, and they know nothing about you. Imagine having to plan your birthday party and think about all the phases of organization. Describe who you would invite and what, in your opinion, are the important aspects of a party. You have three minutes to prepare your speech, and then another five minutes to present it to a jury. This jury will evaluate your performance, and today they will be with us online and not in person, due to the COVID emergency. Try to build your speech in a way that is better than that of the other participants. Competition rules prohibit judges from interacting with participants. Now, get ready.*"

At the end of the protocol, the experimenter debriefs the participants, explaining that the panel of judges displayed on the computer screen, was not truly judging them because it was a videorecording.

We entirely excluded the serial subtraction task from the original version of the TSST (Heilbron et al., 2008; Seddon et al., 2020), because the main interest was on the psychological effects of a social performance task, whereas a second experimental task was developed specifically to assess anxiety towards mathematical contexts (see next paragraph on the *Stressful Mathematical Test*).

Behavioral measures The *behavioral* assessment of the Trier Social Stress Test has been performed by using an adaptation of the Social Performance Rating Scale (SPRS; Fydrich et al., 1998). The adapted rating scale is reported in the Appendix. The public speech was video and audio-recorded to be able to evaluate the participants' quality of the public speech by taking into account different non-verbal and verbal aspects of the performance. Non-verbal aspects were signs of *discomfort* (posture, movements), *gaze* (eye contact, gaze pattern) and *quality of voice* (warmth, enthusiasm, interest in verbal expression, volume); verbal aspects were *adherence to the track* (theme elaboration and analysis), *conversational flow* (length of the sentences, complex/simple phrases) and *lexicon* (high and low frequency words). Two independent raters evaluated the participants' task performance by rating each of the six subscales on a Likert-scale basis from 1 ("Very poor") to 5 ("Very good") and solving discrepancies afterwards. A maximum of 30 points was assigned to the performance of each child by summing the scores obtained from the three non-verbal (max 15 points) and the three verbal (max 15 points) subscales.

Cronbach's α (total raw scale) = .85 (C.I.=.83-.88); Cronbach's α (non-verbal aspects) = .70 (C.I.=.63-.75); Cronbach's α (verbal aspects) = .85 (.81-.88).

Stressful Mathematical Test

A computerized mental calculation task was adapted from Caviola and colleagues (Caviola et al., 2016; 2018), whose purpose was to induce a consistent stress response due to the presence of time constraints. Participants were first asked to watch a video-clip about strategies for mental calculation for three minutes (taken from https://www.s-cool.cloud/), and then to perform the mathematical test for five minutes. The task consisted of 60 multiple-choices trials (plus three practise trials with feedback) presented in two blocks of 30 trials each: the first block involved simple two-digit additions (without carrying), the second involved simple two-digit subtractions (without borrowing). The operations to be solved appeared at the top of the display with the three-answer options underneath arranged horizontally. Participants had to choose the correct answer between the three alternative choices (the correct answer, the correct answer plus or minus 1, and the correct answer plus or minus 10). The order of the three possible answers was counterbalanced. Participants had to press a keyboard key based on the position on the screen of the answer they wanted to select ("z" for the left choice, "v" for the one in the middle, and "m" for the right one). Time pressure was provided by the presence of a count-down clock that marked the time on the left-bottom side of the screen: participants had to solve the operations within the time limit of 10 seconds. If the time ran out, the program automatically moved on to the next operation.

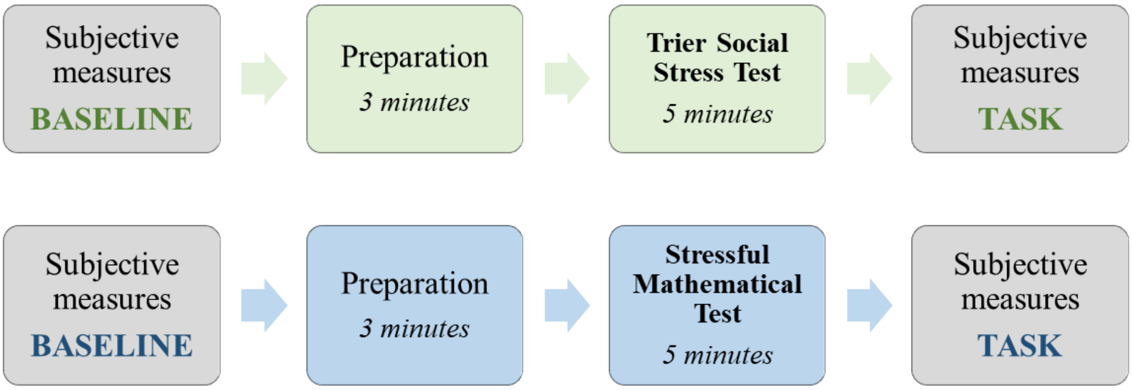
Behavioral measures Accuracy and response times (RTs) were recorded for each operation. RTs were defined as the time lapsing between the appearance of the operation on the screen and the moment an answer was selected. Only accuracy was taken into account in the statistical analyses as a *behavioral* measure, since the time constraint procedure prevented us from obtaining reliable reaction times.

For this sample, Cronbach's α (for ordinal data) = .98.

Subjective measures

Children were also asked to report certain aspects related to their state subjective experience of the two stressful tasks (Trier Social Stress Test, Stressful Mathematical Test). To do so, they were administered two self-report measures, before and after completing the tasks. Aspects reported before starting the task are consistent with participants' disposition in anticipation of the task (baseline measures), whereas those reported after finishing the task relate to emotions and thoughts experienced during execution of the same (task measures). For clarity, Figure 5.1 displays the steps of the applied procedure for both experimental tasks.

Figure 5.1 Outline of the two experimental tasks (Trier Social Stress Test, Stressful Mathematical Test) with subjective measures reported by the participants in two time-points (Baseline, Task).



Note: Subjective measures = valence, arousal, perception of competence, worries. Valence and arousal were investigated using the Self-Assessment Manikin scale (SAM; Bradley & Lang, 1994); perception of competence and worries were explored by using a Likert-type questionnaire adapted from Mammarella et al. (2023).

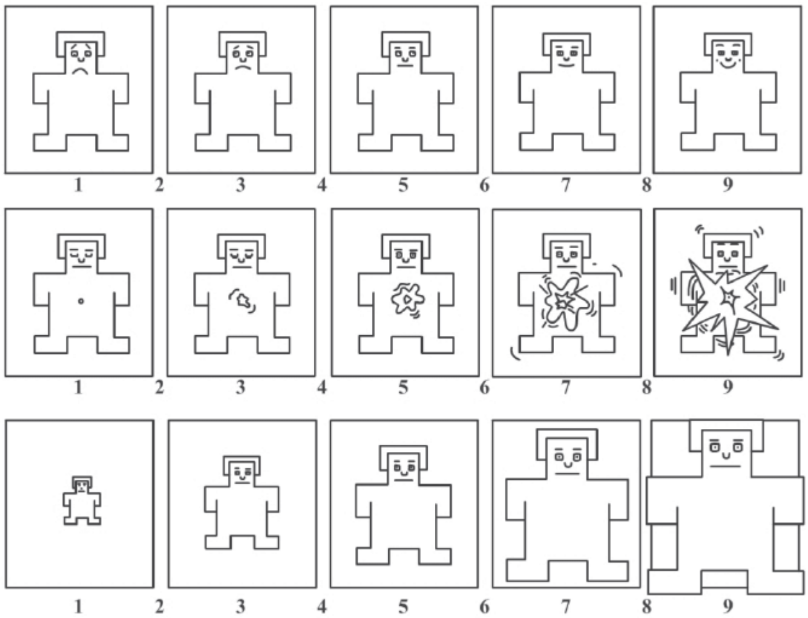
The two self-report measures administered before and after the tasks are described below.

Arousal and valence

The Self-Assessment-Manikin scale (SAM; Bradley & Lang, 1994) is a culture-free non-verbal pictorial assessment technique that assesses three aspects associated with a person's affective reaction to a wide variety of stimuli (see Figure 5.2): valence (from 1 = “unpleasant/negative” to 9 = “pleasant/positive”), arousal (from 1 = “calm” to 9 = “arousing”), and dominance (from 1 = “out of control” to 9 = “under control”). For the purpose of this study, only arousal and valence were administered and taken into account in the statistical analyses, since they are recognized as primary dimensions accounting for most of the variance in emotional judgments (Bradley & Lang, 1994).

Correlations between SAM and a semantic differential method of affective rating were .94 for arousal and .97 for pleasure, showing an excellent criterion validity (Bradley & Lang, 1994).

Figure 5.2 The Self-Assessment-Manikin scale (SAM).



Note: From top to down = valence, arousal, dominance (this latter not considered in the study).

Perception of competence and worries

In addition to participants' affective state, perceived competence and worries were also evaluated through the administration of an ad-hoc questionnaire (derived from Mammarella et al. 2023) before and after finishing the two tasks. It consisted of 6 questions about the participants' perceived competence (3 questions) and worries about the task (3 questions). An example from the perceived competence scale is: "Do you think you were good at taking the test?", while from the worries scale: "During the task, were you worried about your performance?". The child had to answer using a 4-point Likert scale from 1 ("not at all") to 4 ("a lot"), and the total score of each scale was considered. Higher scores on each scale were consistent with higher levels of perceived competence and worries.

Cronbach's α = Baseline: perception of competence 0.80 (TSST-C), 0.77 (Stressful Mathematical Task); worries 0.81 (TSST-C), 0.82 (Stressful Mathematical Task); Task-related: perception of competence 0.86 (TSST-C), 0.87 (Stressful Mathematical Task); worries 0.86 (TSST-C), 0.89 (Stressful Mathematical Task).

5.2.3 Procedure

The study was approved by the ethics review board of the University of Padova (protocol number: 3920), and took place between January 2021 and July 2022. After obtaining the written informed consent of the participants' parents, children were tested individually in a quiet room at specialized centers (ASD, SLD) or at school (ND) during three sessions (a screening and two experimental phases) lasting approximately 30 minutes each. In the screening phase, the IQ was calculated and only participants who scored above 80 were included; reading and math competences were also evaluated in this initial phase. Parents were administered the ADI-R for child autistic symptoms and the MASC-2 for child social anxiety. Then, the two experimental tasks were presented in a counterbalanced order in two different experimental sessions. The computerized tasks were created using PsychoPy3 (Pierce et al., 2019), and administered with a laptop computer with a 15-inch LCD screen.

5.2.4 Statistical approach

First, a series of univariate ANOVAs were performed to estimate differences between the three groups (ASD, SLD, ND) in the measures of interest. Post-hoc comparisons between groups were assessed through the Tukey's correction test. Effect sizes were also computed using adjusted R^2, which represents the effect size of the comparisons between the three groups for the factors considered. Table 5.2 includes the descriptive statistics (*M, SD*) and statistical comparisons between the three groups on the social anxiety subscales of the MASC-2 (parents' version). Table 5.3 shows the descriptive statistics and statistical comparisons of the three groups' performance (*behavioral* measures) on the two experimental tasks: the Trier Social Stress Test and the Stressful Mathematical Test.

Second, we analyzed the *subjective measures* (valence, arousal, perception of competence, worries) vis-à-vis the two experimental tasks (Trier Social Stress Test, Stressful Mathematical Test) divided by the three groups (ASD, SLD, ND) and reported in two time-points (Baseline, Task) by participants. Descriptive statistics (*M, SD*) are displayed in Table 5.4. As reported in Table 5.5, linear mixed-effects models were run to examine the relationship between the dependent variable (*subjective responses* towards the two experimental tasks), and the independent variables (Time and Group). Time was treated as a fixed effect, representing the time points in which participants had to report subjective responses (Baseline, Task), while Group was treated as a fixed effect representing the categorical grouping variable (ASD, SLD, ND). The interactions between Time and Group were also investigated to assess whether the effect of time on the dependent variable differed across the various groups. In other words, it helped us determine if the rate of change in the subjective measures over time (baseline, task) was different for different groups (ASD, SLD, ND). Single participants were included as random effects to consider the individual variations. ANOVAs between linear mixed models were run to test the significance of the fixed effects (Time, Group) and the interactions between them.

Data were analyzed using R version 1.3.1093 (R Core Team, 2022). The following R packages were used: "lmerTest" (Kuznetsova et al., 2017) for computing linear mixed-effect models, and "effects" (Chambers & Hastie, 1992) for graphical effects.

5.3 Results

Parental report of child social anxiety

Concerning the total scale of social anxiety, a statistically significant effect of the group emerged, $F(2, 277)$=16.14, p<.001, $Adj\ R^2$=.10. Parents of children and adolescents with ASD and SLD reported greater levels of social anxiety in their children, both in the Fear of being humiliated and Performance fears subscales, as compared to the ND group (see Table 5.2).

Table 5.2 Descriptive statistics and statistical comparisons on the social anxiety subscales of the MASC-2 (*parents' version*) in the three groups (ASD, SLD, ND): means (M), standard deviations (SD) and results of ANOVAs.

Measures	ASD	SLD	ND	ANOVAs			
	M (SD)	M (SD)	M (SD)	***F* (2, 277)**	***p***	***Adj R²***	***Post-hoc***
Social anxiety (total scale)	66.20 (14.30)	68.11 (12.81)	58.64 (12.07)	16.14	**<.001**	.10	ASD, SLD > ND
Fear of being humiliated	64.20 (15.22)	67.76 (13.28)	57.24 (11.87)	17.43	**<.001**	.11	ASD, SLD > ND
Performance fears	63.65 (12.80)	63.31 (12.34)	57.43 (11.38)	8.91	**<.001**	.06	ASD, SLD > ND

Note: M=mean; SD=standard deviation; MASC-2=*Multidimensional Anxiety Scale for Children* (March, 2017; Italian version, Paloscia et al., 2017). Means and SD are expressed in T scores.

Experimental tasks: Trier Social Stress Test and Stressful Mathematical Test

Behavioral and *subjective* measures associated with the two experimental tasks were analysed.

Behavioral measures

As Table 5.3 displays, the ASD and SLD groups performed worse both in the Trier Social Stress Test, $F(2, 277)$=12.91, p<.001, $Adj\ R^2$=.19, and in the Stressful Mathematical Test, $F(2, 277)$=13.31, p<.001, $Adj\ R^2$=.09, as compared to ND participants. Specifically, to the TSST-C, the clinical groups obtained a worse quality both in the non-verbal, $F(2, 277)$=14.61, p<.001, $Adj\ R^2$=.10, and in the verbal aspects, $F(2, 277)$=7.73, p<.001, $Adj\ R^2$=.05, of the public speech.

No behavioral differences were found between the ASD and SLD groups in both the experimental tasks.

Subjective measures

Table 5.4 shows the descriptive statistics (*M, SD*) of the *subjective* responses (valence, arousal, perception of competence, worries) towards the two experimental tasks (Trier Social Stress Test, Stressful Mathematical Test) reported by the three groups (ASD, SLD, ND). Subjective measures were reported by participants in two time-points: Baseline, and Task).

Results of the linear mixed-effects models with Time, Group, and the interactions Time x Group, are shown in Table 5.5.

<u>Trier Social Stress Test</u>

A significant effect of Time resulted in all considered subjective measures: valence, $F(1,277)=6.11$, $p<.001$, arousal, $F(1,277)=5.64$, $p=.02$, perception of competence, *F(1,277)=8.88, p=.003,* and worries, *F(1,277)=17.03, p<.001*. Therefore, differences between Baseline and Task emerged for all subjective measures regardless the groups' membership.

The main effect of Group emerged for arousal, *F(2,277)=6.67, p=.001,* and perception of competence, *F(2,277)=9.53, p<.001*. The interaction between Time and Group was significant as well for both arousal, *F(2,277)=3.38, p=.03,* and perception of competence, *F(2,277)=3.76, p=.02*.

Table 5.3 Descriptive statistics and statistical comparisons of the three groups' performance (*behavioral* measures) on the two experimental tasks (Trier Social Stress Test, Stressful Mathematical Test): means (M), standard deviations (SD) and results of ANOVAs.

Experimental tasks	**ASD**	**SLD**	**ND**	**ANOVAs**			
	M (SD)	**M (SD)**	**M (SD)**	***F* (2, 277)**	***p***	***Adj R^2***	***Post-hoc***
Trier Social Stress Test (TSST-C)							
Total raw score	15.37 (4.93)	15.66 (4.27)	18.42 (4.84)	12.91	**<.001**	.09	ASD, SLD < ND
Non-verbal aspects	7.35 (2.33)	7.59 (2.29)	9.06 (2.53)	14.61	**<.001**	.10	ASD, SLD < ND
Verbal aspects	8.02 (3.16)	8.07 (2.55)	9.36 (2.69)	7.73	**<.001**	.05	ASD, SLD < ND
Stressful Mathematical Test							
Proportion of total accuracy	.53 (.21)	.48 (.22)	.65 (.22)	13.31	**<.001**	.09	ASD, SLD < ND

Note: M=mean; SD=standard deviation. The scoring of the TSST-C was performed by using an adapted version of the Social Performance Rating Scale (SPRS; Fydrich et al., 1998), which includes both non-verbal aspects (discomfort, gaze, vocal quality) and verbal (adherence to the track, conversational flow, lexicon) aspects.

Table 5.4 Descriptive statistics of the *subjective* measures (valence, arousal, perception of competence, worries) vis-à-vis the two experimental tasks (Trier Social Stress Test, Stressful Mathematical Test) reported by the three groups (ASD, SLD, ND) in two time-points (Baseline, Task): means (M) and standard deviations (SD).

Subjective measures	Baseline			Task		
	ASD	SLD	ND	ASD	SLD	ND
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Trier Social Stress Test						
Valence	6.50 (1.98)	6.36 (1.88)	6.58 (2.12)	6.32 (2.10)	6.06 (2.27)	6.08 (2.31)
Arousal	4.65 (2.52)	5.64 (2.46)	4.91 (2.68)	4.45 (2.64)	6.21 (2.40)	5.86 (2.60)
Perception of competence	7.88 (2.31)	7.01 (2.28)	7.20 (1.92)	8.03 (2.67)	5.97 (2.36)	6.69 (2.36)
Worries	6.93 (2.72)	7.40 (2.73)	7.17 (2.50)	7.15 (2.62)	8.11 (2.65)	7.87 (2.56)
Stressful Mathematical Test						
Valence	6.37 (2.11)	7.01 (1.68)	7.15 (1.83)	5.67 (2.58)	6.44 (1.93)	6.44 (2.03)
Arousal	3.37 (2.52)	3.49 (2.31)	3.25 (2.17)	4.38 (2.70)	4.26 (2.51)	5.02 (2.42)
Perception of competence	8.77 (2.06)	8.13 (2.47)	8.56 (2.17)	7.72 (2.57)	6.51 (2.25)	7.53 (2.38)
Worries	6.05 (2.94)	5.29 (2.10)	5.80 (2.36)	7.63 (2.88)	6.31 (2.59)	6.66 (2.41)

Note: M=mean; SD=standard deviation. Valence and arousal were investigated using the Self-Assessment Manikin scale (SAM; Bradley & Lang, 1994); perception of competence and worries were explored by using a Likert-type questionnaire adapted from Mammarella et al. (2023).

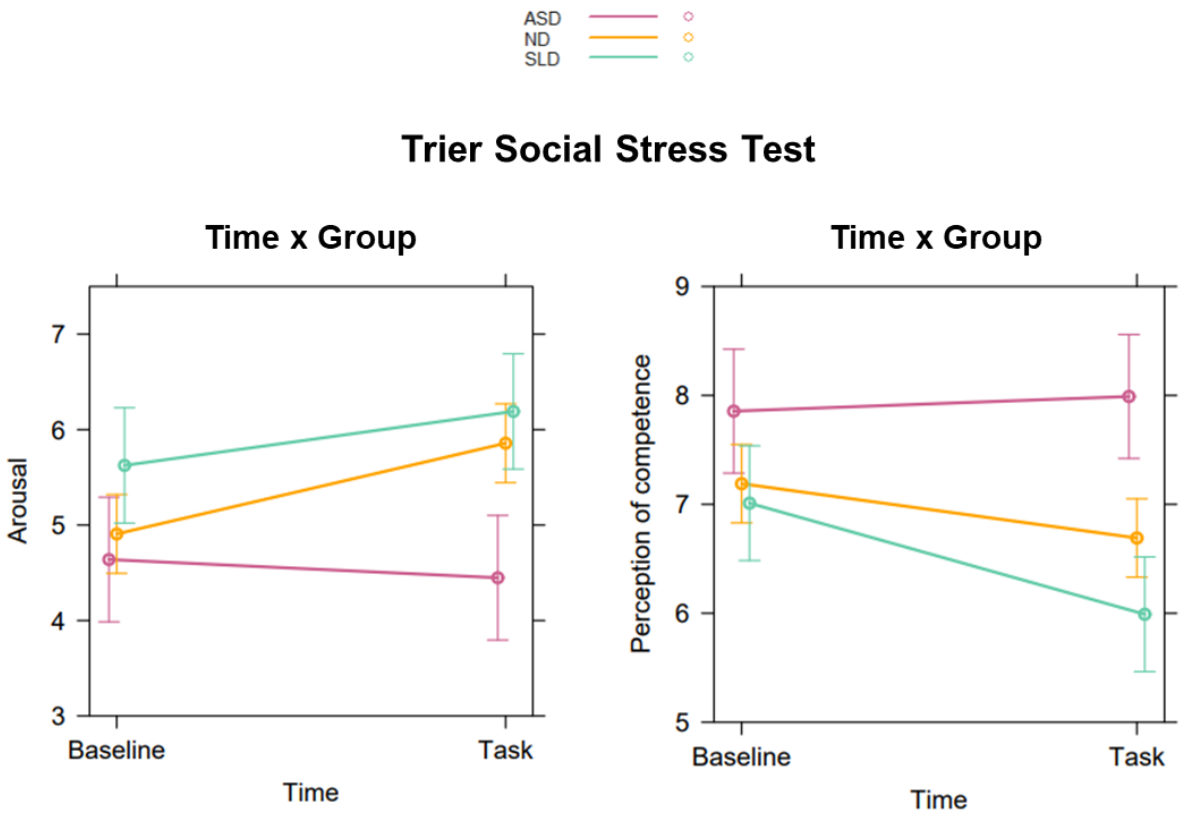
Table 5.5 Results of the ANOVAs in both the Trier social stress task an the Stressful mathematical task, between linear mixed-effects models with Time (Baseline, Task) as within-subject fixed effect, Group (ASD, SLD, ND) as between-subject fixed effect, and the interaction between Time and Group.

Fixed effects	**Trier Social Stress Test**			**Stressful Mathematical Test**		
	F	***df***	***p***	***F***	***df***	***p***
Valence						
Time	6.11	1, 277	**.01**	22.86	1, 277	**<.001**
Group	.20	2, 277	.82	4.89	2, 277	**.008**
Time x Group	.55	2, 277	.58	.09	2, 277	.91
Arousal						
Time	5.64	1, 277	**.02**	48.49	1, 277	**<.001**
Group	6.67	2, 277	**.001**	.53	2, 277	.58
Time x Group	3.38	2, 277	**.03**	4.21	2, 277	**.01**
Perception of competence						
Time	8.88	1, 277	**.003**	72.47	1, 277	**<.001**
Group	9.53	2, 277	**<.001**	4.12	2, 277	**.02**
Time x Group	3.76	2, 277	**.02**	1.89	2, 277	.15
Worries						
Time	17.03	1, 277	**<.001**	65.49	1, 277	**<.001**
Group	1.38	2, 277	.25	3.31	2, 277	**.04**
Time x Group	1.53	2, 277	.22	2.55	2, 277	.08 **.**

Note: Subjective measures towards the two experimental tasks (Trier Social Stress Test, Stressful Mathematical Test) are considered as dependent variables. Single participants were included as random effects.

As Figure 5.3 shows, the ASD group reported lower levels of arousal and greater perception of competence with no change between the Baseline and the Task, contrary to the SLD group, which reported higher levels of arousal in general. The SLD group also reported a decrease in the perception of competence with a statistically significant variation from the Baseline to the Task. Likewise, the ND group reported a statistically significant increase in the level of arousal, and a statistically significant decrease in the perception of competence, from the Baseline to the Task.

Figure 5.3 Significant effects of the ANOVAs between linear mixed-effects models on the Trier Social Stress Test.



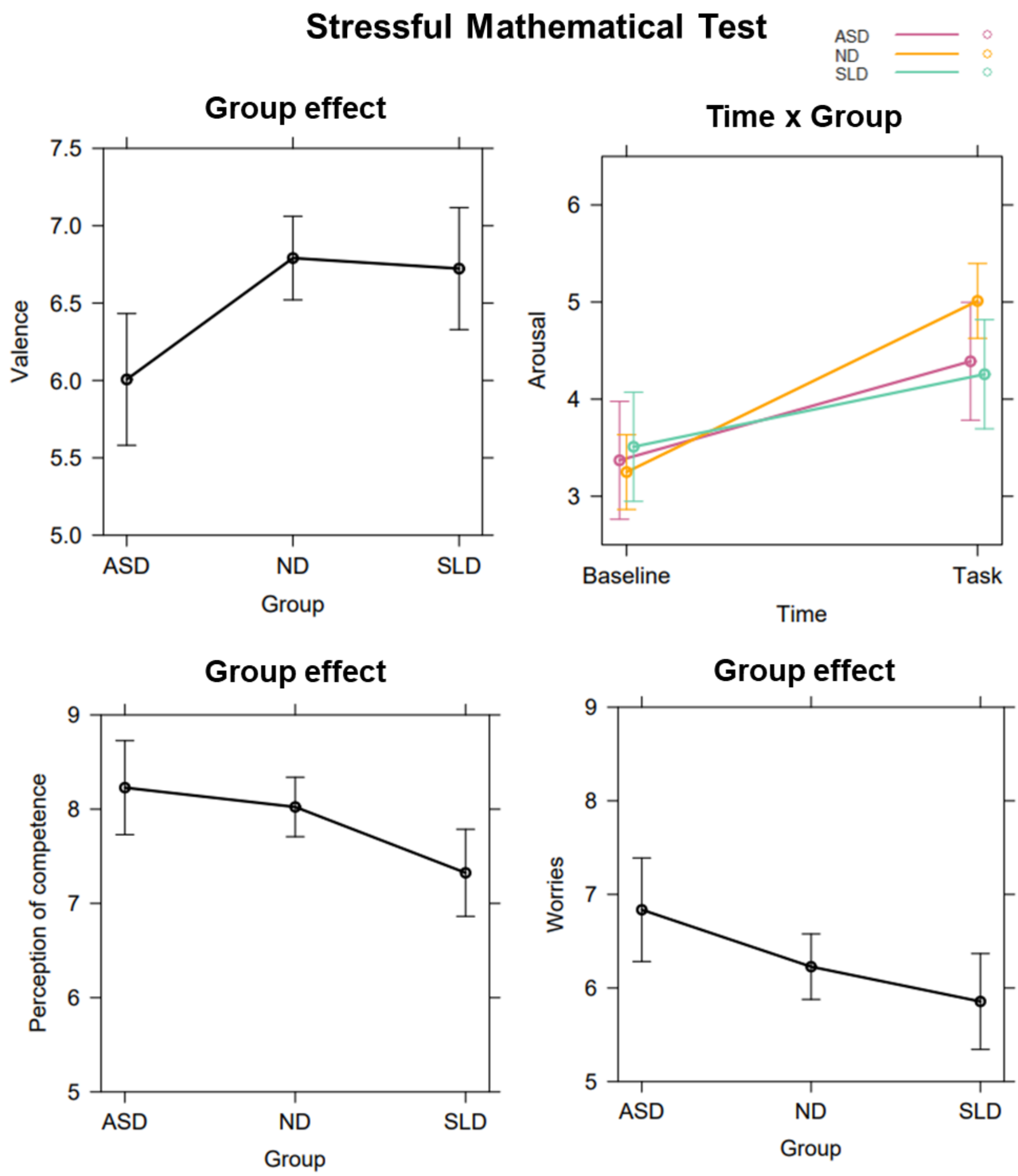
Stressful Mathematical Test

A significant effect of Time resulted in all considered subjective measures: valence, $F(1,277)=22.86$, $p<.001$, arousal, $F(1,277)=48.49$, $p<.001$, perception of competence, $F(1,277)=72.47$, $p<.001$, and worries, $F(1,277)=65.49$, $p<.001$. Therefore, differences between Baseline and Task emerged for all subjective measures regardless the groups' membership.

The main effect of Group emerged for valence, $F(2,277)=4.89$, $p=.008$, perception of competence, $F(2,277)=4.12$, $p=.02$, and worries, $F(2,277)=3.31$, $p=.004$. The interaction between Time and Group instead was significant for arousal, $F(2,277)=4.21$, $p=.01$.

As Figure 5.4 shows, the three groups differed in terms of valence, perception of competence and worries. The ASD group reported a statistically significant lower level of valence as compared to the other two groups (SLD, ND) and a higher level of worries as compared to the SLD group. The SLD group reported a statistically significant lower level of perceived competence as compared to the other two groups (ASD, ND). The three groups reported a significant increase in the level of arousal from the Baseline to the Task, though the highest level of arousal was perceived by the ND group during the Task.

Figure 5.4 Significant effects of the ANOVAs between linear mixed-effects models on the Stressful Mathematical Test.



5.4 Discussion

The main aim of the present study was to investigate performance-based anxieties and, in particular, the *behavioral* (quality of performance) and the *subjective* (valence, arousal, perception of competence, worries) components of social and mathematics anxiety. The state of anxiety was provided by the proposed experimental tasks, which were thought to elicit a temporary stress reaction due to the fear of negative evaluation (during the public speech), and time constraints (during the mathematical task). In addition, we also asked parents to report trait symptoms of their children's social anxiety by using a questionnaire.

The objective was to compare samples of matched children and adolescents with a clinical diagnosis, such as ASD and SLD, with non-diagnosed (ND) participants, to understand whether established social and academic difficulties could be associated with specific behavioral and subjective responses under pressure in different contexts.

Social anxiety in ASD and SLD: trait symptoms reported by parents

Consistent with the literature on the topic, higher levels of child social anxiety were reported by parents of participants in the ASD (Bellini, 2006; Spain et al., 2018; Sukhodolsky et al., 2008) and SLD (Rostami et al., 2014; Terras et al., 2009; Thaler et al., 2010) groups compared to the ND group, confirming our first hypothesis. Both groups with ASD and SLD gained a mean T score higher than 65 in the social anxiety scale, which is one standard deviation and a half over the mean, and represents a clinical cut-off (March, 2012). Besides, no differences were found between children with ASD and SLD in the two subscales of the questionnaire, highlighting that, according to parents' perception, both clinical groups are equally sensitive to the prospect of *being humiliated and rejected by others*, and of *being negatively evaluated for their performance*. That said, it is worth investigating whether trait levels of social anxiety observed by parents in real-life settings, are consistent with state components of anxiety towards performance-based settings, such as those requiring social and mathematical demands.

Behavioral responses to (state) social and mathematics anxiety in ASD and SLD

In line with the parents' report, our findings show that social and mathematical pressure provided by the experimental tasks, might have contributed to impact more the quality of the performance of the clinical groups compared to the control sample. However, the findings related to behavioral measure of social and mathematics anxiety should be taken with caution, as there is no baseline measurement of the abilities that are interpreted as a behavioural component of the specified anxiety, for instance mental calculation without time pressure (for MA), and verbal and non-verbal aspects (for social anxiety).

Trier Social Stress Test

Behavioral responses to social stress were evaluated through a social performance rating scale (adapted from Fydrich et al., 1998) by scoring the presentation on the Trier Social Stress Test (Buske-Kirschbaum et al., 1997), in which participants were asked to prepare and give a public speech in front of an unresponsive committee. Children with ASD and SLD gave a weaker speech quality than the ND group, considering both the non-verbal (i.e., discomfort, gaze, quality of voice) and the verbal (i.e., adherence to the track. conversational flow, lexicon) aspects. Although the verbal content (e.g., vocabulary) has a fundamental role in the communicative exchanges, pragmatic language is also critical in social settings, denoting the need to consider the context, listeners' expectations, nonliteral meanings, and bodily signals (Loukusa et al., 2007; Roselló et al., 2017). In respect of ASD, difficulties with pragmatic skills are widely recognized (Cardillo et al., 2021; Whyte & Nelson, 2015) with challenges in making appropriate judgments about how much to say in a conversation, impaired prosody, structuring narratives, and so on. Besides that, specific characteristics of autism, such as the difficulty in maintaining eye-contact (Senju & Johnson, 2009), might have contributed to decrease the quality of the public speech.

As concern children with SLD, a poor public speech might be a consequence of several factors. First, a public speech requires linguistic competences (e.g., phonological skills), and children with SLD may experience language or communication impairments in comorbidity (Peters & Ansari, 2019; Ramus et al., 2013); in our sample, children with SLD did not present comorbid language deficits, but preexisting challenges and their emotional consequences could have played a role during a demanding task like public speaking. Second, performing in public is very common within the school context, where students are required to perform in front of classmates and teachers. Indeed, students with SLD might experience a certain amount of tension when executing tasks in front of other people, because of their academic challenges. In this sense, the fear of being negatively evaluated by the panel of committee, may have influenced their social performance (Livingston et al., 2018; Terras et al., 2009). Moreover, it is worth mentioning that a restricted number of studies showed that individuals with SLD experience social problems, including self-regulation (de Beer et al., 2014), social interaction (Kempe et al., 2011; Riddick, 2009), and face emotion recognition (Operto et al., 2020).

Stressful Mathematical Test

Predictably, also the mathematical pressure (provided by time constraints) had a significant effect on the performance of the clinical groups. During the mental calculation task, a countdown clock marked the time participants had (maximum 10 seconds), to solve the operations. In fact, both children with ASD and SLD obtained a worse accuracy rate in the mathematical task as compared to the ND group, with no significant difference between them.

To the best of our knowledge, no studies employed an experimental task to assess how time pressure may influence the performance of children with established arithmetic difficulties. However, our results are not surprising for the group with SLD, whose proven difficulties with mathematical concepts might be worsen by the presence of time limitations to solve mental calculations (Caviola, Carey, et al., 2017). For instance, the presence of time pressure may have expedited the participants' decision-making, by making them choose the wrong strategy, or by decreasing the efficiency of the correct strategy execution (Rieskamp & Hoffrage, 2008).

A more remarkable finding emerged for the group with ASD, whose performance did not differ significantly from that of the children diagnosed with SLD, although their intact mathematical competences. Particularly in the field of mathematics, where stress and anxiety are prevalent and there is a strong desire to excel, individuals might not achieve their optimal performance, even if they possess the necessary skills (Benny & Banks, 2015). The time limit for solving single operations may have negatively influenced autistic participants to the extent of obtaining lower scores than their actual competences, consistent with the "choking under pressure" phenomenon (Beilock et al., 2004; Beilock & Carr, 2001). The main hypothesis of this theory, is that contextual stress may interfere with cognitive resources (e.g., working memory [WM]) and negatively impact performance, through the occurrence of performance-based anxiety and worries (Beilock, 2008; Eysenck & Calvo, 1992). A closer look at participants' self-reported emotions, thoughts and worries toward the mathematical task may help disentangling the issue.

All in all, the occurrence of performance-based anxiety, as reported by parents, could have influenced the outcomes of participants with ASD and SLD in both social and mathematical tasks: assessing children's state subjective experience might provide a more comprehensive overview of the phenomena.

Subjective responses to (state) social and mathematics anxiety in ASD and SLD

Besides behavioral components of social and mathematical anxiety, our third aim was to assess the self-reported subjective experience of participants in respect of the stressful social and mathematical tasks. For this purpose, we compared state baseline measures with task-related measures, to gain knowledge about the change attributable to the stressful condition. The assessment of baseline and task-related state measures of anxiety comprised valence (pleasantness), arousal (bodily activation), perception of competence and worries towards the task. Both expected and unexpected findings will be discussed in the next paragraphs, with interesting points for reflection.

<u>Trier Social Stress Test</u>

Concerning the public speech, we were prepared to find heterogeneous patterns of subjective responses reported by the ASD group, consistent with either excessive task-related anxiety (resulting in low valence/perceived competence, high arousal/worries) or the absence of it. The mixed-effects models on the subjective components, revealed that children with ASD reported a general lower arousal (emotional activation) and a higher perception of competence than the other two groups after completing the public speech, in disagreement with their actual performance. On the one hand, autistic children might be unaware of their own social difficulties, thus reporting higher levels of competence and emotional deactivation (Barnhill et al., 2000; Huggins et al., 2021). The inability of identifying and communicating their own subjective experience (i.e., alexithymia) might also be considered (Oakley et al., 2022). In the other hand, it could be possible that the TSST-C may have failed to evoke a physiological response in this clinical group (Corbett et al., 2012; Dijkhuis et al., 2019; Jansen et al., 2003; Lanni et al., 2012). Within this hypothesis, autistic participants might be aware of both social challenges and internal processes, but they do not feel concerned about the social pressure provided by the unresponsive committee, possibly due to diminished social motivation (Chevallier et al., 2012), or they may interpret the social evaluative paradigm as being simply a cognitive exercise (Simon & Corbett, 2013).

On the contrary, children with SLD reported an opposite pattern of state subjective responses compared to those diagnosed with autism. Indeed, mixed-effects models revealed a constant state of greater emotional activation in the SLD group than the other two groups, in addition to a significantly decreased perception of competence after the public speech. These results might indicate self-awareness of their own skills which, combined with a marked fear of negative evaluation, may cause a general state of anxiety both in anticipation and during a social demanding task (Riddick, 2009; Rostami et al., 2014). Additionally, low academic self-esteem may make an important contribution to psychosocial adjustment of children with SLD (Terras et al., 2009); in fact, they reported a general lower perception of competence towards the public speech.

To gain a comprehensive understanding of the complex interplay between self-awareness and performance-based anxiety in ASD and SLD, physiological responses to the TSST-C will be investigated in the next study (Chapter 6).

Stressful Mathematical Test

Interestingly, mathematical pressure had a different effect on the state subjective experience of children with ASD, SLD and non-diagnosed, allowing us to speculate on their emotional reactions and cognitive dispositions experienced within different performance-based contexts.

As regard the SLD group, the noteworthy result stands in the discrepancy between their subjective responses toward the mathematical task. They referred similar levels of valence and worries to those experienced by the ND group, and in respect of worries, even significantly lower than the ASD group. Moreover, it seems that the stressful mathematical task was able to evoke a significant enhancement of the emotional activation, but the reported level of arousal was very similar to that conveyed by the ASD group, and statistically lower to that felt by the ND children. We could hypothesize that children with SLD are used to experience repetitive failures in mathematics, and they might have developed feelings of resignation, appraisal or learned helplessness (Burden, 2008; Hunt & Maloney, 2022; Pekrun, 2006), not experiencing tension, concern or unpleasantness toward academic demands any longer. Nonetheless, in comparison to the other two groups, they reported a significantly lower perception of competence, which we could now describe as a permanent characteristic in SLD (Terras et al., 2009), equally present in both social and mathematical stressful settings. Instead, for ND children, the enhancement of task-related arousal might be a “fostering” factor, because of their preserved mathematical competences. Contrary to threat, arousal associated to challenge does not denote a negative state, signalling that the body is allocating resources to meet the task demands (Eysenck, 2012).

As for the group with autism, mixed-effects models revealed two group’s effects, emphasizing a significant lower valence and higher worries towards the mathematical task in the ASD group, compared to the other two groups. It is worth undertaking the idea that performance-based worries may have impacted mathematical performance of children with ASD by consuming attentional resources and WM capacity (Ashcraft & Kirk, 2001; Beilock, 2008). Moreover, self-deprecating thoughts and concerns may distract from thinking about important math-related features, focusing instead on irrelevant information (Beilock & DeCaro, 2007). However, the level of perception of competence did not differ from that reported by the ND group, despite the lower performance of the ASD group, highlighting a possible unawareness of their academic skills (Furlano & Kelley, 2020). Certainly, positively-biased self-perception of academic abilities may encourage individuals to remain engaged with a task they find difficult. Consistent with valence and worries, it seems that the stressful mathematical task was able to evoke a physiological response in this clinical group, in contrast with the TSST-C, since autistic children reported a significant task-related enhancement of the emotional activation. However, the reported level of arousal was very similar with that conveyed by the SLD group, and statistically lower of that felt by the ND children. To sum up, it is worth hypothesising greater performance-based anxiety towards mathematical demands rather than towards social settings; perhaps autistic students may feel more motivated in succeeding in mathematics than socially.

Limitations, future directions and potential implications

Despite its novelty, the present study is not without limitations, which should be considered in the formulation of future lines of research.

First, we used a computerized version of the Trier Social Stress Test, due to COVID-19 restrictions, thus perhaps the task did not represent an ecological and exact representation of what happens during real-life public performances. It could be worth implementing the original protocol by systematically including all the phases to elicit a more reliable social stress response, as we did in the next study (see Chapter 6 – Study IV).

Second, as for the Stressful Mathematical Test, our paradigm did not include a control condition with a math task without time constraints, thus we cannot conclude that state behavioral and subjective components are strictly related to the time-pressure anxiety. However, based on literature research, time pressure places constraints on the capacity for thought and action and elicits a well-established anxious state.

Third, our study did not include measures of working memory, thus our interpretation that distracting worries in ASD children might have negatively impacted their performance via the overloading of WM, should be examined further in future research. Fourth, we did not include a questionnaire on trait MA, as we did for social anxiety, to have a measure of dispositions towards mathematics in real-life settings. Additionally, we did not measure psychophysiological indexes (e.g., cardiac activity), that might serve as objective real-time measures of anxiety towards social and mathematical stressful conditions. Indeed, children might have found difficulties in reporting emotions closely associated with bodily signals, such as somatic arousal under pressure, indicating the need for more objective measures, which we decided to investigate in Chapter 6 (Study IV) for the social condition.

Nevertheless, our findings could have both educational and clinical implications. Educators must be conscious that public performance could elicit specific subjective responses depending on children's individual characteristics. For instance, children with ASD could benefit from the empowerment of emotional self-awareness and social motivation, to better navigate within the social world. As concerns children with SLD, educators must be aware of the specific subjective reactions that they might experience while performing social practises at school, such as public speaking or working in groups. The fear of negative evaluation seems to be crucial in children with established difficulties at school, thus educational interventions designed explicitly to relieve anxiety and enhance self-esteem might have a positive effect on successful learning (Corcoran et al., 2018; Durlak et al., 2011). Regarding mathematics, teachers and clinicians should be aware that time pressure could be considered a negative factor in terms of proficiency and worries also in children without mathematical difficulties, such as those diagnosed with ASD. Instead, it is important to discourage the development of resignation toward academic learning, a common attribute in children with SLD, to improve positive feelings, self-esteem, and more supportive learning environments.

In conclusion, performance-based anxiety might be a common characteristic of children and adolescents with different neurodevelopmental conditions, such as ASD and SLD. Despite a worse performance of the clinical groups in both the public speech and the mathematical test, subjective responses seem to differ between these groups depending on the task. Our results suggest that social demands might elicit greater anxiety (i.e., arousal) in children with SLD, whereas mathematical pressure could play an intensified role in those diagnosed with ASD, according to reported valence, arousal and worries. That being said, the perception of competence appears to be a stable factor between the two experimental tasks, with opposite outcomes among children with ASD and SLD.

CHAPTER 6

Psychophysiological components of social anxiety in children and adolescents with ASD and SLD

6.1 Introduction

In the previous study, we have investigated how behavioral and subjective responses towards social-evaluative threat could vary depending on the group membership, considering children and adolescents diagnosed with Autism Spectrum Disorders (ASD) and Specific Learning Disorders (SLD), in comparison to non-diagnosed (ND) peers. However, behavioural components of social anxiety might be difficult to recognize in autism, due to the symptoms overlap between the two conditions (Kerns & Kendall, 2014); for instance, the avoidance of eye contact is a common characteristic of both ASD and social anxiety. Moreover, self-reported feelings are often not reliable in children and adolescents, especially in those with established emotional and communication difficulties in social contexts (Mazefsky et al., 2011; Oakley et al., 2022). For these reasons, it might be important to gain a more comprehensive overview of the phenomenon by examining the physiological responses to social stressors, which might serve as objective real-time measures of socially-driven anxiety (Seddon et al., 2020).

The capacity of self-regulating during a stressful and challenging social situation, has been described as *autonomic flexibility* (Appelhans & Luecken, 2006; Friedman, 2007; Friedman & Thayer, 1998). Even before people (intentionally or unintentionally) act to manage their own emotions, internal regulatory processes take place at a physiological level, by automatically activating the autonomic nervous system (ANS). The ANS plays a crucial role in the initial physiological response to stressors and emotional situations, thanks to the dynamic interplay of the two principal efferent branches: the parasympathetic and sympathetic nervous systems (Buijs, 2013). Indeed, while beat-to-beat heart rate (HR) is often discussed in literature as an indicator of autonomic arousal, it varies due to the combined effects of both the systems. Consequently, HR cannot be considered a sole and distinct measure of either system. In fact, the ANS response to stress, known as the "fight or flight" response, generally involves the activation of the sympathetic branch and the inhibition of the parasympathetic system. In this regard, the role of the parasympathetic influence on the sino-atrial node, also known as vagal activity (from the 10th cranial nerve, a major component of the ANS), is particularly important in reducing the HR, and increasing the duration of the heart period (the length of time in milliseconds between successive heart beats), to recover and rest from the stressor (Buijs, 2013).

Within the ANS, the beat-to-beat variation in time, also known as heart rate variability (HRV), plays an important role in the emotion regulation, reflecting the effort of the cardiac activity to adapt to situational demands (Appelhans & Luecken, 2006). The simplest method to measure HRV is through the use of an electrocardiogram (ECG), after which algorithms are used to detect the peaks of the R-waves to perform the analysis of inter-beat intervals. Time domain methods are often employed for computing the parasympathetic cardiac control from HRV indexes, by analysing time intervals between several points in a cardiac cycle (Laborde et al., 2017; Quintana et al., 2016). One commonly used time domain index is the RMSSD, namely the root mean successive square difference of normal R–R intervals in the ECG complex, in milliseconds (ms). The RMSSD is particularly useful for assessing short-term HRV, such as during a few minutes of ECG recording rather than hours, as it reflects rapid changes in HR (Berntson et al., 1997; Task Force, 1996).

Within an evolutionary framework, HRV has been proposed to be strongly related to social affective functioning (Porges, 2001, 2003, 2007). Many studies investigated HRV indexes during social interaction and social performance tasks in adults, adolescents, and children with and without psychopathological conditions (for meta-analyses, see Shahrestani et al., 2014, 2015). In this regard, the most common experimental task used to elicit a physiological social stress response, is the Trier Social Stress Test (Buske-Kirschbaum et al., 1997; Kirschbaum et al., 1993), previously described in Chapter 4 (Study III). High baseline HRV, that reflects greater parasympathetic activity, seems to facilitate social interaction and social adaptive behaviours (Lee, Park & Whang, 2023; Petrocchi & Cheli, 2019; Smith et al., 2020), especially when people have to face challenging tasks. In fact, when experiencing demanding situations, a reduction in the vagal influence inhibits the parasympathetic system, preparing the body for "fighting or flighting" (Seddon et al., 2020). Overall, HRV may be a good biomarker for examining physiological responses during socially changing environments (Porges, 2007; Thayer & Lane, 2000).

The study of HR and HRV while experiencing social-evaluative stress, might be of particular relevance in the field of autism, for the high incidence of social anxiety and emotional dysregulation within this clinical condition (Mazefsky et al., 2013; Spain et al., 2018). A recent meta-analysis (Cheng et al., 2020) revealed a diminished HRV both in resting state (*Hedges' g*=-0.5168, $p<0.0001$) and in reactivity to social stress (*Hedges' g*=-0.4647, $p=0.0033$) in people diagnosed with autism, supporting that low HRV might be a biomarker for ASD, especially under socially stressful conditions. Specifically, few studies used a social challenging task while recording the ECG with autistic children and adolescents, as compared to ND controls. Findings from these studies showed a blunted HR response, consistent with low emotional activation, lower HRV, and decreased HRV reactivity toward the social stressor in ASD (Corbett et al., 2019; Dijkhuis et al., 2019; Edmiston et al., 2016; Guy et al., 2014; Hollocks et al., 2014; Kushki et al., 2014; Neuhaus et al., 2016; Porges et al., 2013; Van Hecke et al., 2009).

As regard children with specific learning disorders, anxiety and affective symptoms are common and reach beyond academic situations (Carroll & Iles, 2006; Haft et al., 2019; Mammarella et al., 2016; Parhiala et al., 2015; Rostami et al., 2014; Terras et al., 2009).

However, little has been done to study emotional regulation in children with SLD. The few studies on the topic revealed that children with SLD could display socio-emotional resilience (Haft et al., 2016) thanks to various protective factors, such as family cohesion (Idan & Margalit, 2014), peer acceptance (Shany et al., 2013), and teacher support (Al-Yagon, 2016). Moreover, studies on autonomic functioning found that children with SLD displayed higher resting parasympathetic activity as well as physiological reactivity to others' emotions than non-diagnosed peers (Palser et al., 2021; Sturm et al., 2021). To the best of our knowledge, no studies have investigated HRV and physiological reactivity to psychosocial stress conveyed by the Trier Social Stress Test in SLD, except for one whose purpose was measuring cortisol secretion (Espin et al., 2019). Results from this study showed that dyslexic children demonstrated a more attenuated cortisol reactivity to the TSST-C than non-dyslexic children, highlighting a lower response to social stress. Authors explained this pattern by suggesting that early life stress initially results in an increased stress response, but as this distress continues over time, like in persistently demanding school settings, it tends to be suppressed (Boyce & Ellis, 2005).

Overview of the present study

To the best of our knowledge, no previous studies investigated social anxiety as a multidimensional construct, by evaluating state behavioural, subjective and autonomic responses to a social stress task, in youth with and without Autism Spectrum Disorders (ASD) and Specific Learning Disorders (SLD). For this purpose, we used a public speaking task (adapted from the Trier Social Stress test, child version; Buske-Kirschbaum et al., 1997) composed by four phases: baseline, preparation, public speech, recovery. During this task, we registered the electrocardiogram (ECG) to measure psychophysiological responses and autonomic changes across all phases of the protocol. Behavioral (i.e., quality of the performance) and subjective (i.e., valence, arousal, perception of competence, worries) components of social stress were also examined. In fact, participants' behavioral performance was evaluated with the use of an adapted rating scale for social performance (SPRS; Fydrich et al., 1998), and they were asked to report state subjective experiences before and after the task. We also asked children and their parents to fill in two questionnaires to further consider trait-like symptoms of social anxiety observed by parents and experienced by participants in real-life settings.

The main aim of the present research was to study how children and adolescents with and without ASD and SLD react to social stress (i.e., public speech), by considering all the components of the state anxiety response: behavioural, subjective and autonomic. Moreover, we were also interested in comparing these state responses with trait-like aspects, as reported by questionnaires on social anxiety filled in by both parents and participants.

Consistent with the literature on the topic, we predicted higher levels of trait-like symptoms of social anxiety as reported by parents in the ASD (Bellini, 2006; Spain et al., 2018; Sukhodolsky et al., 2008) and SLD (Rostami et al., 2014; Terras et al., 2009; Thaler et al., 2010) groups as compared to the ND group. However, children self-reports could be inconsistent with those of their parents, because of difficulties in identifying and verbalizing their internal states and symptoms of anxiety, especially in children and adolescents who experience social challenges (Goldberg et al., 2003; Huggins et al., 2021).

Based on previous findings and on results from the previous study (see Chapter 5, Study III), it was hypothesized a worse quality of the public speech (*behavioral* measure) in both the ASD (Edmiston et al., 2017; Kumazaki et al., 2020) and the SLD group (Kempe et al., 2011; Riddick, 2009) for different reasons. In the former group, challenges with social communication, for instance pragmatic skills, could have negative implications for the public speech task (Cardillo et al., 2021; Whyte & Nelson, 2015). As for children with SLD, the low self-efficacy and the fear of being negatively evaluated by the panel of committee, could influence their social performance (Livingston et al., 2018; Terras et al., 2009).

As concerns *subjective* measures reported before and after the public speech, we could make hypotheses based on the results of the previous study (see Chapter 5, Study III), which had a comparable design with the same subjective variables. We assumed children with ASD to report lower levels of arousal and higher perceived competence in comparison to those with SLD, who were instead thought to report higher emotional activation and lower perception of competence towards the social task.

Finally, regarding the *autonomic* components of social stress, we assumed specific cardiac responses across the four phases of the TSST-C in all considered groups (see HR in Figure 6.4), with the activation of the ANS due to social evaluative threat and unpredictability (Allen et al., 2019). Concerning differences between groups, it was hypothesized that children with ASD would show less HR and HRV reactivity in response to social stress than ND (for a meta-analysis see Cheng et al., 2020), since reactivity from baseline to preparation and public speech is considered to be a marker for adaptation to changing environments. On the contrary, it is worth hypothesizing that the SLD group would show higher HR and HRV reactivity to social stress than the other two groups, especially the ASD group, because of a marked fear of negative evaluation and anxiety (Riddick, 2009; Rostami et al., 2014), which can force the body to adapt to the social demanding situation. Also, based on previous research, we expected lower baseline HRV in the ASD group (Bal et al., 2010; Edmiston et al., 2016) and higher baseline HRV in the SLD group (Palser et al., 2021; Sturm et al., 2021).

6.2 Method

6.2.1 Participants

The study involved 55 participants aged between 10 and 16 years old divided into three groups: 15 with Autism Spectrum Disorders (ASD), 15 with Specific Learning Disorders (SLD), and 25 non-diagnosed (ND) peers. The three groups did not statistically differ in chronological age [$F(2, 52) = 2.11$, $p = .13$, $Adj\ R^2 = .07$], and total IQ [$F(2, 52) = .71$, $p = .50$, $Adj\ R^2 = .03$]. However, there were differences between the groups in terms of sex distribution [$X^2 = 10.79$; $p = .005$], thus we included this variable as a covariate in the analyses.

Inclusion, exclusion criteria and screening measures to confirm the diagnosis, were the same of the study described in Chapter 5 (Study III). We also asked parents to give information about their children's weight and height; the three groups had a mean normal weight, expressed in Body Mass Index (BMI = kg/m^2) between 18 and 25.

The groups statistically differed in all subscales of ADI-R (Reciprocal social interaction: $F(2, 52) = 26.89$, $p < .001$, $Adj\ R^2 = .51$; Language/communication: $F(2, 52) = 22.81$, $p < .001$, $Adj\ R^2 = .47$; Repetitive behaviors/interests: $F(2, 52) = 27.12$, $p < .001$, $Adj\ R^2 = .51$), with autistic participants having higher scores than those with SLD and ND. Diagnoses of SLD were also confirmed by implementing some age-appropriate subtests which evaluated reading and math competencies (AC-MT-3 6-14, Cornoldi et al., 2020; DDE-2, Sartori et al., 2007; MT-Avanzate-3-Clinica, Cornoldi et al., 2017). In both reading (words - errors: $F(2, 52) = 43.34$, $p < .001$, $Adj\ R^2 = .63$; words - time $F(2, 52) = 32.97$, $p < .001$, $Adj\ R^2 = .57$; pseudo-words - errors: $F(2, 52) = 31.26$, $p < .001$, $Adj\ R^2 = .55$; pseudo-words - time $F(2, 52) = 12.96$, $p < .001$, $Adj\ R^2 = .35$) and math (mental calculation - accuracy: $F(2, 52) = 31.78$, $p < .001$, $Adj\ R^2 = .55$; mental calculation - time $F(2, 52) = 10.19$, $p < .001$, $Adj\ R^2 = .55$) subtests, the SLD group was more impaired than the ASD and ND groups.

Table 6.1 includes a summary of the participants' characteristics and of the screening measures with groups' comparison.

Table 6.1 Descriptive statistics and statistical comparisons on the screening measures in the ASD, SLD and non-diagnosed (ND) groups: means (M), standard deviations (SD) and results of ANOVAs.

Measures	**ASD (n=15)**	**SLD (n=15)**	**ND (n=25)**	**ANOVAs**			
Gender (M:F)	**15:0**	**8:7**	**15:10**	***F* (2, 52)**	***p***	***Adj R^2***	***Post-hoc***
	M (SD)	**M (SD)**	**M (SD)**				
Age (in months)	174.40 (30.31)	154.07 (22.50)	161.07 (28.35)	2.11	.13	.07	-
IQ	113.87 (14.85)	107.40 (15.08)	111.36 (15.08)	.71	.50	.03	-
ADI-R							
Reciprocal social interaction	12.67 (5.86)	5.07 (3.90)	2.84 (2.91)	26.89	**<.001**	.51	ASD > SLD, ND
Language/ communication	10.33 (5.83)	5.47 (2.59)	2.32 (2.21)	22.81	**<.001**	.47	ASD > SLD, ND
Repetitive behaviors/interests	6.67 (4.32)	1.40 (1.64)	.76 (1.30)	27.12	**<.001**	.51	ASD > SLD, ND
Reading							
Words (errors)	-.56 (.93)	2.53 (1.27)	-.004 (.81)	43.34	**<.001**	.63	SLD > ASD, ND
Words (sec)	.49 (1.28)	3.06 (.86)	.07 (1.11)	32.97	**<.001**	.57	SLD > ASD, ND
Pseudo-words (errors)	-.26 (.84)	2.29 (1.41)	-.25 (.92)	31.26	**<.001**	.55	SLD > ASD, ND
Pseudo-words (sec)	.37 (1.08)	2.12 (1.15)	.05 (1.31)	12.96	**<.001**	.35	SLD > ASD, ND
Mathematics							
Mental calculation (accuracy)	.82 (1.05)	-1.48 (.93)	.61 (.78)	31.78	**<.001**	.55	SLD < ASD, ND
Mental calculation (sec)	-.54 (.95)	1.07 (.90)	.15 (1.04)	10.19	**<.001**	.28	SLD > ASD, ND

Note: Gender differences ($X^2 = 10.79; p=.005$); M=mean; SD=standard deviation; IQ=intelligence quotient. All reading and mathematics subtests are expressed in standardized z scores.

6.2.2 Materials

Questionnaires

Social anxiety

The Italian version of the *Multidimensional Anxiety Scale for Children* (MASC-2; March, 2012; Paloscia et al., 2017), was administered to parents to assess the presence of social anxiety symptoms in their children. Specifically, the Social Anxiety subscale, which comprises Humiliation/Rejection and Performance Fears, was employed. This section consists of 9 items, each rated on a 4-point scale ranging from 0 (never) to 3 (often). The raw scores obtained were transformed into T scores, taking into consideration the child's age and gender through the use of normative data. Cronbach's α (Social Anxiety scale) =.88 (March, 2012).

The children and the parents' versions of the *Social Phobia and Anxiety Inventory for Children* (SPAI-C; Beidel et al., 1998, 2000) were used to assess the presence of social anxiety in participants. The SPAI-C includes 26 items, in which the children have to report how often they feel anxious in certain potentially anxiety-producing social situations (e.g., reading aloud in class, performing in a play, eating in the school cafeteria), and assesses physical and cognitive characteristics of social phobia as well as avoidance behaviours. The parents' version is identical to the children, except the stem of each item starts with, "My child feels scared …" rather than "I feel scared …". Each of the 26 items is rated on a 3-point scale (1 = "never or hardly ever", 2 = "sometimes", 3 = "most of the time or always"). The maximum score is 78, which indicates that the child experiences anxiety with a high frequency in a broad range of social settings. For the current sample, Cronbach's α (SPAI-C children's version) = .88 (C.I.=.83-.92); Cronbach's α (SPAI-C parents' version) = .92 (C.I.=.89-.95).

Trier Social Stress Test

The children and adolescents' version of the Trier Social Stress test (TSST-C, Buske-Kirschbaum et al., 1997) was used in this study to elicit a psychophysiological stress response in a controlled laboratory setting. As shown in Figure 6.1, the entire protocol consists of a 20-min paradigm entailing four 5-min components: 1) Baseline, 2) Preparation, 3) Public Speech, 4) Recovery.

Baseline During this initial phase, the experimenter asked the child to sit quietly and relax while watching a 5-min Pixar short movie ("The moon"; link: https://www.youtube.com/watch?v=CCQ9v6XMC6c&t=26s).

Preparation After the baseline, participants were informed about the subsequent task they were about to perform. Similar to the study described in Chapter 4, participants were asked to prepare a speech about their ideal birthday party (Poole et al., 2018), but this time for five minutes, and then to publicly perform it in front of the committee for five minutes. Participants were not permitted to take notes during the preparation phase; however, they were given a sheet with a list of things needed when organizing a birthday party, which was being withdrawn at the end of the five minutes.

Public speech The experimenter left the room, while two raters (a man and a woman) representing the committee enters the room and sat behind a table holding clipboards in which they took notes during the speech. The committee pretended to evaluate the 5-min participant's public speech performance, providing no signs of social support or feedback, leading the participant to question the accuracy of their own behavior. A video camera was set up behind the raters to film the participant during the paradigm. After 5 minutes, the committee left the room.

Recovery During this final phase, the experimenter returned in the room, and asked the child to sit quietly and relax while watching a 5-min Pixar short movie different from the one shown during the baseline ("Partly Cloudy";
link: https://www.youtube.com/watch?v=PfyJQEIsMt0).

At the end of the protocol, the experimenter debriefed the participants explaining that the committee was not truly judging them, and gave details about the aims of the project.

Behavioral measures

The *behavioral* assessment of the public speech has been performed by using an adaptation of the Social Performance Rating Scale (SPRS; Fydrich et al., 1998), described in the method section of Chapter 5 (Study III). Specifically, in this study Results' section, we reported the total raw scores, the non-verbal aspects' (discomfort, gaze, vocal quality) raw score, and the verbal aspects' (adherence to the track, conversational flow, lexicon) raw score. The scale and its reliability has also been described in Chapter 5 (Study III). The rating scale is reported in the Appendix.

Subjective measures

As shown in Figure 6.1, state subjective components were asked to be reported during the protocol in two time-points: preparation and public speech. Valence and arousal were assessed using the Self-Assessment-Manikin scale (SAM; Bradley & Lang, 1994); perception of competence and worries through the administration of an ad-hoc questionnaire (derived from Mammarella et al., 2023). The measures and their reliability have been already described in Chapter 5 (Study III).

Autonomic measures

The electrocardiogram (ECG) was recorded with three Ag/AgCl surface electrodes positioned on the child's chest in a modified lead II configuration (as shown in Figure 6.2), by using a mobile Bluetooth ECG unit (link: https://shimmersensing.com/) appropriate for physiological recordings with children (sensors are not tethered to the computer). The ECG was continuously recorded during the entire protocol, as shown in Figure 6.1. To ensure familiarization, participants were shown the electrodes and allowed to place their hand to allow for sensory accommodation to the sensor adhesive, and were explained all the steps of the electrodes' placement. They were also shown their heartbeat signal on the computer screen. Before starting the electrophysiological recording and the entire procedure, the child was asked to keep still to reduce movement artifacts.

The ECG signal was sampled at 256 Hz, then a band-pass filter (1–100 Hz) was applied. The raw ECG signal was then exported to the Kubios HRV Analysis Software 2.2 (The Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland) to estimate the occurrence of each R wave and derive the series of inter-beat intervals (IBIs), calculated as the difference in msec between successive R-waves. The ECG signal was visually inspected, and a piecewise cubic splines interpolation method, which generates missing or corrupted values in the series of IBIs, was used to correct for artefacts (e.g., ectopic beats) into the normal-to-normal (NN) intervals. Inter-beat interval series were obtained using R-peak detection and mean heart rate (HR) was calculated. HR change was then calculated as a variation of HR (bpm) from the baseline to the public speech to have a measure of cardiac activation towards the social stressor. Moreover, we computed the time domain heart rate variability (HRV) indexes. In this study, we considered the square root of the mean squared differences of successive NN intervals (RMSSD) expressed in ms, as a measure of cardiac autonomic modulation, in other words the vagal control heart (Stein et al., 1994).

Figure 6.1 Outline of the study with graphical description of all the phases (baseline, preparation, public speech, recovery).

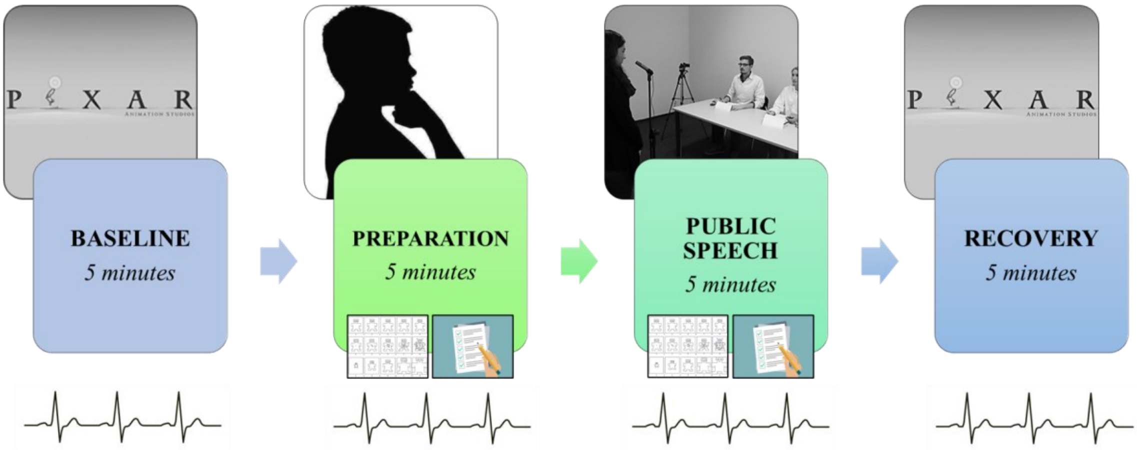
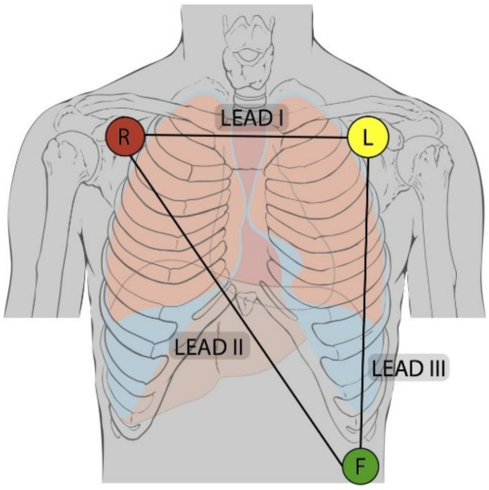


Figure 6.2 Electrocardiogram (ECG): electrodes' placement (modified lead II configuration).



6.2.3 Procedure

The present study involved two sessions which took place at the Department of Developmental and Social Psychology at the University of Padova between December 2022 and July 2023. The study was approved by the ethics review board of the University of Padova (protocol number: 5032). After obtaining the written informed consent of the participants' parents, the first session served as a screening phase in which participants' intellectual functioning, reading, mathematics skills, and autistic symptoms were evaluated. During the second session (experimental phase), the protocol involving the Trier Social Stress Test was applied, and children also filled out the SPAI-C for social anxiety. Meanwhile, parents completed the MASC-2 and the SPAI-C, while waiting for their children to finish the experimental session. At the end of the project, families could request a final report with the raw data and an interpretation of the results.

6.2.4 Statistical approach

First, a series of univariate ANOVAs were performed to estimate differences between the three groups (ASD, SLD, ND) in the measures of interest, with participants' gender as a covariate. Post-hoc comparisons between groups were assessed through the Tukey's correction test. Effect sizes were also computed using adjusted R^2, which represents the effect size of the comparisons between the three groups for the factors considered. Table 6.2 includes the descriptive statistics (*M, SD*) and ANOVAs between the three groups on the questionnaires assessing child social anxiety (MASC-2 and SPAI-C - parents' and children's versions). Table 6.3 and Figure 6.3 show the descriptive statistics and ANOVAs of the three groups' performance (*behavioral* measures) on the Trier Social Stress, divided into non-verbal and verbal aspects of the public speech performance.

Second, we analyzed the *subjective* (valence, arousal, perception of competence, worries) and *autonomic* (HR, RMSSD) measures vis-à-vis the Trier Social Stress Test, divided by the three groups (ASD, SLD, ND) and reported in different time-points by participants. As reported in Table 6.4 and 6.6, linear mixed-effects models were run to examine the relationship between the dependent variable (*subjective* and *autonomic measures*), and the independent variables (Time, Group, Time x Group). Time was treated as a fixed effect, representing the time-points in which subjective (Preparation, Public Speech) and autonomic (Baseline, Preparation, Public Speech, Recovery) responses were registered, while Group was treated as a fixed effect representing the categorical grouping variable (ASD, SLD, ND). The interactions between Time and Group were also investigated to assess whether the effect of time on the dependent variable differed across the various groups. Participants' gender was considered as a covariate because of the statistically significant difference between groups (see Table 6.1). Single participants were included as random effects to consider the individual variations.

ANOVAs between linear mixed models were run to examine the significance of the fixed effects (Time, Group) and the interactions between them. We compared each model with the full model [Dependent variable ~ Gender + Group + Time + (1|ID)], using the Akaike Information Criterion (AIC) and the R-squared (R^2). A lower AIC and a higher R^2 indicates a better model. The R^2 represents the proportion of variance in the outcome variable which is explained by the predictor variables in the sample. In the context of linear mixed-effects models, conditional R^2 measures the proportion of variance explained by both the fixed effects and the random effects in the model, whereas marginal R^2 considers the proportion of variance explained by the fixed effects alone. Descriptive statistics (*M, SD*) and ANOVAs with participants' gender as a covariate, are displayed in Table 6.5 and 6.7.

Data were analyzed using R version 1.3.1093 (R Core Team, 2022). The following R packages were used: "lmerTest" (Kuznetsova et al., 2017) for computing linear mixed-effect models, "lme4" package was used to run the regression models and the AIC (Bates et al., 2015), and "effects" (Chambers & Hastie, 1992) for graphical effects.

6.3 Results

Questionnaires on social anxiety

As shown in Table 6.2, after controlling for participants' gender, a statistically significant effect of the group emerged both concerning in the social anxiety scale of the MASC-2, *F(2, 52)=4.94, p=.001, Adj* R^2*=.18*, and in the SPAI-C (parents' version), *F(2, 52)=8.61, p<.001, Adj* R^2*=.30*. Parents of children and adolescents with ASD and SLD reported greater levels of social anxiety in their children, as compared to the ND group. Instead, no differences emerged between the three groups from the SPAI-C filled out by children, *F(2, 52)=1.66, p=.18, Adj* R^2*=.03*.

Table 6.2 Descriptive statistics and statistical comparisons on the questionnaires assessing social anxiety in the ASD, SLD and non-diagnosed (ND) groups: means (M), standard deviations (SD) and results of ANOVAs. Participants' gender was considered as a covariate.

Variables	**ASD**	**SLD**	**ND**	**ANOVAs**			
	M (SD)	**M (SD)**	**M (SD)**	***F* (2, 52)**	***p***	***Adj*** R^2	***Post-hoc***
MASC-2 parents' version (T score)	65.33 (9.21)	65.20 (11.55)	54.58 (9.51)	4.94	**.001**	.18	ASD, SLD > ND
SPAI-C parents' version (raw score)	47.07 (10.55)	44.13 (6.63)	34.58 (7.53)	8.61	**<.001**	.30	ASD, SLD > ND
SPAI-C children's version (raw score)	43.64 (9.29)	41.60 (8.44)	39.76 (7.63)	1.66	.18	.03	-

Note: M=mean; SD=standard deviation. MASC-2= Multidimensional Anxiety Scale for Children (March, 2012; Italian version, Paloscia et al., 2017); SPAI-C= Social Phobia and Anxiety Inventory for Children (Beidel et al., 1998, 2000).

Trier Social Stress Test: behavioral measures

As Table 6.3 displays, after controlling for participants' gender, the ASD group performed worse in the total score of the TSST-C, $F(2, 52)=3.69, p=.02, Adj\ R^2=.13$, as compared to ND participants. Moreover, the ASD group obtained a lower score in the non-verbal aspects than the other two groups (SLD, ND), $F(2, 52)=6.36, p<.001, Adj\ R^2=.23$. No differences were found between the three groups as concerns the verbal aspects of the public speech, $F(2, 52)=1.03, p=.38, Adj\ R^2=.001$.

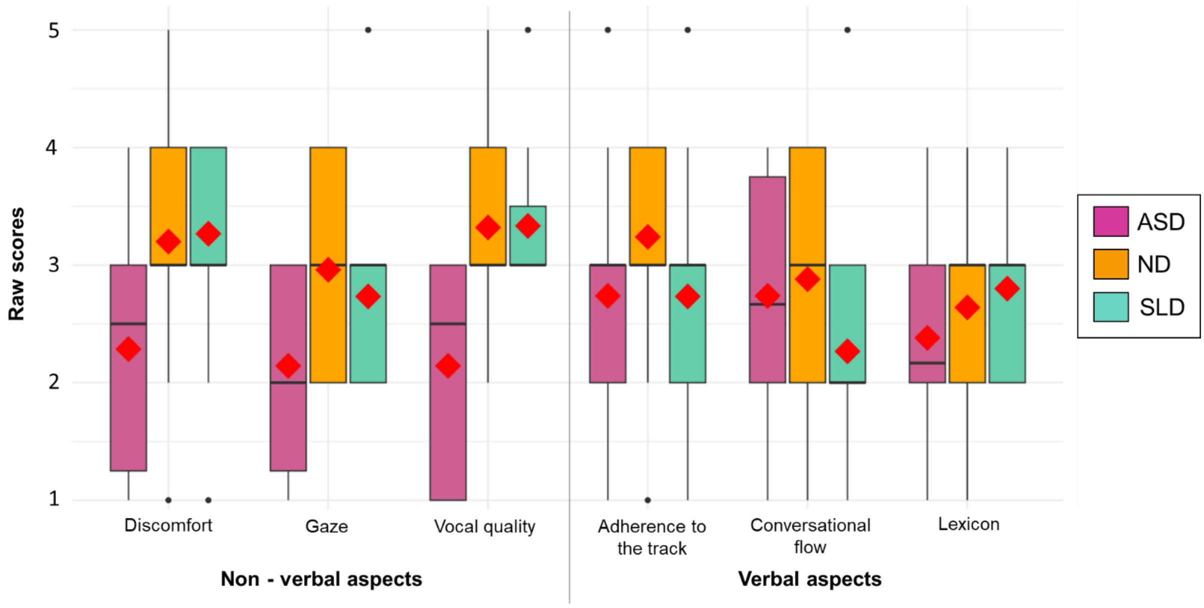
Figure 6.3 includes a graphical representation of the distribution (boxplots) of the non-verbal and verbal aspects' subscales divided per group (ASD, SLD, ND).

Table 6.3 Descriptive statistics and statistical comparisons of the three groups' performance on the Trier Social Stress Test (*behavioral* measures): means (M), standard deviations (SD) and results of ANOVAs. Participants' gender was considered as a covariate.

Measures	**ASD**	**SLD**	**ND**	**ANOVAs**			
	M (SD)	**M (SD)**	**M (SD)**	***F* (2, 52)**	***p***	***Adj R^2***	***Post-hoc***
Total score (raw score)	14.33 (4.13)	17.80 (3.99)	18.36 (3.91)	3.69	**.02**	.13	ASD < ND
Non-verbal aspects	6.60 (2.09)	9.33 (1.91)	9.48 (2.09)	6.36	**<.001**	.23	ASD < SLD, ND
Verbal aspects	7.73 (2.63)	8.47 (2.29)	8.88 (1.90)	1.03	.38	.001	-

Note: M=mean; SD=standard deviation. The scoring of the TSST-C was performed by using an adapted version of the Social Performance Rating Scale (SPRS; Fydrich et al., 1998); Non-verbal aspects = discomfort, gaze, vocal quality; Verbal aspects = adherence to the track, conversational flow, lexicon.

Figure 6.3 Boxplots of the non-verbal and verbal aspects' subscales divided per group (ASD, SLD, ND).



Note: The red diamond represents the mean value for each group.

Trier Social Stress Test: subjective measures

As reported in Table 6.4, after controlling for participants' gender, ANOVAs between linear mixed-effects models revealed a significant interaction effect of Time x Group for valence, $\chi2(df=2)=6.66, p=.03, AIC=414.54$, and perception of competence, $\chi2(df=2)=8.83, p=.01, AIC=415.82$. The main effect of Time emerged for arousal, $\chi2(df=1)=10.46, p=.001, AIC=454.67$, and worries, $\chi2(df=1)=6.11, p=.01, AIC=478.45$. Results also show a trend towards significance for the main effect of the Group for arousal, $\chi2(df=2)=5.51, p=.05, AIC=458.91$.

As shown in Table 6.5, after controlling for participants' gender, post-hoc comparisons displayed a trend towards significance regarding valence, in terms of change between preparation and public speech, with ASD reporting an increase as compared to ND. Instead, significant differences between ASD and ND were found for arousal in the preparation and the public speech phases, with ASD < ND. As concerns perception of competence, the ASD group reported a significant increase from the preparation to the public speech phase as compared to the ND and SLD groups. A trend towards significance was also found for worries in the public speech phase, with ASD < ND.

Table 6.4 Results of the ANOVAs between linear mixed-effects models of the *subjective* measures (valence, arousal, perception of competence, worries) with Time (Preparation, Public Speech) as within-subject fixed effect, Group (ASD, SLD, ND) as between-subject fixed effect, and the interactions between Time and Group.

Fixed effects	**ANOVAs**			***Goodness of fit***			
				AIC	***df***	***R^2***	
	χ2	***df***	***p***			***c***	***m***
Valence							
Time	1.00	1	.31	415.74	5	.57	.01
Group	.78	2	.68	415.76	6	.58	.02
Time x Group	6.66	2	**.03**	414.54	9	.62	.04
Arousal							
Time	10.46	1	**.001**	454.67	5	.69	.09
Group	5.51	2	**.05 .**	458.91	6	.64	.13
Time x Group	1.40	2	.49	452.57	9	.70	.16
Perception of competence							
Time	.02	1	.74	418.47	5	.56	.002
Group	.11	2	.99	418.28	6	.58	.002
Time x Group	8.83	2	**.01**	415.82	9	.63	.03
Worries							
Time	6.11	1	**.01**	478.45	5	.59	.08
Group	.48	2	.79	483.28	6	.56	.06
Time x Group	3.77	2	.15	477.87	9	.62	.09

Note: Single participants were included as random effects. Participants' gender was considered as a control variable. *AIC* = Akaike Information Criterion; R^2 *c* = conditional (both fixed and random effects); R^2 *m* = marginal (only fixed effects).

Table 6.5 Descriptive statistics and ANOVAs of the *subjective* measures (valence, arousal, perception of competence, worries) towards the Trier Social Stress Test reported in two time-points (Preparation, Public Speech) in the three groups (ASD, SLD, ND). Participants' gender was considered as a covariate.

Subjective Variables	**ASD** M (SD)	**SLD** M (SD)	**ND** M (SD)	***F*** **(2, 52)**	***p***	***Adj R^2***	***Post-hoc***
Valence							
Preparation	5.42 (.94)	6.33 (1.79)	6.56 (1.68)	1.60	.20	.03	-
Public speech	5.78 (2.08)	6.27 (1.91)	5.80 (2.08)	.37	.77	-.04	-
Public speech - Preparation	.36 (1.28)	-.07 (1.28)	-.76 (1.76)	2.13	**.10.**	.06	ASD>ND
Arousal							
Preparation	2.07 (1.77)	4.47 (1.96)	5.40 (1.91)	3.00	**.03**	.11	ASD<ND
Public speech	3.64 (2.40)	5.73 (2.52)	6.16 (1.95)	2.71	**.04**	.09	ASD<ND
Public speech - Preparation	.50 (1.79)	1.27 (2.02)	.76 (1.74)	.52	.67	-.03	**-**
Perception of competence							
Preparation	7.85 (1.96)	8.47 (1.36)	8.48 (1.45)	.56	.64	-.02	**-**
Public speech	8.86 (1.92)	7.93 (1.91)	8.08 (1.96)	.66	.58	-.02	**-**
Public speech - Preparation	1.00 (2.00)	-.53 (1.41)	-.40 (1.35)	2.96	**.04**	.10	ASD>ND,SLD
Worries							
Preparation	6.14 (2.59)	6.93 (2.49)	6.24 (2.31)	.71	.55	-.01	**-**
Public speech	4.57 (1.95)	6.00 (2.10)	6.04 (2.65)	2.23	**.09.**	.06	ASD<ND
Public speech - Preparation	-1.57 (2.56)	-.93 (2.05)	-.20 (2.02)	1.29	.28	.02	**-**

Note: M=mean; SD=standard deviation. Public speech – Preparation = the change between the two time-points.

Trier Social Stress Test: autonomic measures

As reported in Table 6.6, after controlling for participants' gender, ANOVAs between linear mixed-effects models revealed a significant effect of Time for both HR, $\chi 2(df=3)= 186.75$, $p<.001$, $AIC=1412.57$, and RMSSD, $\chi 2(df=3)=15.53$, $p=.001$, $AIC=1936.74$. The main effect of Group emerged as well for RMSSD, $\chi 2(df=2)= 7.10$, $p=.03$, $AIC=1941.90$. The interaction between Time and Group was found to be statistically significant for HR, $\chi 2(df=6)= 13.49$, $p=.03$, $AIC=1386.55$, and a trend for significance emerged for RMSSD, $\chi 2(df=6)= 12.28$, $p=.05$, $AIC=1889.80$.

As shown in Table 6.7, after controlling for participants' gender, post-hoc comparisons displayed a significant difference between the groups in HR change between baseline and preparation, and between baseline and public speech, with ASD < SLD. Regarding RMSSD, a significant effect was found for baseline, with ASD < SLD, ND; and recovery, with ASD < SLD. A trend towards significance was found for RMSDD change between baseline and preparation, and baseline and public speech, with ASD < SLD.

Figure 6.4 shows the autonomic measures (HR, RMSSD) registered in four time-points (baseline, preparation, public speech, recovery) divided by group (ASD, SLD, ND) with error bars of 95% confidence intervals.

Table 6.6 Results of the ANOVAs between linear mixed-effects models of the *autonomic* measures (HR, RMSSD) with Time (Baseline, Preparation, Public Speech, Recovery) as within-subject fixed effect, Group (ASD, SLD, ND) as between-subject fixed effect, and the interactions between Time and Group.

Fixed effects	**ANOVAs**			***Goodness of fit***			
				AIC	***df***	R^2	
	$\chi 2$	***df***	***p***			***c***	***m***
Heart rate (HR)							
Time	186.75	3	**<.001**	1412.57	7	.88	.19
Group	4.32	2	.11	1587.88	6	.67	.07
Time x Group	13.49	6	**.03**	1386.55	15	.89	.24
RMSSD (ms)							
Time	15.53	3	**.001**	1936.74	7	.78	.03
Group	7.10	2	**.03**	1941.90	6	.77	.10
Time x Group	12.28	6	**.05 .**	1889.80	15	.80	.13

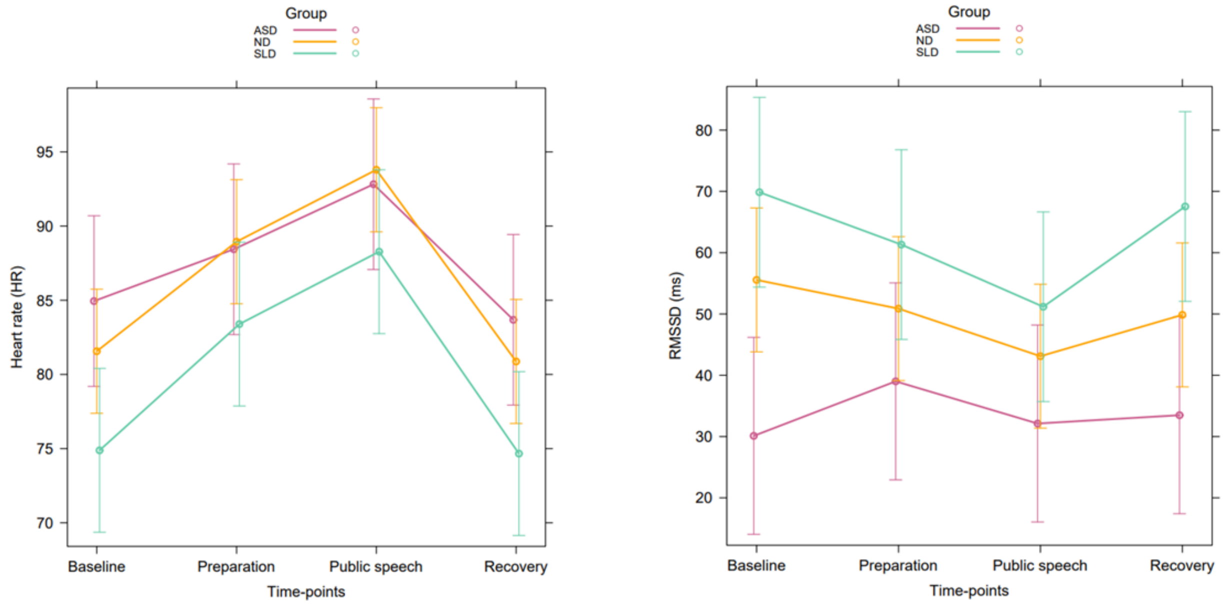
Note: Single participants were included as random effects. Participants' gender was considered as a control variable. *AIC* = Akaike Information Criterion; R^2 *c* = conditional (both fixed and random effects); R^2 *m* = marginal (only fixed effects).

Table 6.7 Descriptive statistics and ANOVAs of the *autonomic* measures (HR, RMSSD) towards the Trier Social Stress Test registered in four time-points (Baseline, Preparation, Public Speech, Recovery) in the three groups (ASD, SLD, ND). Participants' gender was considered as a covariate.

Autonomic Variables	**ASD**	**SLD**	**ND**	***F* (2, 52)**	***p***	***Adj R^2***	***Post-hoc***
	M (SD)	**M (SD)**	**M (SD)**				
Heart rate (HR)							
Baseline	83.19 (13.07)	75.98 (10.32)	81.95 (9.61)	1.62	.19	.03	-
Preparation	86.69 (10.88)	84.49 (10.86)	89.33 (9.32)	1.82	.15	.04	-
Public speech	91.07 (12.39)	89.37 (10.23)	94.18 (11.03)	2.02	.12	.03	-
Recovery	81.93 (13.76)	75.76 (9.47)	81.26 (8.88)	1.97	.13	.05	-
Preparation - Baseline	3.49 (4.25)	8.50 (6.32)	7.38 (4.36)	3.81	**.01**	.13	ASD<SLD
Public speech - Baseline	7.87 (5.96)	13.39 (7.92)	12.23 (6.22)	3.14	**.03**	.11	ASD<SLD
Recovery - Baseline	-1,26 (3.33)	-.22 (3.15)	-.69 (4.07)	1.27	.29	.01	-
RMSSD (ms)							
Baseline	35.78 (20.54)	66.28 (39.95)	54.29 (41.59)	2.65	**.04**	.10	ASD<ND,SLD
Preparation	44.68 (22.46)	57.74 (35.83)	49.61 (36.59)	1.59	.20	.03	-
Public speech	37.79 (18.84)	47.60 (21.65)	41.85 (22.55)	1.79	.16	.04	-
Recovery	39.16 (22.93)	63.96 (33.93)	48.59 (26.57)	3.26	**.02**	.11	ASD<SLD
Preparation - Baseline	8.89 (19.46)	-8.54 (15.86)	-4.68 (25.39)	1.83	**.09 .**	.04	ASD<SLD
Public speech - Baseline	2.01 (17.43)	-18.68 (26.61)	-12.44 (24.98)	2.42	**.06 .**	.11	ASD<SLD
Recovery - Baseline	3.37 (14.18)	-2.32 (14.13)	5.70 (24.81)	.83	.48	-.009	-

Note: M=mean; SD=standard deviation. Preparation – Baseline, Public speech – Baseline, Recovery – Baseline = the change in HR and RMSSD between the two time-points.

Figure 6.4 Time x Group: *autonomic* (HR, RMSSD) measures. Error bars display 95% confidence intervals.



6.4 Discussion

The aim of the current study was to investigate social anxiety as a multidimensional construct, by evaluating state behavioural (i.e., quality of performance), subjective (i.e., valence, arousal, perception of competence, worries) and autonomic responses (i.e., HR, HRV) towards a social stress task (i.e., public speech), in youth with and without Autism Spectrum Disorders (ASD) and Specific Learning Disorders (SLD). For completeness, we also asked children and their parents to fill in two questionnaires to further consider symptoms of social anxiety observed by parents and experienced by participants in real-life settings, namely trait social anxiety.

Trait social anxiety: discrepancy between parents and children

Consistent with the literature on the topic, higher levels of child social anxiety were reported by parents of participants in the ASD (Bellini, 2006; Spain et al., 2018; Sukhodolsky et al., 2008) and SLD groups (Rostami et al., 2014; Terras et al., 2009; Thaler et al., 2010) compared to the ND group, in both the questionnaires used to assess social anxiety (MASC-2 and SPAI-C). However, a clear discrepancy could be observed between parents and children reports. Indeed, questionnaires filled out by children in the ASD and SLD groups did not result in a clinical level, expressing lower internalizing symptoms than their parents did. This finding could be interpreted in two different ways. First, it is worth hypothesizing that children with a formal developmental diagnosis might not be able to identify and express their own internal feelings (Goldberg et al., 2003; Huggins et al., 2021), especially when speaking about anxiety. In alternative, parents of children might overestimate their children social anxiety as well (Lerner et al., 2012), relying too much on observation of their behaviours (e.g., avoidance of social interactions) rather than on focusing on their feelings and thoughts about the overreaching situation (e.g., worries about others' judgment).

That said, it is worth investigating whether *trait* levels of social anxiety observed by parents and reported by children in real-life settings, are consistent with *state* components of social stress elicited by social performance contexts.

Behavioral responses to (state) social anxiety in ASD and SLD

Our findings show that social stress provided by the TSST-C, might have contributed to impact more the quality of the performance of the ASD participants compared to SLD and ND. In fact, autistic children obtained a worse performance in comparison to the other two groups, both in the total and in the non-verbal (i.e., discomfort, gaze, vocal quality) score of the Social Performance Rating Scale (adapted from Fydrich et al., 1998). However, no differences between groups were found for the verbal aspects (i.e., adherence to the track, conversational flow, lexicon). However, the findings related to behavioral responses to social anxiety should be taken with caution, as there is no baseline measurement of the aspects that are interpreted as a behavioural component of social anxiety (i.e., discomfort, gaze, vocal quality, adherence to the track, conversational flow, lexicon).

Our results confirm the previous hypothesis of a worse quality of the public speech in ASD (Edmiston et al., 2017; Kumazaki et al., 2020) possibly due to challenges with social communication, for instance pragmatic skills (Cardillo et al., 2021; Whyte & Nelson, 2015). Moreover, it is worth noting the correspondence with symptoms of social anxiety reported by parents through the questionnaires, since we used an observational scale based on the child's behaviours during the task: the non-verbal aspects (e.g., avoidance of eye-contact) have definitely proven to be the ones that weigh the most in the overall evaluation of social anxiety, and they could be those more noticed by parents in real-life situations. The question is whether behavioral responses do match subjective and autonomic experiences of social anxiety; or are they just typical "social" features of autism?

On the other hand, as regards the hypothesis of a poor public speech performance in children with SLD, findings do not confirm it, contrasting those of the previous study (see Chapter 5, Study III), perhaps due to the small numerosity (see limitations' section) or to the characteristics of the sample. In fact, most of the children in the SLD group were undergoing a specific psychological or learning intervention at the time of data collection, perhaps positively influencing their social performance skills (Vaughn et al., 2004). When interpreting our findings, we should bear in mind that unfortunately this is not the golden rule.

Subjective responses to (state) social anxiety in ASD and SLD

As concerns *subjective* measures reported before and after the public speech, findings do support previous hypotheses regarding ASD, and partially confirm those for SLD.

Linear mixed-effects models revealed that, in comparison to the ND group, children with ASD expressed: a significant increase of positive valence from the preparation to the speech, a lower arousal during both preparation and public speech, a higher perception of competence after completing the task, and lower worries towards the speech. Taken together, the reported subjective experience of autistic children might underlie a detached affective disposition towards the social demanding context, for different reasons. The task required participants to give a public speech in front of an unresponsive committee. The results confirmed our first hypotheses, as we expected autistic participants to report lower levels of arousal and higher perceived competence, as compared to the other two groups, based on the findings of the previous study (see Chapter 5). First, it is worth considering the potential unawareness of (or inability to express) their own internal states (Barnhill et al., 2000; Huggins et al., 2021; Oakley et al., 2022), but also the possibility of a diminished social motivation (Chevallier et al., 2012), such that the TSST-C could have failed to evoke a stress response in this clinical group (Corbett et al., 2012; Dijkhuis et al., 2019; Jansen et al., 2003). To this end, the study of the physiological activity while social performing, will be a valuable source of information. Moreover, it is worth considering that a different type of social task, for example one requiring social interaction, might have an amplified impact on emotional reactivity, and therefore on the subjective experience of children and adolescents with ASD.

As regards children with SLD, our results are consistent with the finding from the previous study (see Chapter 5, Study III) of a significant decrease in the perception of competence as compared to those with ASD. Lower self-efficacy seems to represent a stable characteristic across various contexts (social, academic) of children with SLD (Livingston et al., 2018; Terras et al., 2009), despite participants considered in this study demonstrated good social performance skills (and as we will see in the next paragraph, good autonomic flexibility).

All in all, autonomic responses to social stress could help us understanding whether children with and without ASD and SLD are bodily activated by social distress in the first place, and how do they manage to regulate their emotions and adapt to environmental demands.

Autonomic responses to (state) social anxiety in ASD and SLD

After excluding that the heart rate (HR) was different in baseline between the three groups, the analyses of the linear mixed-effects models encompass some interesting differences in socially-driven autonomic responses between the two clinical groups (ASD, SLD). Indeed, the mean HR change between the phases, differed among the ASD and SLD groups, with ASD children experiencing a significant lower increase than those with SLD. As concerns HRV (expressed in RMSSD) instead, not only the ASD children had a lower reactivity across the phases as compared to those with SLD, but also they showed a lower level during baseline and recovery.

Regarding the autistic children, it could be possible that the TSST-C might not be effective in eliciting a socially-driven stress response by enhancing the HR (Corbett et al., 2012; Dijkhuis et al., 2019; Jansen et al., 2003; Lanni et al., 2012), confirming previous assumptions drawn from their reported subjective experiences. Moreover, a lower baseline HRV indexes in ASD has been shown in previous studies (for a meta-analysis see Cheng et al., 2020). Likewise, the mean HRV change between the phases is minimal, highlighting a blunted physiological stress response to the social cue: in general, the ASD group demonstrated a diminished ability to self-regulate by flexibly adapting to the context, that was present at baseline, endured through the task up to and including the recovery phase (Edmiston et al., 2016). These findings could be interpreted from different perspectives. On the one hand, children with ASD may have not felt motivated to do the task, highlighting either an unwillingness to participate in the research project, or a reduced social motivation (Chevallier et al., 2012; Itskovich et al., 2021). It is worth considering that different patterns of social responses might be dependent on the type of stressor, for instance children with ASD might display a different physiological reactivity to social interactions (Corbett et al., 2019). On the other hand, we could acknowledge a good level of awareness of one’s own internal states in children with ASD (Simon & Corbett, 2013): not only they reported less emotional activation (arousal), but also they did not report social anxiety when filling out the trait-like questionnaire (SPAI-C).

Concerning the SLD group, an opposite physiological pattern has emerged. HR change and HRV reactivity was significantly higher in this group than the ASD group, somehow consistent with high levels of social anxiety reported by their parents. Most importantly, the HRV change throughout the task can be interpreted as the body's effort to self-regulate when facing social stressors, possibly driven by the marked fear of negative evaluation (Livingston et al., 2018; Riddick, 2009; Rostami et al., 2014). Our findings, thought limited by the small sample size, are consistent with previous research, that stated a higher parasympathetic activity in people with SLD at rest and when handling with different social scenarios (Palser et al., 2021; Sturm et al., 2021). Combined with good performance skills demonstrated by this sample, autonomic flexibility may represent a source of resilience in children with SLD, and it could potentially shield them from the negative impact of their learning difficulties, by empowering social engagement (Haft et al., 2016).

Finally, no differences resulted between the ND group and the other two groups, possibly indicating that typically developing children "stand in the middle" between the ASD and the SLD group. Indeed, results suggest that the public speech was able to elicit a moderate stress response by influencing both the ANS and the subjective experiences in ND children. However, their self-regulatory mechanisms were not involved as much as those of children with ASD and SLD, which turned out to be those more vulnerable to the social stressor, with specific (and opposite) emotional reactions.

Limitations, future directions and potential implications

One of the main limitations of the present study relies on the sample numerosity. The findings should be therefore interpreted cautiously due to the small sample size, which may affect the generalizability of the results. However, based on previous studies on HRV in autism (for a meta-analysis see Cheng et al., 2020), our sample size seems to be acceptable (see for example Edmiston et al., 2016; Guy et al., 2014). Another limitation associated with the sample size, is the large variability in the RMSSD, as an index of HRV and parasympathetic activity, indicating considerable heterogeneity. Future studies should also focus on other psychophysiological indexes, for example skin conductance and respiratory sinus arrhythmia (RSA), to gain a better (and more comprehensive) understanding of the construct of social anxiety. Regarding the measurement of heart rate, our results could go in the direction of suggesting a biologically higher level of HR in autism, characterized by patterns of persistent hyperarousal (Klusek et al., 2015; Owens et al., 2021), which could be explored in further research with larger sample size.

Moreover, the ASD group was composed only by boys, and for this reason we controlled for sex. However, valuable insights could be driven by comparing autonomic flexibility and responses to social stress between boys and girls diagnosed with autism and SLD, in future studies.

Finally, as previously mentioned, future studies should compare autonomic responses to tasks involving different social demands (e.g., social interaction, facial emotion recognition) (Corbett et al., 2010, 2012, 2019), which could be informative about emotional arousal and regulation in different social contexts (Lievore et al., 2022).

Nevertheless, our findings could have both educational and clinical implications. Educators should be aware of children's emotions, thoughts and worries during public performance in front of other people, especially peers. In fact, children with SLD might overreact when being exposed to others' evaluation, by experiencing an amplified level of arousal and negative thoughts. A lower self-efficacy and perception of competence, combined with the fear of being negatively judged, could have detrimental effects on their academic learning and relationships. On the other hand, social challenges in autistic children may be closely related to social motivation, self-awareness and physiological functioning; therefore, educators and clinicians might consider all these individual characteristics when advising interventions aimed at empowering social skills and reducing social anxiety.

In conclusion, our work aimed at detecting (state) behavioral, subjective and autonomic components of social anxiety, by also comparing them with trait social anxiety, in children and adolescents who experience everyday challenges mainly due to social and academic difficulties. Our findings show unique pattens of responses within each of the considered groups: the fear of being evaluated might negatively influence the subjective (and behavioral; see Chapter 4) experience of children with SLD, but they showed to be able to adaptively regulate their emotions; instead, for children with ASD, this type of stressor might not be effective in eliciting a physiological arousal, as demonstrated by both subjective and autonomic responses. In addition, they seem less able to regulate their emotions, as suggested by the analyses of physiological measures. Moreover, the combined used of trait and state anxiety and its components could be a valuable insight in clinical practice. All in all, HR and HRV reactivity could be considered as a biomarker of social anxiety across different developmental disorders, such as ASD and SLD, with differences and specificities associated with each condition.

CHAPTER 7

General Discussion

The first part of the present PhD dissertation focused on the main difficulties that children with ASD and SLD usually face in real-life situations based on their diagnostic criteria: those related to social skills (i.e., facial emotion recognition) and mathematical abilities (i.e., mental calculation). Some researchers have proposed a bidirectional relationship between social challenges and social anxiety in ASD (Bellini, 2006; Spain et al., 2018, 2020; White et al., 2010). The same has been suggested for the association between mathematical performance and mathematics anxiety (Cipora et al., 2022; Hill et al., 2016; Jansen et al., 2013). Moreover, higher-order cognitive skills, such as executive functions, might represent supporting factors of social and mathematical performance (Beauchamp & Anderson, 2010; Cragg & Gilmore, 2014); yet, children with these two different neurodevelopmental disorders might experience common weaknesses in inhibiting irrelevant information, updating an information in the working memory, and switching between different mental sets (Agostini et al., 2022; Hill, 2004). For all these reasons, the possible emotional (anxiety) and cognitive (executive functions) underlying factors of social and mathematical performance, were investigated by taking into account groups of children with ASD or SLD in comparison to non-diagnosed participants.

Moving to the second part of the present PhD dissertation, the study of performance-based anxiety, such as social and mathematics anxiety, might be of particular interest in vulnerable populations, especially ASD and SLD. As often discussed in literature (Cipora et al., 2022; Heeren et al., 2012; Mammarella et al., 2023), anxiety should be studied considering all the components of the distress (e.g., subjective, behavioral, physiological), and different sources of information (e.g., children, parents), to be able to capture both trait and state features.

In the studies conducted for this PhD thesis, social and mathematics anxiety were assessed in groups of children with ASD, SLD and ND, giving attention to the reciprocal relationship between social and academic functioning. For example, children with SLD might also face socio-emotional challenges as a consequence of their academic difficulties (Livingston et al., 2018; Riddick, 2009; Willcutt et al., 2011). In particular, they could experience anxiety within social situations because of feelings of shame and lower self-esteem (Elgendi et al., 2021; Kohli et al., 2005; Sahoo et al., 2015). On the other hand, difficulties with social skills may impact the learning process of children with ASD, since they may not actively search for social learning opportunities, thus missing chances to learn (Brook & Willoughby, 2015; Ricketts et al., 2013). For example, social challenges in ASD may limit engagement in both educational and familial settings, hindering children's opportunities to develop their mathematical knowledge, leading to poor mathematical achievement (for a meta-analysis see Tonizzi & Usai, 2023), and possibly developing performance-based anxiety at school.

In the following sections the main findings of each study will be summarized. The strengths and limitations of the studies will also be mentioned, as well as the questions that remain open and the suggestions for further research. Finally, the clinical and educational implications of the study findings will be discussed.

7.1 Research findings overview

Table 7.1 summarizes all the studies by reporting groups involved, number of participants, the topic examined, the main aims and findings. In the first two studies, we focused on **abilities,** and particularly on specific deficits of children with ASD or SLD. We investigated the risk and protective factors for social skills in ASD and for mathematical skills in SLD, focusing on both emotional (specific anxiety) and cognitive aspects (executive functions).

Study I aimed to investigate the abilities of facial emotion recognition (FER) in children and adolescents with and without ASD, by also studying how different emotions are recognized. A second aim was to examine whether social anxiety and executive functioning (inhibition, updating and set-shifting) might lie behind FER skills in these two groups (ASD, ND). FER and EFs were assessed with computerized tasks, whereas the occurrence of social anxiety in children was reported by a parents-report questionnaire. Findings indicate that participants with ASD seem to experience difficulties in recognizing all basic emotions included in our task (Ekman, 1993), except for sadness, as compared to the ND group, giving support to the hypothesis of a generalized face-emotion recognition deficit in ASD (Lindner & Rosén, 2006; Lozier et al., 2014; Rump et al., 2009). Moreover, two statistically significant interactions emerged between social anxiety, EFs and group in predicting FER ability. First, a better FER was consistent with higher levels of social anxiety reported by parents of autistic participants. It is possible that better FER skills might trigger social anxiety in children and adolescents with ASD, because of their discomfort with social interactions, which may increase when they are more aware (Hunter et al., 2009; Nikolíc et al., 2019; Tibi-Elhanany & Shamay-Tsoory, 2011). On the other hand, autistic children with higher levels of social anxiety may have heightened attentional resources (hypervigilance) towards external stimuli (Schultz & Heimberg, 2008) when executing a socially-based test. Livingston and colleagues (2019) conducted a compelling study highlighting that among autistic adolescents, those exhibiting enhanced social skills often experience elevated levels of anxiety. This intriguing finding suggests that the ability to compensate in social situations may come at a psychological cost, potentially fostering anxiety as individuals strive to meet social demands. The second significant interaction was between updating skills and group's membership in predicting FER abilities. Updating skills seem to be predictive of social abilities in ASD children and adolescents (Phillips et al., 2008; Sivaratnam et al., 2018; Torske et al., 2018), supporting the idea that EFs are required to appropriately respond to social cues (Denham et al., 2012; Moriguchi, 2014; Spikman et al., 2013). As a fact, higher order cognitive abilities may support social engagement, acting as a compensatory mechanism (Johnson et al., 2015; Livingston et al., 2019).

Likewise the previous study, **Study II** aimed at assessing mathematics' performance using a mental calculation task in children with and without SLD, with major impairments in mathematics. Additionally, to explore underlying mechanisms of mathematics' achievement, we asked participants to fill out a self-report measure of MA, and to complete three EFs tasks specifically evaluating inhibition, updating and set-shifting abilities. Parents filled in a questionnaire about their children's general anxiety level, useful for controlling the influence of a general state of tension. As previously observed (Kucian et al., 2018; Lai et al., 2015; Passolunghi, 2011; Rubinsten & Tannock, 2010), the SLD group reported higher mean levels of MA in comparison to the ND group, besides weaknesses in terms of inhibition (Agostini et al., 2022), updating (Passolunghi & Mammarella, 2012; Szűcs et al., 2013) and set-shifting (Van Der Sluis et al., 2004; Willcutt et al., 2013). Moreover, our best-fitting model revealed two significant interaction effects, predicting the mental calculation performance: the first between group and MA, and the second between group and updating skills. As for the first interaction (group x MA), we found that higher levels of MA were related to a better mental calculation performance in the ND group, suggesting that lower levels of MA might be a supporting factor for mathematical achievement (Carey et al., 2016; Caviola et al., 2022). However, our results indicated no linear relationship between MA and mental calculation skills in children diagnosed with SLD. Indeed, though the significant difference between SLD and ND in the self-reported MA (SLD>ND), children with SLD exhibited greater variability in MA levels. On one hand, our findings suggest that there are individuals with SLD who experience MA and emotional problems, but on the other hand, there are also students with SLD not suffering from MA. This confirms that MA and SLD can be dissociated, as proposed by Devine and colleagues (2018). In addition, as for the second interaction (group x updating), we found that better updating skills were related to higher math accuracy in the ND group, suggesting that updating, among all the EFs considered, might be supportive of mental calculation performance (Hu et al., 2023; Lee & Bull, 2016; Passolunghi & Pazzaglia, 2005). However, our results found no linear relationship between updating and mental calculation skills in children diagnosed with SLD. It's worth noting that children with SLD demonstrated a lower average performance in both tasks (mental calculation and updating), potentially hindering the establishment of a score distribution that would enable a significant correlation. In addition, we assumed children with SLD to have a poor WM profile (Giofrè & Cornoldi, 2015; Toffalini et al., 2017), incapable of providing performance support. Updating skills, whether present, seem not to be enough to overcome the core mathematics difficulties experienced by participants with SLD.

Overall, the results of the first part of the present PhD dissertation indicate that in ND group, skills are predicted by anxiety and executive functions, as frequently reported in the literature. However, in clinical groups, there is a different pattern regarding the relationship between anxiety and abilities, both social and academic. In Study I, it is observed that with increasing social anxiety in children with ASD, there is an improvement in facial emotion recognition skills. In Study II, no significant relationship was found between mathematics anxiety and mental calculations' performance in SLD.

Based on these findings, moving to the second area of this PhD thesis, we delve more specifically into **social anxiety** and **mathematics anxiety** as multidimensional constructs, to overcome the possible problems associated with relying solely on *trait* anxiety levels from parents-reports (study I) and participants' self-reports (study II). Indeed, we aim to understand the behavioral and subjective *state* anxiety variables that come into play in social and mathematical contexts, where children with ASD and SLD may experience greater distress. We decided to merge the two clinical groups into a larger study because we realized that children with ASD and SLD may experience performance-based anxiety in different contexts with different characteristics based on their specific difficulties, as described throughout the thesis.

Study III aimed at examining the characteristics of social and mathematics anxiety by considering (and comparing) children and adolescents with ASD, SLD and ND. For this purpose, we asked participants to complete two stressful tasks: for social anxiety, we used a public speaking task (adapted from the Trier Social Stress test, child version; Buske-Kirschbaum et al., 1997) and, for mathematics anxiety, a mental calculation test with time restrictions (adapted from Caviola et al., 2016, 2018). State behavioral (i.e., quality of the performance) and subjective (i.e., valence, arousal, perception of competence, worries) components of anxiety towards the two stressful tasks have been examined. We also asked participants' parents to fill in a questionnaire on their children social anxiety, to further consider trait symptoms of social anxiety observed by parents in real-life settings. Consistent with the literature on the topic, higher levels of trait social anxiety were reported by parents of participants in the ASD (Bellini, 2006; Spain et al., 2018; Sukhodolsky et al., 2008) and SLD (Rostami et al., 2014; Terras et al., 2009; Thaler et al., 2010) groups compared to the ND group, equally sensitive to the prospect of *being humiliated and rejected by others*, and of *being negatively evaluated for their performance*. Regarding state anxiety, the results indicate that, despite poor performance of both clinical groups in both tasks (behavioral component), different subjective experiences were observed in individuals with ASD and DSA depending on the condition. The findings from our study suggest that social demands may evoke heightened anxiety (i.e., arousal) in children with SLD, while mathematical pressure could play a more pronounced role in those diagnosed with ASD, based on reported valence, arousal, and worries. Interestingly, the perception of competence emerged as a stable factor across the two experimental tasks, with divergent outcomes observed among children with ASD (high perception of competence) and those with SLD (low perception of competence).

In **Study IV**, we found it interesting to delve into the components of social anxiety by incorporating psychophysiological variables to verify their correspondence with the behavioral and subjective aspects of the previous study. In addition to behavioral and subjective variables, we registered the electrocardiogram (ECG) to measure psychophysiological responses and autonomic changes across all phases of the Trier Social Stress Test (child version; Buske-Kirschbaum et al., 1997). Findings indicated that the mean HR change between the phases, differed among the ASD and SLD groups, with ASD children experiencing a significant lower increase than those with SLD. As concerns HRV (expressed in RMSSD) instead, not only the ASD children had a lower reactivity across the phases as compared to those with SLD, but also they showed a lower level during baseline and recovery. Regarding ASD, it could be possible that the TSST-C might not be effective in eliciting a socially-driven stress response by enhancing the HR, highlighting a blunted physiological stress response to the social cue (Corbett et al., 2012; Dijkhuis et al., 2019; Jansen et al., 2003; Lanni et al., 2012). Moreover, a lower baseline HRV indexes in ASD has been shown in previous studies (for a meta-analysis see Cheng et al., 2020). On one hand, it's possible that children with ASD may not have felt motivated to engage in the task, as suggested by Chevallier et al. (2012) and Itskovich et al. (2021). On the other hand, an intriguing aspect to consider is the observed high level of awareness of their own internal states among these children (Simon & Corbett, 2013). Not only did they report lower state emotional activation, but they also did not express social anxiety when completing the trait-like questionnaire. Concerning the SLD group, an opposite psychophysiological pattern has emerged. HR change and HRV reactivity was significantly higher in this group than the ASD group, someway coherent with high levels of social anxiety reported by their parents. Most importantly, our findings, thought limited by the small sample size, are consistent with previous research, that stated a higher parasympathetic activity in people with SLD at rest and when handling with different social scenarios (Palser et al., 2021; Sturm et al., 2021). Indeed, the HRV change throughout the task can be interpreted as the body's effort to self-regulate when facing social stressors, possibly driven by the marked fear of negative evaluation (Livingston et al., 2018; Riddick, 2009; Rostami et al., 2014).

Table 7.1 Summary of the studies: groups involved, number of participants (N), the topic examined, the main aims and findings.

Study	Groups	N	Topic	Aims	Main findings
I	ASD ND	60 90 Total = 150	Social skills (i.e., facial emotion recognition) and related factors: • Social anxiety (SA) • Executive functions (EFs)	1. To evaluate facial emotion recognition (FER) skills in children with and without ASD, by also considering single emotions (happiness, sadness, anger, fear, surprise, disgust); 2. To understand which factors (SA, EFs) might be associated with FER in children with and without ASD.	1. Overall FER accuracy: ASD<ND; all single emotions (except for sadness): ASD<ND, giving support to the hypothesis of a generalized FER deficit in ASD (Lindner & Rosén, 2006; Lozier et al., 2014; Rump et al., 2009); 2. **↑SA = ↑FER in ASD**: better FER skills might trigger social anxiety in ASD, because of the discomfort with social interactions, which may increase with awareness (Hunter et al., 2009; Nikolíc et al., 2019; Tibi-Elhanany & Shamay-Tsoory, 2011). Autistic children with higher SA may have heightened attentional resources towards external stimuli, thus a better FER performance (Schultz & Heimberg, 2008). **↑updating = ↑FER in ASD** (Philipps et al., 2008; Sivaratnam et al., 2018; Torske et al., 2018). Higher order cognitive abilities may support social engagement, acting as a compensatory mechanism (Johnson et al., 2015; Livingston et al., 2019).
II	SLD ND	39 48 Total = 87	Mathematical skills (i.e., mental calculation) and related factors: • Mathematics anxiety (MA) • Executive functions (EFs)	1. To examine levels of MA in children with and without SLD; 2. To investigate EFs (inhibition, updating and set-shifting) in children with and without SLD; 3. To understand which factors (MA, EFs) might be associated with mental calculation accuracy in children with and without SLD.	1. MA: SLD>ND (Kucian et al., 2018; Lai et al., 2015; Passolunghi, 2011; Rubinsten & Tannock, 2010); 2. Inhibition (errors): SLD>ND (Agostini et al., 2022; Mammarella, Caviola, Giofrè, & Borella, 2018; Szűcs et al., 2013) – Updating (accuracy): SLD<ND (Passolunghi & Mammarella, 2012; Szűcs et al., 2013) – Shifting (perseverative errors): SLD>ND (McDonald & Berg, 2018; Van Der Sluis et al., 2004; Willcutt et al., 2013); 3. ↓MA = ↑mental calculations' performance in ND (Carey et al., 2016; Caviola et al., 2022). • No significant relationship between MA and performance in SLD, for the large variability of MA levels, supporting the distinction between SLD and MA (Devine et al., 2018);

					↑updating = ↑mental calculations' performance in ND (Hu et al., 2023; Lee & Bull, 2016; Passolunghi & Pazzaglia, 2005). • No significant relationship between EFs and performance in SLD: the reduced WM functioning might be incapable of providing performance support (Giofrè & Cornoldi, 2015; Toffalini et al., 2017).
III	ASD SLD ND	60 70 150 Total = 280	Social and mathematics anxiety: • Behavioral components • Subjective components	1. To evaluate the (trait) levels of SA reported by the participants' parents; 2. To assess the (state) **behavioral** components of anxiety, by analysing the quality of the public speech (Trier Social Stress Test) and the mathematical performance accuracy (Stressful Mathematical Test); 3. To evaluate the (state) **subjective** responses towards the two stressful tasks by considering baseline and task-related self-reports.	1. Both ASD (Bellini, 2006; Spain et al., 2018; Sukhodolsky et al., 2008) and SLD (Rostami et al., 2014; Terras et al., 2009; Thaler et al., 2010) groups are equally sensitive to the prospect of *being humiliated and rejected by others*, and of *being negatively evaluated* for their performance; 2. **Trier Social Stress Test (quality of the speech)** ASD, SLD < ND (Edmiston et al., 2017; Livingston et al., 2018; Kumazaki et al., 2020; Terras et al., 2009) **Stressful Mathematical Test (accuracy)** ASD, SLD < ND ((Beilock, 2008; Eysenck & Calvo, 1992; Kucian et al., 2018; Rubinsten & Tannock, 2010); 3. **Trier Social Stress Test** **ASD:** ↓ arousal ↑ perception of competence, because of their unawareness or inability to express feelings (Barnhill et al., 2000; Huggins et al., 2021; Oakley et al., 2022). In alternative, they do not feel concerned about the social pressure, possibly due to diminished social motivation (Chevallier et al., 2012), or the TSST-C is perceived as being a cognitive exercise (Simon & Corbett, 2013). **SLD:** ↑ arousal ↓ perception of competence, due to the fear of being negatively judged, and low self-esteem (Livingston et al., 2018; Novita, 2016; Rostami et al., 2014). **Stressful Mathematical Test** **SLD:** ↓ perception of competence ↓ worries, due to feelings of resignation, appraisal or learned helplessness (Burden, 2008; Hunt & Maloney, 2022; Pekrun, 2006); **ASD:** ↓ valence ↑ worries. The task was able to evoke a physiological response, in contrast with the TSST-C

					(Ashcraft & Kirk, 2001; Beilock, 2008; Beilock et al., 2004). Overestimation of their mathematical performance (Furlano & Kelley, 2020).
IV	ASD SLD ND	15 15 25 Total = 55	Social anxiety: Psychophysiological components	To evaluate autonomic responses, registered with an electrocardiogram (ECG), to a social stress task (Trier Social Stress Test - child version, TSST-C).	**ASD**: the TSST-C might not be effective in eliciting a socially-driven stress response (Corbett et al., 2012; Dijkhuis et al., 2019; Jansen et al., 2003; Lanni et al., 2012). Lower baseline HRV indexes in ASD (Cheng et al., 2020). **SLD:** Consistent HR change across the phases, possibly driven by the fear of negative evaluation (Livingston et al., 2018; Riddick, 2009; Rostami et al., 2014). Higher HRV reactivity when facing social pressure (Palser et al., 2021; Sturm et al., 2021).

ASD=Autism Spectrum Disorders; SLD=Specific Learning Disorders; ND=non-diagnosed matched participants.

7.2 Study limitations and future perspectives

Although the present PhD dissertation offers novel evidence and highlights the importance of studying risk and protective factors for social and mathematical performance, some limitations need to be mentioned, and a number of other aspects might be addressed in future research.

A main limitation concerns the sample considered in the studies. The first point is about the restricted sample size in some studies of this dissertation (e.g., Study IV). The number of participants with a clinical diagnosis (ASD, SLD) was based on the need to strike a delicate balance between the availability of clinicians and families. As we explained in the descriptions of our samples, children had to satisfy very restrictive inclusion criteria (a previously-established clinical diagnosis of ASD or SLD according to the DSM 5, a complete assessment in their medical records, and confirmation of the diagnosis with age-appropriate tests) and exclusion criteria (e.g., other known genetic conditions, a history of neurological diseases, comorbid psychopathologies, or certified physical and intellectual disabilities, ongoing use of medication, or a certified intelligence quotient below 80). Second, the relatively small sample sizes made us unable to study possible differences related to the sex, which could be an important predictor of social and mathematical functioning, due to the likelihood of more severe social anxiety symptoms (May et al., 2014) and mathematics anxiety (Devine et al., 2012) in females rather than males. However, it is worth considering the clear discrepancy of the female-to-male ratio of around 1 in 4 (Fombonne, 2009): the difficulty in the assessment of ASD in girls, for instance due to the phenomenon of camouflaging, may contribute to an under-diagnosis of ASD in these patients (Beggiato et al., 2017), making their recruitment into research projects more challenging. Third, the wide age range considered in our studies may have influenced the results, as social and mathematical skills undergo significant changes over the years. Nonetheless, participants in the clinical groups were always matched for age, gender and IQ with ND children, and when it was not possible, the confounding variable was considered as a covariate in the analysis (see Study IV). Future research should replicate our studies with larger sample sizes to be able to draw valuable conclusions on sex differences, and age-related considerations.

Another limitation linked to the samples considered in our studies, is related to the participants diagnosed with SLD. In fact, in Studies III and IV, we included children diagnosed with SLD with major impairments in reading and mathematics in the SLD group. In the Opinion Paper written by Peters and Ansari (2019), the authors explained the necessity of overcoming the problems associated with a categorical approach by considering the overlap between learning disorders, rather than entirely distinct domains of learning. As a fact, children with difficulties in one domain (e.g., reading) frequently experience challenges in at least another domain (e.g., arithmetic) (Landerl & Moll, 2010; Moll et al., 2015; Peterson et al., 2021; Willcutt et al., 2019). Dyslexia and dyscalculia seem to be characterized by different behavioral but similar neuropsychological (Willcutt et al., 2013) and brain activity profiles (Peters et al., 2018). However, we understand the possible implications and limitations of considering children with SLD rather than those with only mathematical difficulties in Studies III and IV. Indeed, it is worth mentioning that combining participants with dyslexia and dyscalculia may represent a confound, because of the different cognitive profiles which could have distinctly influenced the performance on the math task (Moll et al., 2016). Future studies should try to replicate our findings, especially that on mathematics anxiety, by considering only children with mathematical learning difficulties.

Another limitation that seems important to mention, concerns the type of task used to assess social anxiety (Studies III and IV). As a matter of fact, the Trier Social Stress Test is a performance task which is thought to elicit a temporary stress response, due to the unpredictability and the fear of negative evaluation. However, people who are afraid of public speaking may not react in the same way during other social situations, such as group interactions or face-to-face encounters. As previously mentioned, future studies should compare autonomic responses to tasks involving different social demands (e.g., social interaction, facial emotion recognition) (Corbett et al., 2010, 2012, 2019), which could be informative about emotional arousal and regulation in different social contexts (Lievore et al., 2022). Moreover, in future studies, social motivation should also be investigated to try to explain the link between social skills and social anxiety, in relation to the individual's interest in the social world (Briot et al., 2020).

Finally, due to time constraints, we were unable to carry out a final study necessary to complete the research line thoroughly, which we are currently conducting. The purpose of the study is to investigate the psychophysiological responses in the contexts of mathematical distress in children and adolescents with ASD and SLD, as we did in Study IV for the social domain. The objective is to assess whether children with autism activate physiologically in response to a mathematical task, as the results in Study III indicate that they may experience higher levels of worries, lower pleasure, and an increased arousal from baseline to the math task. Moreover, we are interested in understanding how children with SLD regulate their emotions while doing a demanding mathematical task, as their autonomic responses might be shaped by repetitive failures at school, alongside feelings of resignation and learned helplessness.

7.3 Clinical and educational implications

Clinical and educational implications may be drawn from our findings, shedding more light on assessment and interventions on social and mathematical performance of children and adolescents with different neurodevelopmental conditions, such as ASD and SLD. While several implications have been presented in the Discussion sections of the single studies based on the specific results, the focus here will be on general aspects.

As concerns the assessment, a *global comprehensive evaluation* of both cognitive abilities and emotional aspects may be important to identify potential strengths and weaknesses when addressing social and mathematical skills. For instance, a widely-recognized model has point out the relationship between cognitive and social abilities, by defining the core areas of social skills (biological–psychological–social) and their interactions within a developmental framework based on empirical and clinical evidence (the SOCIAL model; Beauchamp & Anderson, 2010). Educators and clinicians should be aware of the negative consequences of repetitive social and academic failures of children with ASD and SLD, to be able to prevent the development of negative self-beliefs and learned helplessness. Among the cognitive domain, the ability to inhibit irrelevant information, update the information in memory, and switch between different mental sets, might represent a critical skill in real-life contexts, which should be further considered during interventions and at school. Individual characteristics, such as anxiety and executive functioning, should be considered to adapt the interventions aimed at empowering the skills of both children with ASD and SLD.

Moreover, the *trait-state distinction* in the field of performance-based anxieties, such as social and mathematics anxiety, might deepen theoretical understanding of these two constructs. Regarding the social domain, participants' parents reported higher levels of trait social anxiety in ASD, but it is worth noting that their report is based on behavioral observations, confirmed by the worse performance in the public speaking task in Study III and IV. On the contrary, results indicated an agreement between trait and state social anxiety reported by the autistic children, suggesting any self-reported emotional distress within the social domain. Concerning the mathematical domain, trait-state disagreement might explain the findings of Study II, in which no linear relationship emerged between trait mathematics anxiety and mental calculation accuracy in the SLD group. As a fact, in Study II, children with SLD reported higher trait levels of MA in comparison to the ND controls, but in Study III, they reported lower state worries towards the real-time assessment with mathematical pressure. For all these reasons, educators and clinicians should be aware that trait and state levels of anxiety might differ, especially in children diagnosed with neurodevelopmental conditions, possibly because of a reduced self-awareness and/or inability to express their feelings, or a lower motivation toward the issue, as discussed in the previous Chapters.

Another important implication of the present PhD dissertation, is the necessity of assessing social and mathematics anxiety by using a *multidimensional* and *multi-informant* approach, allowing for a more comprehensive understanding of the individual's experience. Using a multidimensional approach in assessing anxiety is crucial because anxiety is a complex and multifaceted psychological phenomenon that involves various aspects of cognition, emotion, behavior, and physiology. In addition, anxiety may be experienced differently by children, and different informants (such as the person experiencing anxiety, family members, teachers, or peers) can provide unique insights. This is particularly true when the sources of anxiety are specific social and academic difficulties experienced by children with ASD and SLD. Combining information from multiple informants, allows to tailor individualized interventions, by understanding the impact of anxiety across different contexts (e.g., school, home), and ensuring a holistic approach to support and treatment.

To conclude, investigating factors associated with social and mathematical performance, is a highly complex issue. One strength of this thesis is to explore different aspects by comparing populations with and without clinical diagnosis, aligning with the neuroconstructivist approach. However, there is still space for further research on the relationship between skills, anxiety and performance-deficit in children and adolescents with ASD and SLD, with the aim of understanding the relevant mechanisms associated with each symptomatology. The current PhD dissertation provides some answers to the gap highlighted in the literature on the topics, but also open new avenues and new research ideas for the future.

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APPENDIX

Social Performance Rating Scale (adapted from Fydrich et al. 1998)

Non-verbal aspects

Gaze	Score	Interpretation
The participant completely avoids looking at the screen (Study 3)/at the committee (Study 4) or maintains a fixed gaze into the void. This attitude is detrimental to performance.	1	Very poor
The participant often avoids looking at the screen (Study 3)/at the committee (Study 4) or maintains a fixed gaze into the void for most of the time. This attitude is detrimental to performance.	2	Poor
The participant occasionally avoids looking at the screen (Study 3)/at the committee (Study 4). This pattern is intermittently detrimental to performance.	3	Fair
The participant looks at the screen (Study 3)/at the committee (Study 4) during the performance.	4	Good
The participant maintains eye contact during the performance, does not stare into space; during breaks, he/she moves their gaze.	5	Very good
Vocal quality		
a) The participant speaks with a monotone, flat voice, or b) speaks too loudly or mumbles, or c) speaks decidedly too loudly or has intrusive tones (unpleasant and strident vocal quality).	1	Very poor
a) The participant does not demonstrate warmth, enthusiasm, or interest through verbal expression, or b) speaks in a low voice and the speech is not clear, or c) speaks slightly loudly or in an intrusive or sarcastic tone.	2	Poor
a) The participant demonstrates warmth in verbal expression but most of the time appears unenthusiastic or non-interested, or b) speaks with an appropriate volume and clear vocal quality, and c) does not speak with intrusive tones or sarcasm.	3	Fair
a) The participant demonstrates moderate warmth in verbal expression but inconsistent enthusiasm or disinterest. They may also appear forced ("fake"), or b) speaks with an appropriate volume and clear vocal quality, and c) does not speak with intrusive tones or sarcasm.	4	Good
The participant shows enthusiasm and warmth in vocal expression without seeming forced or condescending.	5	Very good
Signs of discomfort		
The participant shows complete rigidity in arms, legs, or entire body. There are constant movements of the legs or restlessness with hands, hair, or clothes. There is extreme facial rigidity or constant facial tics. He/she frequently clears his/her throat nervously, swallows, or stutters. He/she laughs or giggles inappropriately often. He/she seems extremely uncomfortable and eager to escape. The participant does not pay attention to requests.	1	Very high
The participant shows rigidity or restlessness for most of the time. He/she has difficulty remaining seated. Frequent facial rigidity or facial tics. Sometimes he/she clears his/her throat nervously, swallows, or stutters.	2	High

Occasionally, he/she laughs or giggles inappropriately. He/she shows signs of discomfort confirmed by frequently looking around.		
The participant is not rigid. He/she slightly moves his/her legs, swallows, clears his/her throat, or shows restlessness. He/she only exhibits brief moments of typical discomfort. He/she focuses on the task for most of the time without ever interrupting him/herself.	3	Moderate
The participant does not show rigidity, does not swallow, and does not clear their throat. There is minimal restlessness that is not detrimental to performance. He/she laughs or smiles appropriately. There are no glaring signs of discomfort. He/she remains focused on the task and, at times, relaxes.	4	Low
The participant maintains a relaxed posture and performs natural body movements. He/she laughs or smiles appropriately. He/she demonstrates effective body language. He/she appears comfortable and relaxed throughout the task.	5	Very low

Verbal aspects

Adherence to the track		
The participant provides a partial and superficial discussion of the required aspects.	1	Very poor
The participant offers a partial discussion of the topics.	2	Poor
The participant correctly addresses all the required aspects, but in a simple and concise manner.	3	Fair
The participant addresses all aspects correctly and comprehensively, with hints of critical elaboration on the topic.	4	Good
The participant offers a critical, comprehensive, and articulate analysis of the required aspects.	5	Very good
Conversational flow		
The participant forms monosyllabic sentences ("mmmh," "ok") or excessively long sentences without pauses. The participant is unable to provide a logical structure to the presentation, with persistent difficulties in maintaining a correct division into parts and an adequate order of elements.	1	Very poor
The participant mainly constructs short sentences with very long pauses or very long sentences without pauses. The participant demonstrates a poor ability to organize the speech logically, yet he/she maintains a division into macro-topics.	2	Poor
The participant expresses one sentence at a time with occasional long pauses. The participant divides the speech into macro-topics and develops them one at a time logically. However, the structure of the presentation remains superficial and limited to the macro-topics. Occasionally, there are instances of losing the "thread" of the discourse.	3	Fair
The participant expresses him/herself through one or two sentences at a time without long pauses, but there may be occasions where the speech is either too short or excessive. The participant demonstrates a good control of the key content of the presentation, which is well connected. The logical organization is good.	4	Good
The participant expresses him/herself for most of the time with one or two long sentences at a time. The participant pays great attention to the key aspects of the speech and demonstrates a high ability to make connections. The logical organization of the presentation is excellent, thanks to the correct division into parts and the adequate order of speech elements.	5	Very good

Lexicon		
The participant communicates solely through high-frequency words, and occasionally, inappropriate vocabulary with lexical errors is evident, or he/she expresses him/herself through gestures. The composed sentences are mundane, vague, and lacking in substance.	1	Very poor
The participant mostly uses appropriate vocabulary with high-frequency words. However, the composed sentences are vague, and lacking in substance.	2	Poor
The participant uses a vocabulary primarily consisting of high-frequency words, with occasional use of low-frequency terms. There may be synonyms of common usage.	3	Fair
The participant uses a combination of high and low-frequency terms. The lexical choice is appropriate, and the expressive form is correct. There may be synonyms present.	4	Good
The participant employs appropriate and contextualized terminology. There is a wide variety of vocabulary with sophisticated synonyms.	5	Very good