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Factors Influencing the Recent Increase of Clinically Diagnosed Autism Spectrum Disorder in Girls and Women

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Abstract

Autism is an umbrella term of neurodevelopmental conditions characterised by two main core symptom clusters: deficit in socio-communicational functioning and restrictive, repetitive behaviours. Although autism affects more males than females, it is not yet clear whether this difference reflects the phenotypical differences in autism across sexes. In this thesis, I included and analysed 31 peer-reviewed articles to shed more light on the sex difference in autism. PRISMA guidelines were used to identify the articles included in the final analysis. In the meta-analysis assessing the core symptom clusters, 13 papers were included. Weighted mean effect sizes were calculated for the standard assessments (ADI-R, ADOS, or RBS/RBS-R) subscales and the overall effects of sex were determined. Additional multi-regression investigated whether age and assessment influenced the effect sizes. Finally, I conducted a thematic analysis of seventeen articles to investigate the phenotypical differences in cognitive skills executive functioning and intelligence. In line with the hypotheses, results indicated that women with autism are less impaired than males on both symptom clusters. Regarding cognition, males with autism outperformed women on executive functioning, which is in line with the hypothesis. However, contrary to our expectations, most studies found no significant difference between males and females with autism in intelligence. Findings further indicate that different phenotypical features may characterise females compared to males with autism. Therefore, the revision of the standard, rather male-based and culturally influenced assessment methods, are required to establish a realistic sex ratio in the diagnostics of autism.

Keywords: autism, sex differences, core symptom clusters, cognition

Factors Influencing the Recent Increase of Clinically Diagnosed Autism Spectrum Disorder in Girls and Women

Autism represents a group of neurodevelopmental conditions with increasing prevalence, which has doubled within the last decade. Additionally, a significant body of research points to a higher prevalence rate of autism in males, about four times more frequently than in females. In addition, research evidence suggests that the clinical representation of autism differs in males and females, including less severe socio-communicational problems or repetitive behaviours but higher cognition-related difficulties (Fombonne, 2009; Holtmann et al., 2007; Mandy et al., 2011; Ros-Demarize et al., 2020; Wijngaarden-Cremers et al., 2014). However, it is still unclear whether the potential phenotypic gender differences within autism are the reasons not only for the large ratio gap present between the sexs but also for the delayed or overlooked diagnosis in women with autism (Begeer et al., 2013; Rivet & Matson, 2011b). It is not without exception that females receive a misdiagnose, for example, a diagnosis of social phobia instead of autism.

Consequently, such mistakes can influence their lives by receiving wrong mental health support or medication, leading to, for example, decreased quality of life (Wijngaarden-Cremer et al., 2014). When discussing differences between females and males, it is necessary to note the differentiation between gender and sex, although these terms are often used interchangeably. Sex refers to biological attributes and characteristics. In autism research, the biological factors associated with sex differences are more established owing to technological developments in biology research than sex-related factors. On the other hand, gender is a socially constructed concept that includes roles, specific behaviours and expectations; for example, girls are expected to play more with dolls, while cars are considered appropriate for boys (Chowdhury et al., 2010). It can be challenging to understand these factors as gender roles continue to change parallel to the increasing gender equality and flexibility.

Core Symptoms

Autism is one of the most frequently occurring neurodevelopmental disorders, and well-established work has documented higher autism prevalence rates in males. In particular, recent estimates from the Centers for Disease Control and Prevention suggest that males have a four times higher probability of being diagnosed with ASD than females (Ros-Demarize et al., 2020).

Although the underlying factors of this significant sex-based difference are not yet apparent, it is likely due to a combination of various factors, such as increased recognition and early detection by professionals and improved diagnostic tools. All these factors contribute to broadening the original concept of autism proposed by Kanner (1943) and changing the diagnostic guidelines. For example, the latest adaptation of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) has adopted the umbrella term 'autism spectrum disorder' without any subtypes and also reorganised the symptoms from three subcategories into two categories. These changes were implemented due to our improved understanding of this condition. Thus, the present concept of ASD distinguishes two types: difficulties in social communication and interaction; and repetitive and restricted behaviours (RRBs) (Lai et al., 2013). Furthermore, there are additional symptoms associated with the presence of autism, such as delayed or disordered language, sensory processing difficulties, and other comorbid mental health-related conditions, such as anxiety, mood disorders such as depression and Attention Deficit Hyperactivity Disorder (ADHD) (DSM-5, 2013). The presence of these difficulties, cognitive functioning and level of adaptability vary vastly depending on the severity level, ranging from mild to severe (American Psychological Association, 1994).

Social Communication and Interaction

Social communication and interaction difficulties include verbal and nonverbal communication, for instance, poor eye contact, a problem with recognising others' emotions, and language-related challenges, such as keeping a back-and-forth conversation going. These challenges impose additional risk for maladaptive socio-emotional development that reflects on friendships, self-esteem, internalising problems and peer bullying (Hull et al., 2020; Sedgewick et al., 2019).

Current theories on the neurobiological basis of autism explain impairments in the socio-communication domain by an altered pattern of connectivity involving the whole brain network (Peterson et al., 2014). Although autism has a complex heterogeneous, multifactorial aetiology, data is progressively and robustly accumulating and seem to offer additional empirical support for molecular/cellular signalling abnormalities in autism (Parellada et al., 2014). For example, the connectivity theory of autism proposes that atypical connectivity patterns within and between brain regions can be observed in autistic individuals, pointing to the possibility that certain aspects of brain development might be altered by the prevalence of genetic variations (Parellada et al., 2014;

Peterson et al., 2014). In particular, studies using functional connectivity MRI (fcMRI) have found atypical patterns in the so-called 'social brain', which is the collective name of a vast network of brain regions that are associated with functions of social communication such as processing social signals and understanding others (Müller & Fishman, 2018). Studies reported consistent dysfunction of most of the 'social brain' regions individually. This indicates that brain abnormalities in autism are not localised to one or a few regions but rather implicate alterations in the connectivity of distributed brain networks (Müller & Fishman, 2018). Although numerous findings of atypical activity and connectivity have been observed, few neuroimaging findings are at odds with these finding. Yet, no consensus view on the causes of social communication deficits has emerged (Müller & Fishman, 2018). While growing evidence indicates that profiles of social communication impairments in autism likely differ between sexes, it is unclear whether this might be due to different biological mechanisms, for example, the presence of specific features that protect females from developing autism (see section'Sex Issues in Autism Assessment' below) (Müller & Fishman, 2018).

Although the underlying neurobiological mechanisms of autism are unclear, the sex differences established using observational tools are well found (Harrop et al., 2014; Lai et al., 2011). Studies reported that typically developing and autistic girls both show less impairment from an early age and therefore demonstrate better social-communication skills compared to boys (Harrop et al., 2014; Lai et al., 2011; Lai et al., 2015; Mandy et al., 2012; Szatmari et al., 2012; Wijngaarden-Cremers et al., 2014).

Restricted and Repetitive Behaviours (RRBs)

Little is known about Restricted and Repetitive Behaviours (RRBs)' phenomenology, diagnosis, and treatment, despite their potential significant impairment in one's life. RRBs, like other characteristics of autism, have been known to be life-long conditions that most often manifest in childhood and continue into adulthood (Szatmari et al., 1989). RRBs can be categorised as communicative (e.g., echolalia), behavioural (e.g., stereotypies and repetitive use of objects), or cognitive (e.g., obsessions, rigidness in routines, fixed, sometimes unusual interests) (Bishop et al., 2006; Chowdhury et al., 2010; Harrop et al., 2015; Lai et al., 2015; Postorino et al., 2015; Szatmari et al., 2008).

Several theories proposed an explanation for the cause of RRBs in autism (Chowdhury et al., 2010; Lovass et al.,1987; Pierce & Courchesne, 2001). Approaching these behaviours from a neurobiological perspective, it has been postulated that RRBs are associated with activities in several brain areas, such as the frontal lobe and cerebellum. In particular that these behaviours result from abnormalities present in the basal ganglia circuits, which are responsible for, among other things, controlling speech, movement, and posture (Chowdhury et al., 2010; Pierce & Courchesne, 2001). Furthermore, the caudate nucleus was associated with the severity of RRBs (Qiu et al.,2016). However, it is also possible that these deficits are not related to anatomical abnormalities but reflect more on functional anomalies.

From the developmental perspective, Lovass and colleagues (1987) suggested that these behaviours stem from the self-stimulatory behaviours observed in infants. They argued that these behaviours usually fade as children develop, and more mature behaviours replace these self-stimulatory behaviours. Still, they remain in autistic children because they fail to acquire new, more mature behaviours. Executive processing theories propose that RRBs are a direct extension of the effort to persevere, and it is thought that autistic individuals cannot control their focus leading to hyperfocus and getting "stuck" in specific behaviours (Amaral et al. 2008).

Previous studies have shown that girls with autism show RRBs less frequently than boys (Kreiser & White, 2014; Lai et al., 2015; Mandy et al., 2012; Szatmari et al., 2012). In particular, it was found that boys seemed to show more RRBs after the age of six, which was not present in girls (Szatmari et al., 2012). However, besides potential genetical differences, no explanation of this phenomenon has been suggested. Although evidence is scarce and contradicting, the literature about autism and sex strongly suggests that the differences observed between females and males are due to societal expectations rather than neurobiology-based (Hull et al., 2020). In particular, what is considered atypical interest for boys and girls; for example, girls like animals, so a girl who is highly interested in this topic may not be regarded as odd, which leads to lower scores on RRBs assessments (Chowdhury et al., 2010).

Cognition

Individuals with autism present a specific cognitive profile characterised by impaired social cognition and perception, executive function, and atypical perceptual and information processing (Lai et al., 2013). Several theories from a variety of fields explain these impairments. One of the

theories is the cognitive theory of autism (Hill, 2004), which hypothesise that cognitive, as well as some behavioural impairments, such as deficits in theory of mind, communication skills, maladaptive behaviours, or repetitive behaviours, arise from executive function deficits (Mermari et al., 2013; Ozonoff et al., 2006).

Executive function is an umbrella term that describe initiating and controlling functions such as planning, self-monitoring, response inhibition, cognitive control, and flexibility (Hill, 2004; Mermari et al., 2013; Russo et al., 2007). The most consistent deficits in autism are poor planning and low cognitive flexibility (Mermari et al., 2013). Cognitive flexibility and Theory of Mind (ToM) ascribe the ability to shift to different thoughts or actions based on the situation or adapt perspectives during social interactions. The inability to do so leads to rigid behaviours frequently noted in autistic individuals (Hull et al., 2020). It is increasingly difficult to establish clear links between the characteristics of autism and performance on EF tasks despite the clear, logical connection due to the complex system of brain structures underlying cognitive flexibility, such as the prefrontal cortex and its role in controlling social and environmental information processing (Ozonoff et al., 2006) and the cognitive functions working very closely together (Hill & Bird, 2006; Lopez et al., 2005; South et al., 2007). Studies showed mixed performance in cognitive ability in females with autism compared to males (Baron-Cohen et al., 2002; Memari et al., 2013). In particular, females with autism were found to perform worse on planning, working memory, and response inhibition than males with autism, yet they performed better on cognitive flexibility (Blöte et al., 2011; Lehnhart et at., 2016; Lemon et al. 2011).

Another aspect of cognition is intelligence. The intelligence profile of autism seems to differ between sexes, pointing to a better performance in males than females (Mandy et al., 2012; Rivet & Matson, 2011b). In particular, results indicate that males with autism obtain statistically significantly higher scores on several assessments, including generalised IQ, than females (Mandy et al., 2012). This difference could be explained by the evidence indicating that women with lower IQ are more likely to be diagnosed compared to women with high IQ because lower IQ is associated with more profound impairments (Mandy et al., 2012; Rivet & Matson, 2011b; Van Wijngaarden-Cremers et al., 2014).

Sex Issues in Autism Assessment

The profound male bias in autism diagnosis is well documented. It raises questions about how etiological and developmental mechanisms play a relevant role in these differences in the core and cognitive domains and, consequently, in the diagnostics of autism. Several theories explain the differences between males and females, including the Female Phenotype Theory (FPT) and the Female Protective Effect (FPE) (Hiller et al., 2014; Hull et al., 2020; Sedgewick et al., 2019). The FPT argues that females with autism possess a lower degree of socially unaccepted/maladaptive socio-communicational skills and a higher level of social motivation, thus the desire to form friendships with others (Hiller et al., 2014; Hull et al., 2020). The lower level of impairment and stronger socialisation desire activates a 'compensatory mechanism' that aids females in counterbalancing the social impairments they might experience (Lai et al., 2016; Ratto et al., 2017). The FPE proposes that for females to express a similar degree of autistic symptoms as males, more considerable genetic and environmental risks must be present (Hiller et al., 2014; Hull et al., 2020).

In particular, females are less affected by neurodevelopmental conditions than males; females with autism have fewer inherited mutations than males with autism (Duchenne, haemophilia, colour blindness), which the "protective" X chromosome can explain. Females have two X chromosomes, and therefore they less frequently show signs of conditions (they still carry the problematic gene) connected to the X chromosome compared to males, who inherit only one X, therefore more vulnerable to conditions associated with this chromosome. This genetics-based understanding aligns with the FPE theory, suggesting that females with autism have more genetic and environment-related problems than receiving a diagnosis (Hull et al., 2020). Closely linked to the FPE theory, another aspect likely to influence the diagnostic ratio difference in autism is the time of diagnosis. Shattuck and colleagues (2009) found that the time of diagnosis heavily depends on the severity of the symptoms; thus, females showing minor or less severe symptoms receive a diagnosis not only later than males but also later than females with more severe impairments. In other words, women with autism must show higher impairment to receive a diagnosis in most cases. Consequently, women with less impairment are more likely to encounter more hardships before acquiring the needed support.

Another important argument is that the diagnostic criteria and the tests used to establish the diagnosis guidelines were all built on samples with heavy, if not exclusive male presence (Dworzynski et al., 2012). Consequently, it is highly possible that the existing screening

assessments of diagnosis, which lack reliable biomarkers, cannot detect the features demonstrated by females with ASD (Reinhardt et al., 2014). In addition, the insensitivity of the measurements would further imply that the female phenotype may not be perceived as a "typical" set of symptoms immediately pointing towards autism diagnosis despite a similar level of symptom severity in males. Therefore, the lower number of diagnoses in women may reflect a proportion of the non-diagnosed autistic female population (Halladay et al., 2015; Hull et al., 2016; Kirkovski et al., 2013; Ratto et al., 2017).

Present Study

As autism diagnosis is established based on a distinct set of behavioural symptoms, changes in gender roles due to societal changes (such as gender equality) pose further hardships in establishing a correct diagnosis. In return, this can lead to misdiagnosis or no diagnosis. Therefore, it is crucial to understand the underlying mechanism of the phenotypes and how they are associated with diagnostics. Thus, the focus of this thesis is to shed more light on the sex differences observed in autism by reviewing previous findings on the discrepancies observed in the core symptoms and the cognitive skills associated with phenotypic characteristics of autism. Assessing these discrepancies would allow us to improve our current understanding of the differences and consequently improve the diagnostics in women, leading to higher and more appropriate support for their needs.

Hypotheses

Existing literature has demonstrated that sex differences exist in core symptoms and cognitive skills associated with phenotypic characteristics of autism spectrum disorder. However, the conclusions are divisive due to inconsistency in research. Nevertheless, studies seem to agree that females with autism are less impaired in the core symptoms than males. Thus, my first aim was to determine whether sex differences in social communication and RRBs exist. First, I hypothesise that females show a lower impairment in socio-communicational functioning compared to males with autism. Next, our second hypothesis is that women with autism score lower on restrictive-repetitive behaviours than males with autism.

Literature shows that women diagnosed early on show more deficits and lower IQ (Van Wijngaarden-Cremers et al., 2014). Consequently, suggesting that females with autism are more impaired in the cognitive domain, including executive function and IQ, compared to males with

autism. Thus, our third hypothesis examines whether women with autism perform poorer on executive function-related tasks than males with autism. Lastly, based on the literature mentioned earlier, we predict that women with autism would score lower on tasks assessing intelligence than males with autism.

Method

Data Selection

A meta-analysis was conducted to investigate the proposed research questions of the sex differences in the core symptoms of autism (social cognition and RRBs). Then a literature review was conducted to investigate the differences in cognition in women and men with autism. The data selection was completed, for both the core symptoms section and for the cognition section, following the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA, Moher et al., 2009). The PRISMA statement consists of a 27-item checklist and a 4-phase flow diagram (see Figure 1 and Figure 2 below).

The literature was first searched electronically for both sections via databases like PsychINFO, PubMed, and Web of Science. Other articles were identified by checking the reference lists of included studies. The primary keywords for Part I was “autism or ASD or autism spectrum disorder”, “gender differences or sex differences”, and “core symptoms”. For Part II, the primary keywords were “autism or ASD or autism spectrum disorder”, “gender differences or sex differences”, and “cognition”. Eligibility criteria for both sections were (a) the articles published in the English language and (b) both sexs represented in the study for comparison. Considering the clinical diagnosis of autism, studies were included (c)if they used a classification system not older than DSM-IV. Thus studies using a classification based on DSM IV-TR (APA; 2000), DSM-5 (APA; 2013), ICD-9 (WHO; 1992), or ICD-10 (WHO; 2007) were included. The exclusion criteria were the same for both sections. Articles were excluded if the participant pool had twins or the study used animal models. Individuals with comorbid diagnoses such as bipolar disorder, epilepsy, schizophrenia, attention-deficit/hyperactivity disorder (ADHD), obsessive-compulsive disorder (OCD), and learning disability (LD) were also excluded in both sections.

Furthermore, details regarding the tests and questionnaires used in the study, the type of the study, test scores for the core symptoms and findings of the studies were extracted and

organised in tables (see Table 1 in Appendix). Some participants were included in more than one analysis of core symptoms because different test instruments assessed the symptom characteristics. To avoid these studies getting too much weight when calculating the weighted effect sizes, they are only counted once in the total (N) used. Based on the gathered information, studies were excluded if they only assessed part of the core symptom cluster, for example, if they examined communication but not social interaction.

Figure 1

PRISMA Flow Diagram Showing Identification and Selection of Studies for Inclusion in the Meta-analysis of Sex Differences in Autism Core Symptoms of Social Communication and RRBs.

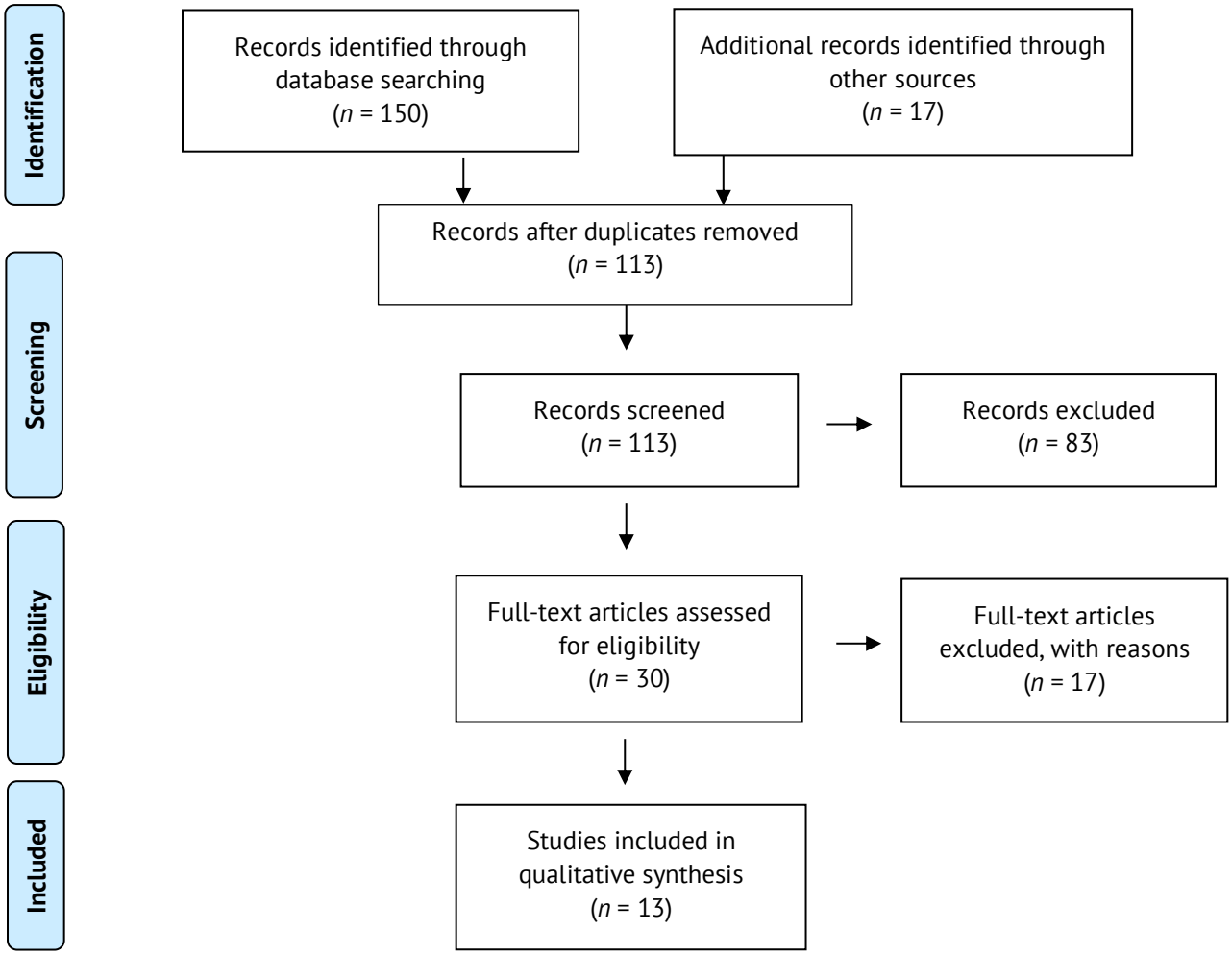
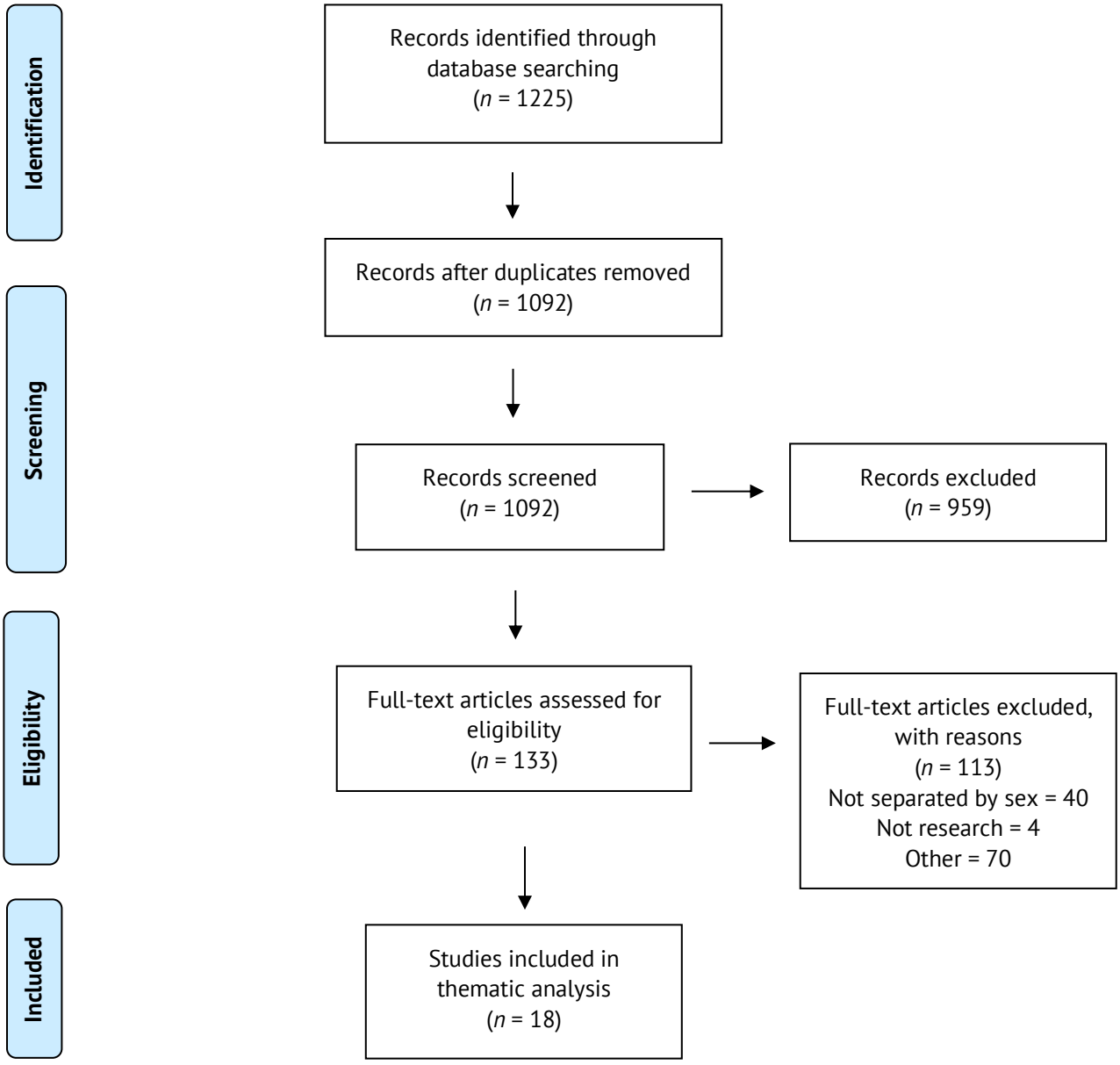


Figure 2

Flow Diagram Showing Identification and Selection of Studies for Inclusion in the Thematic Analysis of Sex Differences in Cognition



Data Extraction

Information was collected from the fitting studied in both sections. This included name of the authors, date of publication, the study's sample size, gender distribution, age, autism diagnostic criteria and the measurements of interest (see next section).

Measurements

Quantitative Analysis- Instruments Used to Measure Core Symptoms

The Autism Diagnostic Interview (ADI-R) is a standardised semi-structured interview based on the DSM-IV and ICD-10 diagnostics of autism. It includes exploring the individual's early development, language development and skills, communication functioning, social development and play, sensory aspects, interests and behaviour, general behaviour and caregiver concerns by using 93 items (Lord, 1994a; Rutter, 2003). In addition, the caregiver's report of the person's developmental history and behaviour across time and place is also recorded and coded accordingly. Most often, the ''diagnostic algorithm'' scores are used for analysis, reflecting on the three main functional areas: reciprocal social interaction, communication, language, and Repetitive RRBs. Individuals who reach the cut-off in all three domains plus also present a number of symptoms before the age of 36 months are given the autism classification.

The Autism Diagnostic Observation Schedule (ADOS) is a standardised, interview-based semi-structured assessment for current autistic behavioural presentation (Lord 1999; Lord, 2000a; Lord, 2012b). The intake can be done following one of the four modules based on the individual's expressive language skills and chronological age. The assessment takes approximately 45 minutes to an hour, depending on the module.

Social Responsiveness Scale (SRS; Constantino &Gruber, 2005) and its update, the Social Responsiveness Scale-2 (SRS-2; Constantino & Gruber, 2012), are parent-report measures of autistic characteristics for children ages 4–18. First, children are rated by their parents on several different behaviours, using a Likert scale of 1–4. Then, the total score is calculated, where higher scores indicate higher levels of autistic traits.

Developmental, Dimensional and Diagnostic Interview (3Di; Skuse et al., 2004) The 3Di is a computer-based parent report completed in an interview format that utilises the ADI-R

diagnostic algorithms and measures the associated features of autism. Several instruments can be used to assess the full range of RRBs and their' dimensions in autism, such as the ADI-R or the Repetitive Behaviour Scale (RBS) and its' updated version, RBS-Revised (RBS-R) (Bodfish et al., 2000). The original RBS differentiates between three scales, and the new RBS-R identifies six subscales. An independent study assessing the validity of these subscales was found to support more or less all the RRB subtypes (Lam & Aman, 2007). The subscales are the following: Stereotyped Behaviour (apparently purposeless movements or actions that are repeated similarly); Self-Injurious Behaviour (activities or actions that cause or have the potential to cause redness, bruising, or other injuries to the body); Compulsive Behaviour, repetitive behaviours which are performed according to a rule or habit); Ritualistic Behaviour (performing activities of daily living similarly); Sameness Behaviour (resistance to change, insisting that things stay the same); and Restricted Behaviour, which includes (a limited range of focus, interest, or activity).

Thematic Analysis – Instruments Used to Measure Cognitive Abilities

The studies included in this section used several tests and later in the tables; however, only the ones relevant to this thesis will be discussed. Several different tests assessed executive functioning. For example, the Trail Making Test (TMT) includes three sub-tests: visual-and psychomotor speed abilities (TMT-A), multiple conceptual tracking and cognitive flexibility (TMT-B), and Wisconsin Card Sorting Test (WCST). The WCST is a standard neuropsychological test of executive functions, including cognitive flexibility, set maintenance and problem-solving. The Towers of Hanoi or London test measures executive function domains such as planning and working memory. Inhibition control was assessed by the Go/No-Go test, where participants respond to certain stimuli ("go" stimuli) and make no response for others ("no-go" stimuli). The Purdue Pegboard Test is a psychomotor test of dexterity. The test involves two different abilities: gross movements of arms, hands, and fingers, and fine motor extremity, also called "fingerprint" dexterity. The F-A-S test was also used to assess word generativity, a type of phonemic verbal fluency part EF (Patterson, 2011). During the trial, the participants are asked to produce words that begin with the letters F verbally, A and S. Most often, the participants are given one min to name as many words as possible beginning with one of these letters.

Intellectual ability was measured by standard measurements like the WAIS Wechsler Abbreviated Scale of Intelligence (WASI-II; Wechsler, 1999), the Wechsler-Adult-Intelligence-

Scale (WAIS-III; Wechsler, 1997). WASI measures verbal, performance, and full-scale IQ. The WAIS-III (Wechsler 1997) test comprising Full-Scale-(FSIQ), Verbal-(VIQ) and Performance-IQ (PIQ), the Index-Values Verbal Comprehension (Index-VC), Perceptual Organization (Index-PO), and Working Memory (Index-WM). Another frequently used test is the Wechsler Intelligence Scale for Children (WISC-III & IV), an intelligence assessment for children between the ages of six and sixteen. The tests consist of ten subtests (e.g.Visual Puzzles, Figure Weights, and Picture Span) which assess the mastery of analysing information, quantitative reasoning, and visual working memory (Wechsler, 1991; 2003). The Wechsler Preschool and Primary Scale of Intelligence (WPPSI; Wechsler, 1989) is also a standard measurement of intelligence for children between the age of three and seven. It measures progress via five subtests based on the five main areas of cognitive ability: verbal comprehension, fluid reasoning, visual-spatial ability, processing speed, and working memory. A less frequently used assessment is Leiter International Performance (Leiter-3) which offers an entirely nonverbal measure of intelligence using fluid reasoning and visualisation, as well as appraisals of visuospatial memory and attention from age three to 75+ years (Roid & Koch, 2017). The Mullen Scales of Early Learning (MSEL; Mullen et al., 1995) was used in younger children. The MSEL measures gross motor, visual reception, fine motor, expressive language, and receptive language abilities in children under five. Some studies used the Differential Ability Scale (DAS-II; Elliott, 2007). It is an assessment for children and adolescents between the ages of two and eighteen. The 22 subscales produce a general conceptual ability score corresponding to full-scale IQ and standard scores on Verbal (VIQ) and Nonverbal (NVIQ) domains.

Statistical Analysis

To investigate the phenotypical differences in the core symptoms, Cohen's *d* effect sizes of the corresponding subscales of the measurements of ADI-R, ADOS, SRS,3Di and RBS/RBS-R were compared between females and males with autism by weighted mean effect sizes. Random effect model weighted mean ES was computed for each study per core symptom cluster by first transforming the Cohen's d effect sizes from the studies using Fisher Z-Transformation, so they are all normally distributed. Then the inverse variance weight is computed by the study's sample size - 3. Next, the weighted mean effect sizes were calculated by multiplying the transformed ES by the inverse variance weights. The overall ES was calculated by summing the weighted mean

effect sizes and dividing the number by the overall weight. Where multiple assessments were used, producing more than one effect size, the studies were listed multiple times so that effect sizes of all subscales could be considered. To avoid giving these studies too much power by using their total sample size several times, the total sample size included the inverse variance weight of a study only once, even if they participated several times.

When conducting a meta-analysis, one can choose between a fixed and random effect model. The fixed effect model assumes that all differences between effect sizes observed in different studies are only due to sampling error. In other words, it is assumed that there is no heterogeneity. In the random effect model, it is assumed that there is heterogeneity. A method often used to study the potential sources of heterogeneity in meta-analyses is the 'subgroup analysis. In a subgroup analysis, the studies that I include were divided into several subgroups, and pooled effect size are calculated and then compared in R to see whether they differ significantly from each other. In this we assessed the heterogeneity via subgroup analysis by using odd ratio (*OR*). Additionally, forest plots were utilised to show the effect size by measuring the strength of the relationship among the sex outcomes and to explore the dispersion of effect sizes. The point estimate of the effect for a single study is represented by the box in the center of each horizontal line (confidence interval) in the forest plot. The box's size reflects how much the study weighs in comparison to the cpooled estimate. Additionally, funnel plots were made for all research, commonly used to identify publication bias in systematic reviews and meta-analyses. To investigate the associations more in dept, meta-regression was conducted. Meta-regression allows us not only to see how multiple study features are related to effect size, but also informs us about how they are affecting the effect size.

A thematic analysis was conducted to investigate the hypothesis regarding phenotypical differences in cognition in autism. Thematic analysis is a method of qualitative da analysis where we identify, analyse and report patterns within the data. It is helpful to organise and describe our data in detail, which helps to interpret the findings appropriately.

Results

Quantitative Analysis

The initial search yielded 150 records; thirteen studies were included after removing duplicates, screening, and excluding irrelevant articles. In total, five instruments were used to assess the core symptoms of autism, and two instruments had two versions (the ADOS and ADOS-G, RBS, and RBS-R). Only one study used 3Di; five used the RBS/RBS-R to investigate the RRBs, and five used SRS to examine the core symptoms. Two studies used only ADI-R, and two used only ADOS. Finally, five studies used both ADOS and ADI-R. The analysis included 7155 individuals: 6920 with ASD and 235 typically developing. 1251 (18.1%) females and 5672 males with autism participated (see Table 1 in Appendix).

Sex Differences in the Core Symptom Socio-Communication

Out of all included studies (K = 11), studies reported female superiority in Social Interaction (11) and Communication domains. The fixed model weighted mean ES for Communication was 0.13, with the standard error being 0.01. The significance test, which was conducted to test whether the population means (female vs male) are different, was 10.05. Thus the Null hypothesis was rejected. The fixed model weighted mean ES for Social Interaction was 0.11, with the standard error being 0.01. The significance test, which was conducted to test whether the population means (female vs male) are different, was 9.00. Thus the Null hypothesis was rejected. One study reported that males performed better in both domains (Hartley et al., 2009) and five studies reported mixed findings (Blöte et al., 2011; Holtmann et al., 2007; Ratto et al., 2017; Rodrigues et al., 2019; Solomon et al., 2012). In particular, one study found that males performed better than females with autism in the Social Interaction domain (Solomon et al., 2012-ADOS), while two studies reported that males with autism outperformed females with autism in the domain of Communication (Blöte et al., 2011-ADI-R; Holtmann et al., 2007-ADI-R). Four studies found that males outperformed females with autism in both Social Interaction and Communication domains (Blöte et al., 2011- ADOS; Hartley et al., 2009; Ratto et al., 2017- ADI-R; Rodrigues et al., 2019- ADI-R). All the studies with mixed findings included a young sample with an average age between eight and fourteen. Ratto and colleagues (2017) and Rodrigues and colleagues (2019) both used a sample of younger children with an average age of eight and ten, and both had an equal sample size of boys and girls with autism. The study by Blöte and colleagues

(2011) used a sample of older children with an average age of fourteen and an unequal sample size for girls and boys with autism. Two studies (Holtmann et al.,2007; Solomon et al., 2012) used equal sample sizes of girls and boys with autism. The effect sizes, both unweighted and weighted mean effect sizes, for these comparisons can be seen in Table 2 and Table 3 in the Appendix.

Sex Difference in the Core Symptom RRBs

A comparison between females and males on RRBS found that males with autism exhibited more RRBs than females with autism; out of all included studies included (n = 13), two studies found that some aspects of RRBs were higher in girls, while males scored higher on other features of this core symptom cluster (Antezana et al., 2019; Holtmann et al., (2007). Antezana and colleagues (2019) and Holtmann and colleagues (2007) utilised different diagnostic criteria and assessments. Both studies had samples of children between the ages of approximately six and fifteen. However, other studies with similar age groups had contradicting results. The fixed model mean weighted mean ES of this symptom cluster was -.30 with a .01 standard error. The significance test, which was conducted to test whether the population means (female vs male) are different, was -24.51. Thus the Null hypothesis was rejected. The mean effect sizes for these comparisons can be seen in Table 4 in the Appendix.

Meta-Analysis

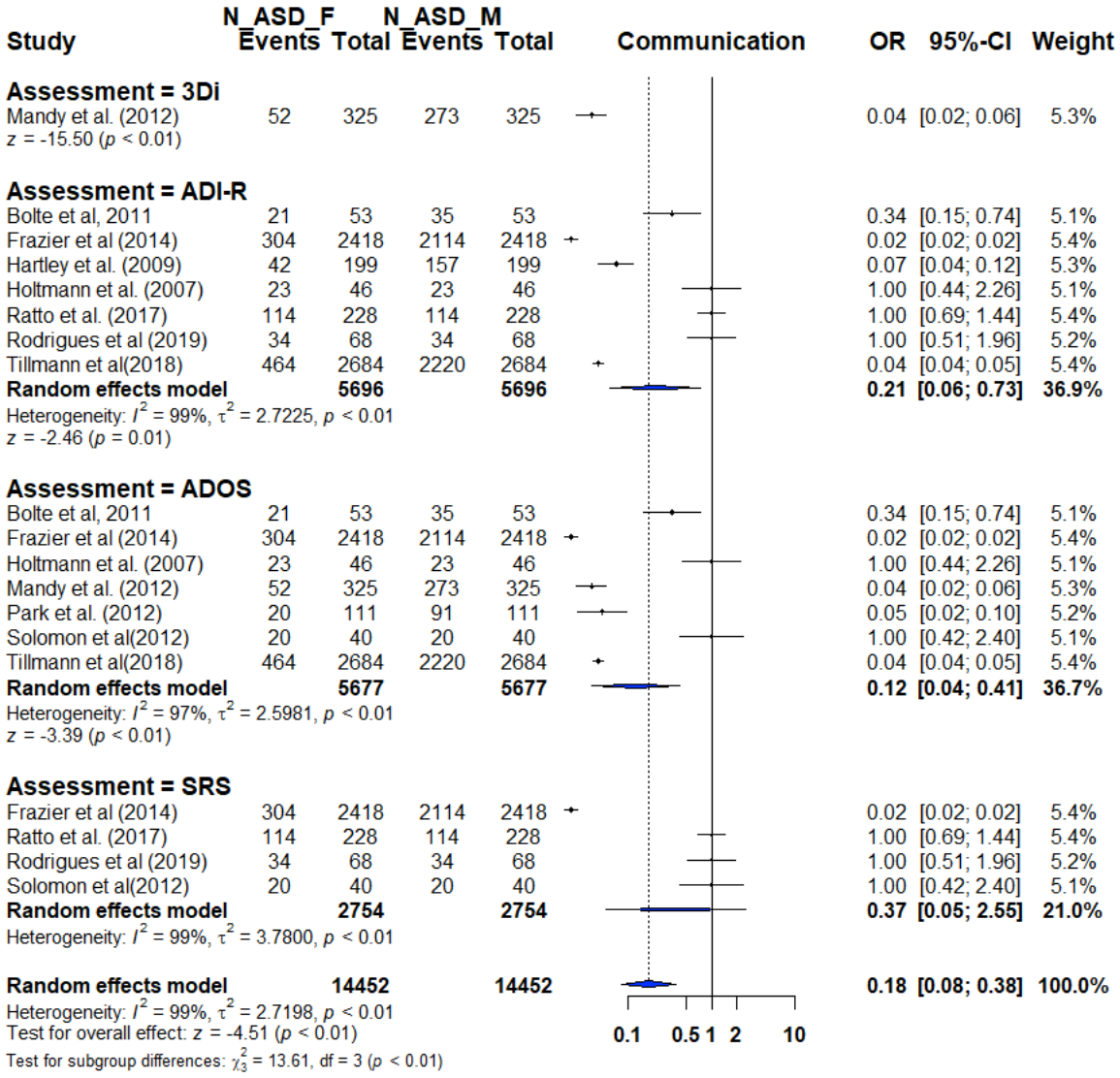
Communication Symptom Cluster

A Forest plot was created to display the effect size of the core symptom clusters between females and males with autism across all reported assessment tools. The overall effect of the forest plot was found to be statistically significant at $p < 0.05$ (95% *CI*), which implies that the findings can be generalised to the entire population.

A subgroup random effect meta-analysis using odd ratio (OR) was conducted to measure the effect of communication core symptom cluster between females and males with autism across the assessment tools. Females with autism perform significantly better compare to males with autism in all communication core symptoms clusters for any assessment tools used. The overall heterogeneity between the included studies was high and significant (I^2 = 99%, $p < 0.05$).

Figure 3

Forest Plot of All Communication Core Symptoms between Females and Males with Autism



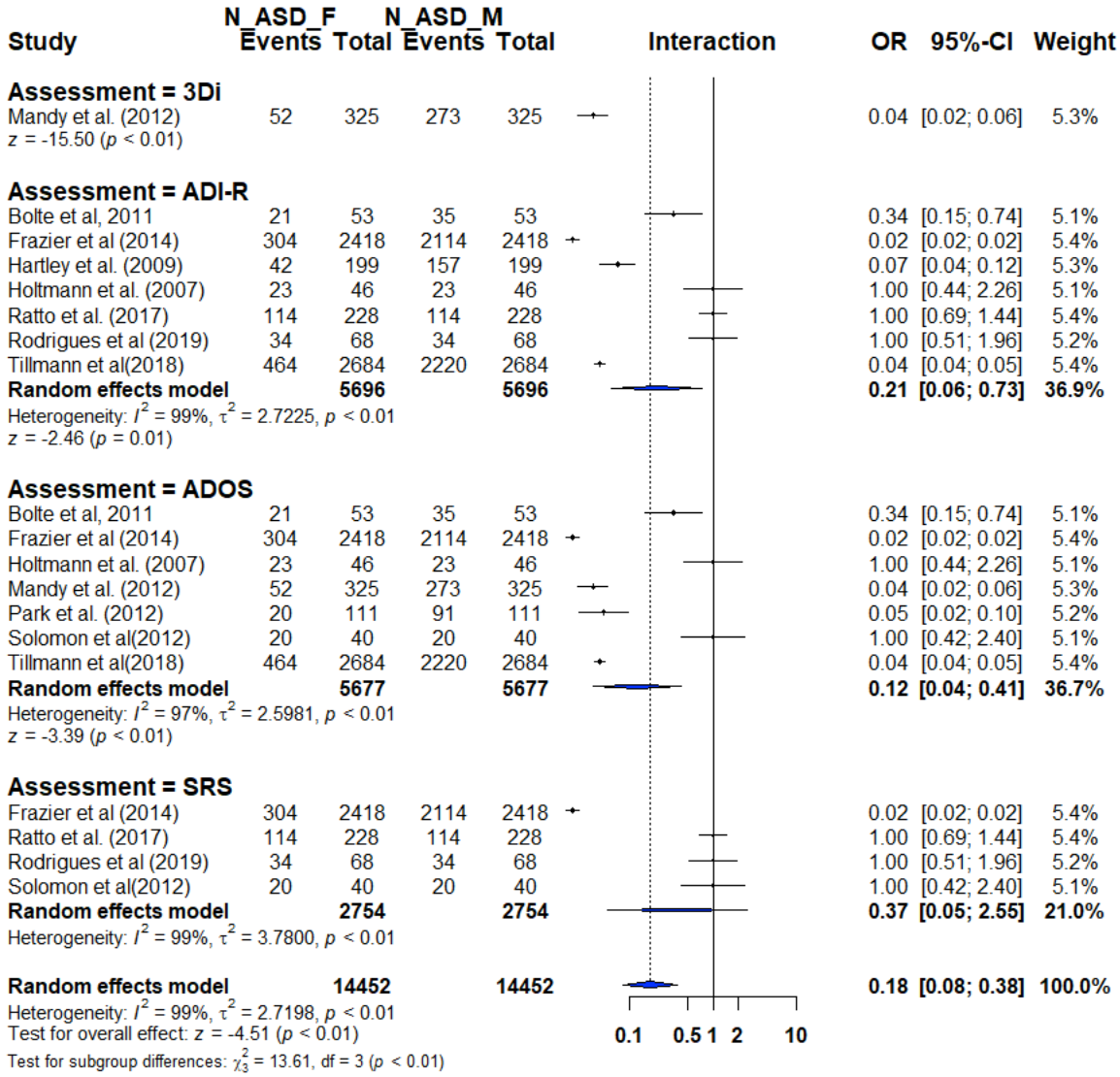
Meta-analysis of Interaction Core Symptoms

A subgroup random effect meta-analysis using odd ratio was conducted to measure the effect size of interaction core symptom cluster between females and males with autism across all reported assessment tools. Females with autism perform significantly better compare to males with autism in RRBs core symptoms cluster across all assessment tools used (Overall effect; Z = -4.51,

OR = 0.18, $p < 0.01$, 95% CI; 0.80-0.38). All p values < 5%). The overall heterogeneity between the included studies was high and significant ($I^2 = 99\%$, $p < 0.05$).

Figure 4

Forest Plot of Interaction Core Symptoms between Females and Males with Autism



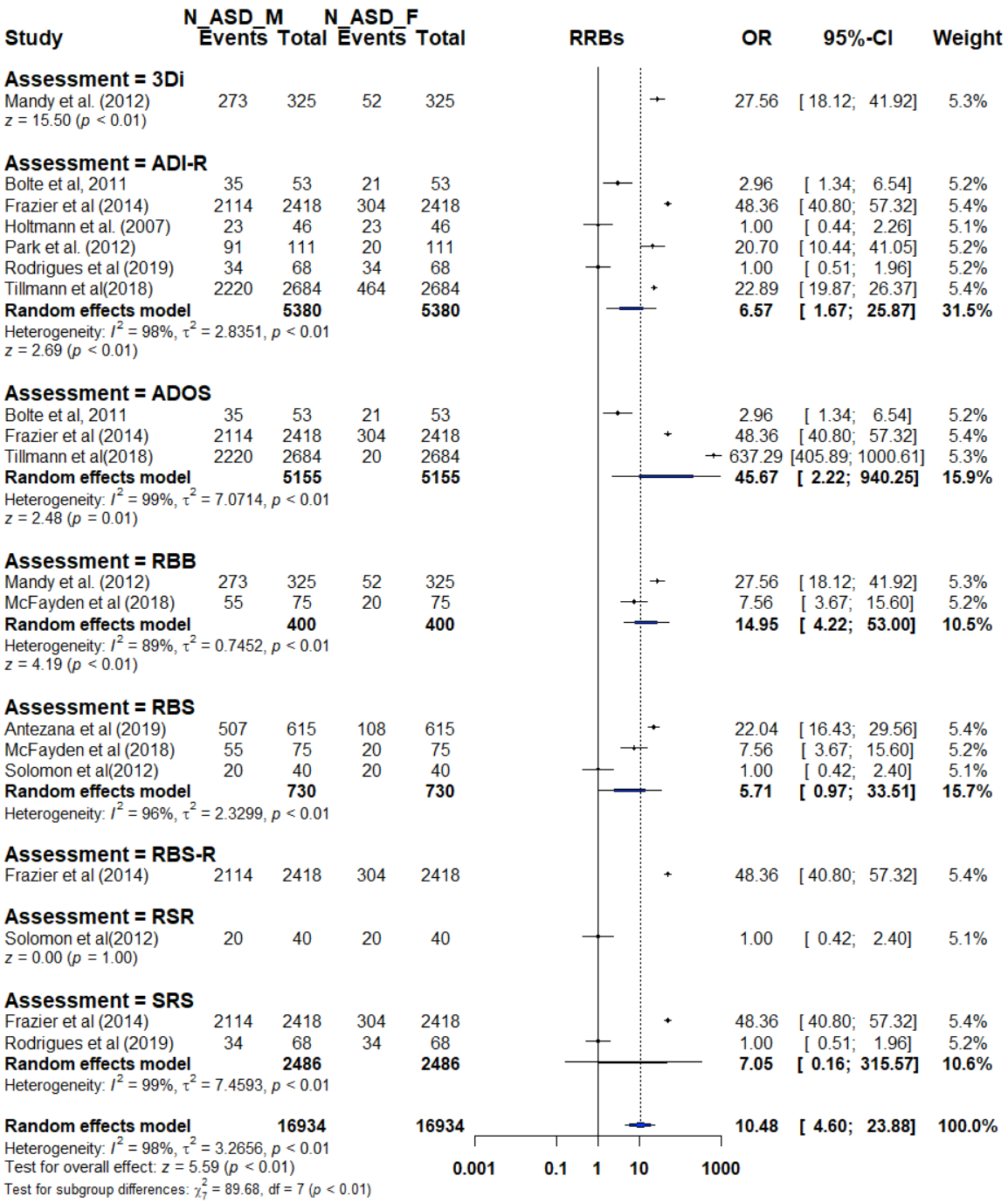
Meta-analysis of RRBs Core symptoms

A subgroup random effect meta-analysis using odd ratio was conducted to measure the effect size of RRBs core symptom cluster between females and males with autism across all reported assessment tools. Males with autism perform significantly better compared to females

with autism on RBBs core symptoms clusters across all assessment tools used (Overall effect; $Z = 5.59$, $OR = 10.48$, $p < 0.01$, 95% CI; 4.60-23.88). All p values < 5%). The overall heterogeneity between the included studies was high and significant ($I^2 = 98\%$, $p < 0.05$).

Figure 5

Forest Plot of RBBs Core Symptoms Comparison between Females and Males with Autism.


N_ASD_M N_ASD_F
Study Events Total Events Total RRBs OR 95%-CI Weight
Assessment = 3Di
Mandy et al. (2012) 273 325 52 325 27.56 [18.12; 41.92] 5.3%
z = 15.50 (p < 0.01)
Assessment = ADI-R
Bolte et al, 2011 35 53 21 53 2.96 [1.34; 6.54] 5.2%
Frazier et al (2014) 2114 2418 304 2418 48.36 [40.80; 57.32] 5.4%
Holtmann et al. (2007) 23 46 23 46 1.00 [0.44; 2.26] 5.1%
Park et al. (2012) 91 111 20 111 20.70 [10.44; 41.05] 5.2%
Rodrigues et al (2019) 34 68 34 68 1.00 [0.51; 1.96] 5.2%
Tillmann et al(2018) 2220 2684 464 2684 22.89 [19.87; 26.37] 5.4%
Random effects model 5380 5380 6.57 [1.67; 25.87] 31.5%
Heterogeneity: I^2 = 98%, τ^2 = 2.8351, p < 0.01
z = 2.69 (p < 0.01)
Assessment = ADOS
Bolte et al, 2011 35 53 21 53 2.96 [1.34; 6.54] 5.2%
Frazier et al (2014) 2114 2418 304 2418 48.36 [40.80; 57.32] 5.4%
Tillmann et al(2018) 2220 2684 20 2684 637.29 [405.89; 1000.61] 5.3%
Random effects model 5155 5155 45.67 [2.22; 940.25] 15.9%
Heterogeneity: I^2 = 99%, τ^2 = 7.0714, p < 0.01
z = 2.48 (p = 0.01)
Assessment = RBB
Mandy et al. (2012) 273 325 52 325 27.56 [18.12; 41.92] 5.3%
McFayden et al (2018) 55 75 20 75 7.56 [3.67; 15.60] 5.2%
Random effects model 400 400 14.95 [4.22; 53.00] 10.5%
Heterogeneity: I^2 = 89%, τ^2 = 0.7452, p < 0.01
z = 4.19 (p < 0.01)
Assessment = RBS
Antezana et al (2019) 507 615 108 615 22.04 [16.43; 29.56] 5.4%
McFayden et al (2018) 55 75 20 75 7.56 [3.67; 15.60] 5.2%
Solomon et al(2012) 20 40 20 40 1.00 [0.42; 2.40] 5.1%
Random effects model 730 730 5.71 [0.97; 33.51] 15.7%
Heterogeneity: I^2 = 96%, τ^2 = 2.3299, p < 0.01
Assessment = RBS-R
Frazier et al (2014) 2114 2418 304 2418 48.36 [40.80; 57.32] 5.4%
Assessment = RSR
Solomon et al(2012) 20 40 20 40 1.00 [0.42; 2.40] 5.1%
z = 0.00 (p = 1.00)
Assessment = SRS
Frazier et al (2014) 2114 2418 304 2418 48.36 [40.80; 57.32] 5.4%
Rodrigues et al (2019) 34 68 34 68 1.00 [0.51; 1.96] 5.2%
Random effects model 2486 2486 7.05 [0.16; 315.57] 10.6%
Heterogeneity: I^2 = 99%, τ^2 = 7.4593, p < 0.01
Random effects model 16934 16934 10.48 [4.60; 23.88] 100.0%
Heterogeneity: I^2 = 98%, τ^2 = 3.2656, p < 0.01
Test for overall effect: z = 5.59 (p < 0.01)
Test for subgroup differences: χ^2_7 = 89.68, df = 7 (p < 0.01)
0.001 0.1 1 10 1000

Meta-Regression

To investigate and estimate the effect of the assessment tools and age factors on the effect size, I performed a meta-regression. The results of the regression presented in Table 1, 2 and 3 show that the estimated coefficient of 3Di, ADI-R and ADOS assessment models were all significant (All p values < 0.05). This implies that the three assessment tools have a significant impact on the effect size. Furthermore, the age of females with autism (X_Age ASD Females) had significant effect on the effect size (p < 5%).

Table 1

Results of Meta-regression Assessing the Effects of Assessment and Age on the Overall Effect Size in the Communication Symptom Cluster

				95% Confidence Interval	
Factors	Estimate	*SE*	*P value*	Lower	Upper
3Di	3.3164*	1.71	0.0111	-4.96	0.33
ADI-R	-1.5564*	0.64	0.0302	-1.95	-0.27
ADOS	-2.0983**	0.55	0.0049	-3.49	-0.80
SRS	-0.9966	0.76	0.0649	-2.73	0.84
X_Age_ASD_M	1.4906	0.02	0.4010	2.00	0.64
X_Age_ASD_F	2.6000*	0.01	0.0020	1.83	0.41

Note. I^2 = 99.05%, Test for Residual Heterogeneity: QE (df = 15) = 1192.94, p-value < .0001, Test of Moderators (coefficients 1:4): F (df1 = 4, df2 = 15) = 5.30, p-value = 0.0073.

* p < 0.05, ** p < 0.01

Table 2

Results of Meta-regression Assessing the Effects of Assessment and Age on the Overall Effect Size in the Interaction Symptom Cluster

				95 % Confidence Interval	
Factors	Estimate	SE	P-value	Lower	Upper
3Di	-3.3165*	1.71	0.0713	-6.96	0.33
ADI-R	-1.5564*	0.65	0.0301	-2.94	-0.17
ADOS	-2.0983**	0.65	0.0057	-3.49	-0.71
SRS	-0.9966	0.86	0.2649	-2.83	0.84
X_Age_ASD_M	0.4906	0.22	0.1600	2.00	0.64
X_Age_ASD_F	0.6000*	0.012	0.0000	1.83	0.31

Note.I^2 = 99.05%, Test for Residual Heterogeneity: *QE* (df = 15) = 1192.94, p-value < .0001, Test of Moderators (coefficients 1:4): *F*(df1 = 4, df2 = 15) = 5.30, p-value = 0.0073.

* $p < 0.05$, ** $p < 0.01$

Table 3

Results of Meta-regression Assessing the Effects of Assessment and Age on the Overall Effect Size in the RRBs Symptom Cluster

				95 % Confidence Interval	
Factors	Estimate	*SE*	P-value	Lower	Upper
3Di	1.2165*	1.61	0.0013	-6.96	0.33
ADI-R	1.4564*	0.66	0.0301	-2.94	-0.17
ADOS	4.0983**	0.61	0.0057	-3.49	-0.71
SRS	0.9966	0.06	0.2649	-2.83	0.84
X_Age_ASD_M	2.4900	0.12	0.0000	0.00	0.10
X_Age_ASD_F	2.6001*	0.11	0.0700	0.33	0.42

Note. I^2 = 99.05%, Test for Residual Heterogeneity: *QE* (df = 15) = 1192.94, p-value < .0001, Test of Moderators (coefficients 1:4): *F*(df1 = 4, df2 = 15) = 5.30, p-value = 0.0073.

* $p < 0.05$, ** $p < 0.01$

Thematic Analysis

The initial search yielded 1225 records; after removing duplicates, screening, and excluding irrelevant articles, 18 studies were included in the qualitative analysis. Five studied executive functioning, and eleven investigated IQ and two both (see Table 8 in the Appendix).

Sex Difference in Executive Function (EF)

Of the seven studies that were included in this analysis, four found sex differences on tasks assessing the domains of EF.; three of the four studies found that males performed better on EF tasks compared to females with autism (Lemon et al., 2011; Mermari et al., 2013; Kiep & Spek, 2016). The study by Memari and colleagues (2012) showed that girls performed worse in WCST measures (e.g. girls made significantly more perseverative errors and completed fewer categories) than autistic boys, which supports our hypothesis. Similarly, in the study of Kiep and Spek (2016), females with autism performed better on some aspects of working memory tasks than males with autism. In particular, they were able to reproduce more extended digit spans repetition (of increasingly longer strings of numbers in the same order as was presented to the participant) than men with autism. However, autistic men could produce longer sequences (by digit span sequencing, a sequence of numbers is read and recalled in ascending order) than women with autism. Additionally, women with autism completed more strategies than men with autism. Lemon and colleagues (2011) found slowed response inhibition in females with autism compared to autistic males on the stop task.

One study found that females with high-functioning autism outperformed high-functioning males with autism on EF tasks (Kumazaki et al., 2015). Out of all the included papers, this study (2015) utilised the youngest participants, with an average age of seven and a half years.

Three studies reported mixed results, namely Lehnhardt and colleagues (2016), who assessed the domain of cognitive flexibility and found that females with autism outperformed males in EF-related tasks such as processing speed and the Trail-Making-Test (TMT), showing showed higher verbal abilities. Similarly, Blöte and colleagues (2011) results also showed that females performed better compared to males with autism on TMT, but males outperformed females on BD. Lai and colleagues (2012) found that although both female and male groups showed a deficit, males with autism performed worse on response inhibition and sensitivity to signal tasks and on the dexterity subtest of motor executive function, males and females with autism performed similarly. In all of

these studies, the verbal and non-verbal IQ of the participants were average above 105, which are the highest among the included studies.

Intelligence

Out of 13 papers assessing intelligence, two found sex differences on at least one of the subscales. Banach and colleagues (2009) reported that in their study, in the IQ range 0-50, females with autism (54,8%) were more precedent compared to males (20.3%), while in the IQ range 51-70 the sex ratio was similar. In the higher range (IQ>70), males were more predominant (56,4%) compared to females with autism (21,4%). Frazier and colleagues (2014) found that females with autism showed significantly lower overall verbal and nonverbal cognitive scores and reduced language scores than males with autism.

Six studies found no significant sex difference (Hartley et al.,2009; Lai et al., 2011; Mandy et al., 2012; Mussey et al., 2007; Kumazaki et al., 2015; Reinhardt et al., 2015). Four of these studies used young participants, ages ranging from approximately two to nine years (Hartley et al.,2009; Mandy et al., 2012; Mussey et al., 2007; Kumazaki et al., 2015). Lai and colleagues (2011) and Reinhardt and colleagues (2015) both had participants in their 20s. All studies included had a higher male-to-female ratio. The design and diagnostic criteria do not seem to show any patterns across the studies.

Five studies reported mixed results, where females performed better on specific subtests while males on others (Ankenman et al., 2014; Carter et al., 2007; Howe et al.,2015; Koyama et al.,2009; Lehnhardt et al., 2015). Four studies included younger participants, ages ranging from approximately two to nine years (Ankenman et al., 2014; Carter et al., 2007; Howe et al.,2015; Koyama et al.,2009). The studies where the design was Simons Simplex Collection (SSC) had participants whose IQ scores were the lowest; in Howe and colleagues' study (2015), the participants' IQ was less or equal to 70, and in Ankenman and colleagues' (2014) the average IQ was approximately 91.

Discussion

The main goals of the meta-analyses and the thematic analysis conducted as part of this thesis were to increase further our understanding of the differences in females and males with autism on the two main core symptom clusters, namely social communication and restricted and repetitive behaviours (RRBs) and cognition processes such as executive function and IQ. Due to

the small number of studies that fitted the search parameters, the analysis was divided into two questions: First, sex differences in core symptoms were examined and second, the sex differences in cognitive aspects were addressed.

Differences in Core Symptoms - Social Communication and RRBs

Autism spectrum disorder (ASD) comprises a phenotypically heterogeneous group of disorders. Phenotypic aspects indicating heterogeneity are, among others, age of onset, severity, and combination of symptoms, as well as language and cognitive development. Although it is expected that the delineation of phenotypically distinct autism subgroups will allow a more comprehensive understanding of the disorder and the individuals' needs regarding diagnostic and treatment options (Cholemkery et al., 2016), it might not be as helpful in understanding the differences seen in sexs, as it focuses the attention more to the individual differences while ignores the larger context, for example, differences in the expression of symptoms.

The meta-analysis determined that gender has a significant effect on all three symptom clusters. The effect size calculation and the meta-analysis both found that in line with hypotheses females with autism performed better on the social communication symptom cluster. In line with our hypothesis results indicate that males with autism scored higher on RRBs compared to females with autism. The meta-regression investigating whether age and assessment type affect the effect size found that three assessments namely 3Di, ADI-R and ADOS have a significant impact on the effect size. Additionally, the findings of the meta-regression further indicate that on all three symptom clusters, female age significantly affected the overall effect size.

When interpreting these results, the following points should be considered. The findings indicating that females with autism perform better than males with autism could also be explained by the aftermath of the re-organisation of symptom clusters for DSM-5, where ADOS has been altered accordingly while ADI-R is yet to be revised. As not all the studies included in this thesis used the criteria of DSM-5, these differences may be influenced by the present results. Furthermore, the studies used several different measurements to assess autism symptoms and, in several studies, (Blöte et al., 2011; Holtmann et al.,2007; Ratto et al., 2017; Solomon et al.,2012; Rodrigues et al., 2019). The different assessments arrived at differing conclusions, namely that the females with autism outperformed males with autism on one assessment while not on the other.

These differences found in the subscales (Social interaction and Communication) were inconsistent between the assessments. The study by Blöte and colleagues (2011) found that females with autism performed better on the Social Interaction subscales of ADI-R, while on the Communication subscales of ADI-R and the ADOS subscales, males with autism scored higher. Holtmann and colleagues (2007) also used ADOS and ADI-R to assess the core symptoms. Their results showed that autistic women performed better than males except on the ADI-R communication subscale, where autistic males outperformed females with autism. Solomon and colleagues (2012) used SRS and ADOS in their study. Their results showed females with autism performing better than males with autism on all subscales except ADOS social interaction subscale.

In two studies (Ratto et al., 2017; Rodrigues et al., 2019), the differences were consistent between the subscales: males with autism performed better than females with autism on both ADI-R Social Interaction and Communication scales. Both studies used a sample of younger children with an average age of eight and ten, and both had an equal sample size of boys and girls with autism. This indicates that the varying result might be a result of imbalanced gender representation in the sample and not so much the differences in assessments as suggested previously (Falkmer et al., 2013; Lebersfeld et al., 2021).

Social-Communication

The first part of the analysis investigated whether females and males differ in socio-communication core symptoms, namely, whether females show a lower level of impairment in socio-communicational functioning compared to males with autism. The analysis included 21 studies and demonstrated mixed results. In particular, 16 studies supported female superiority in the socio-communicational dimension, while four studies concluded that males with autism outperformed females in the socio-communication cluster. In addition, one study found that males performed better on the social interaction subscale of ADOS (Solomon et al., 2012), and two studies reported that males with autism performed better on the Communication subscale of ADI-R compared to females (Blöte et al., 2011; Holtmann et al., 2007). All studies included a young sample with an average age between eight and fourteen. Ratto and colleagues (2017) and Rodrigues and colleagues (2019) both used a piece of younger children with an average age of eight and ten, and both had an equal sample size of boys and girls with autism. The study by Blöte

and colleagues (2011) used a sample of older children with an average age of fourteen, and unequal sample size for girls and boys with autism was present. Two studies (Holtmann et al.,2007; Solomon et al., 2012) used equal sample sizes of girls and boys with autism. These inconsistencies may be due to the age of the children, and their social (for example, language, verbal fluency) and cognitive development were influential, as well as the difference in the assessment methods. For instance, while ADI-R explores a child's early developmental history through interviewing parents, the ADOS focuses on assessing the child's current functioning in social communication and play through a play session.

The results of the meta-analysis indicates that gender has a significant effect on all three symptom clusters. The effect size calculation and the meta-analysis both found that in line with hypotheses females with autism performed better on the social communication symptom cluster. Furthermore both gender and assessment type were found to have significant effect on the effect size. When interpreting these results, the following points should be considered. First, the current results of females with autism performing better in the socio-communication cluster than males with autism fit well with previous findings. Studies established that females and males might meet the diagnostic criteria differently. Females with autism seem to be better at this core symptoms cluster. Namely that similarly to their typically developing, they seem to be better at engaging in reciprocal social interaction,s including integrating both non-verbal and verbal expressive behaviours (Lai & Szatmari, 2020).

Similarly to the typically developing population, females with autism seem to view friendship as more desired, meaningful and rewarding. Thus as expected, they seem to have better social attention skills, higher social motivation and interest in friendships and, therefore, better friendship initiation than males with autism (Lai & Szatmari, 2020). This points to how the reported differences, besides potential biological bases, may reflect on the influence of current gender norms and associated socio-cultural contexts that might shape the assumptions of professionals and educators regarding people with autism and their assumed behaviour.

Additionally, it has been suggested that the accuracy of the assessments might fluctuate with age (Gray et al., 2008), which would also explain the mixed results. For example, a higher level of inaccuracy for all domains was reported in older children, significantly when lower levels of expressive language abilities also hinder assessments (Falkmer et al., 2013; Gray et al., 2008). Thus, some assessments may be used in childhood, while others in adulthood.

'Camouflaging' has been also suggested as a potential factor influencing the mixed results in socio-communication skills in females with autism (Lai & Szatmari, 2020). Camouflaging is considered a common way of compensating for difficulties experienced in the socio-communication cluster. Besides compensating, camouflaging also includes masking behavioural features considered symptoms of autism (Lai & Szatmari, 2020). Camouflaging has been difficult to conceptualise because it consists of complex behaviours and research investigating its' effect in autism research is still in its infancy (Lai & Szatmari, 2020).

Finally, the higher prevalence of diagnosis among males with autism may stem from multiple sexes/gender-related factors which affect behavioural presentations (mentioned above). Still, the biases of the referral sources and diagnostic processes might also significantly affect this under-recognition of females with autism. Regarding biases in referral sources such as parents, general practitioners, or therapists, studies found that expectancy bias is associated with autistic characteristics and the common knowledge that autism is more prevalent in males than females. This means that females might be labelled as shy while boys are unresponsive. This is problematic because this limited view hinders further examination and can lead to dismissal and delayed diagnosis (Lai & Szatmari, 2020). Additionally, results show that parents are less likely to name autism as a cause of difficulties in females than in males (Lai & Szatmari, 2020). Similarly, older females report dismissal by GPs and are often misdiagnosed, as autism is not considered (Lai & Szatmari, 2020).

Restricted repetitive behaviours (RRBs)

The result of the meta-analysis align with the second hypothesis that women score lower on restrictive-repetitive behaviours than males. Of the thirteen studies, eleven found that males with autism exhibit a higher frequency of RRBs than females with autism. These results align with several studies demonstrating that females with autism show fewer RRBs (Frazier et al., 2014; Hartley & Sikora, 2009; Lord et al., 1982; Mandy et al., 2012; Szatmari et al., 2012; Tillman et al., 2018; Van Wijngaarden-Cremers et al., 2014). The results of one of the papers (Antezana et al., 2019) used in our study partially contradict our hypothesis and other findings on which our hypothesis is based. They assessed participants with autism between three and eighteen years of age. Their results showed sex distinction based on elevated scores on items related to different aspects of RRBs (e.g. stereotyped motor behaviour, pre-occupation with objects or with the

movement of things, self-injurious and compulsive behaviours such as biting and sensory challenges). In line with previous research, Antezana and colleague found increased stereotyped motor behaviour and preoccupation with the movement of objects in affected boys compared to girls with autism. However, girls presented more self-injurious and compulsive behaviours and sensory challenges.

It has been observed that lower RRBs occur when no co-occurring or low intellectual disability is present. Lower RRBs in females are more likely found in young children without intellectual disabilities and adults, including those diagnosed later in life. It has been suggested that non-verbal intelligence is related to the differences found in RRBs in autism (Tillman et al., 2018); however, the small sample size-related power issue might affect the reliability of this study. On the other hand, a connection between RRBs and cognitive flexibility in autism has been suggested (Albeit -Urious et al., 2018).

Detailed observation shows that differences in the subdomains (e.g. stereotype and repetitive motor behaviour, preoccupation with restricted interest, self-injurious and compulsive behaviours, sensory challenges) do not influence the overall RRBs score. For example, females with autism exhibit less stereotyped use of objects and less or different contents of narrow interests, such as topics related to people and animals rather than objects and things which are more likely to be noted by parents as "odd". If the seemingly gender-typical contents shadowed the intensity, exclusivity, and functional impact of their interests, the presence of narrow interests could be overlooked. Consequently, it is more than likely that some behavioural examples of autism may not be well captured by standard measures, which contributes to the mixed picture (Antezana et al., 2019).

To sum up, these thesis findings seem to add to the growing literature suggesting that females with autism show fewer RRBs, but exhibit a more similar autistic phenotype to males concerning social communication difficulties at younger and older ages. However, in the absence of longitudinal data in this study, conclusions about symptom trajectory or developmental changes should be considered with caution (Tillman et al., 2018).

Differences in Cognition

Executive Functioning (EF)

Although it has been established that individuals with autism experience more EF difficulties compared to typically developing persons (Lai et al.,2012, Memari et al.,2013; Toske et al.,2018), studies on EF-related sex differences are limited, and the results are mixed with some research findings point to differences between males and females with autism on EF (Kiep & Spek, 2016; Lai et al., 2012, 2017; Lehnhardt et al., 2016; Lemon et al., 2011; Memari et al., 2013), while others do not (Lai et al., 2011;2017) therefore distinct profiles are yet to be defined. To investigate this topic further, our third aim was to determine whether women with autism perform poorer on EF domains than males with autism and this thematic analysis results offer partial support to our hypothesis. The results of assessing sex differences in executive functioning, a domain of cognition, indicate mixed results. Four studies found sex differences in tasks assessing the domains of EF.; three of these four found that males performed better on EF tasks than females with autism (Lemon et al., 2011; Mermari et al., 2013; Kiep & Spek, 2016). One study found that females with autism outperformed males with autism on EF tasks (Kumazaki et al., 2015). Three studies reported mixed results.

Executive function and self-regulation skills are the mental processes that enable us to plan, focus attention, remember instructions, and juggle multiple tasks successfully. One of the skills of EF is cognitive flexibility which is adapting our behaviour and thinking as a response to changes in the environment, which is often more difficult for individuals with autism. The resulting behaviour is often described as “rigid thinking”. Two of the included studies indicated that females with autism outperformed males in EF-related tasks such as the Trail-Making-Test (TMT) (Blöte et al., 2011; Lehnhardt et al., 2016). Contrary to these findings, Memari and colleagues (2012) showed that girls performed worse in WCST measures (a test assessing set shifting, among other things), which supports our hypothesis.

Similarly, Kiep and Spek's (2016) results showed differences between females and males with autism in terms of errors; they made more preservative errors, continuing with the same response strategy after a rule switch than autistic males. The sex differences in EF support theories derive from studies such as Hedvall and colleagues (2013). They argued that the performance of higher-order cognitive tasks is significantly influenced by individual processing speed. As discussed previously, females often get diagnosed at an earlier stage of life if they show an increased level of impairment. Consequently, the difference found in the current study likely reflects this fluctuation in individual processing speed among females and males with autism. An

alternative explanation is similar to what has been found in typically developing populations, which is that sex is not always significantly related to WCST performance, especially once possible confounding factors (developmental delay, education) have been accounted for (Lai et al., 2011; Memari et al., 2012). For example, in the study of Lai and colleagues (2011), developmental language delay was found to influence cognition. Considering the evidence collected from these studies, our hypothesis that women with autism show better executive functioning (e.g. TMT) than men with autism has not been proved. Further investigation is needed where confounding variables such as education and comorbid disorders (e.g. Tourette syndrome) are controlled, and IQ is matched between the participants.

Response inhibition, a cognitive aspect, when impaired, is associated with impulsiveness, risk-taking, and general executive dysfunction (e.g., impaired planning and organisation (Lemon et al., 2010). In the context of autism, impaired response inhibition is thought to impact social abilities (e.g., appropriate social conduct). The studies included in this analysis showed mixed results; Lemon and colleagues (2011) found slowed response inhibition in females with autism compared to autistic males on the stop task, which aligns with our hypothesis, while Lai and colleagues (2012) did not replicate these findings in their sample. There are several explanations for these mixed results. First of all, the effect of age should is considered; Lemon and colleagues used a sample of children, while Lai and colleagues (2012) had a sample of adults with autism. Another explanation for such varying findings can be the effect of dexterity. Lai and colleagues (2012) reported a strong sex-by-diagnosis interaction on the dexterity subtest of motor executive function. This implies a potential sex difference in fine motor impairment that is common in autism, such as dyspraxia. In line with the idea that in a large sample of children and adolescents, females with autism have been found to have less fine motor impairment (Mandy et al., 2012). Another aspect of dexterity was assessed using Coding measurements (Kumazaki et al.,2015), where females with high-functioning autism performed better than males with autism. This also supports the above-mentioned possible sex difference in fine motor impairment and highlights the importance of understanding other confounding variables when assessing aspects of EF.

Working memory is an EF skill that is essential for reasoning and the guidance of decision-making. In contrast, the verbal fluency domain facilitates information retrieval from memory and is closely connected with other cognitive processes, such as inhibition and set-shifting. Notably, both domains seem to be impaired in individuals with autism, but the results regarding sex

differences are mixed. Kiep and Spek's (2016) study, females with autism, performed better on some aspects of working memory tasks than males with autism. Furthermore, based on their result,s they argued that Full-Scale IQ, measuring an individual's overall cognitive and intellectual functioning level, is closely associated with working memory. The hypothesis that women need to be more significantly impaired to receive a diagnosis might explain these findings, as it suggests that women who participate in these studies might have lower functioning, including IQ (Hiller et al., 2014; Hull et al., 2020). If IQ is an influential factor in EF, then it is expected to see these women underperforming on such tasks.

All in all, EF skills function multi-directionally, making it challenging to understand how individual skills are affected by autism and whether there is a notable difference between the sexes. Age and severity and, consequently, intelligence seem to be three recurring features that are believed to affect EF significantly. Therefore, further investigation is needed where participants are either clustered or matched by age and intelligence to verify the effect of these two features.

Intelligence

The FPE theory has suggested that women need to be more significantly impaired to receive a diagnosis (Hiller et al., 2014; Hull et al., 2020). In addition, findings suggest that women with lower IQ are more likely to be diagnosed than females with high IQ because lower IQ is associated with more profound impairments (Mandy et al., 2012; Rivet & Matson, 2011b; Van Wijngaarden-Cremers et al., 2014). Based on these, our fourth and final hypothesis was that females with autism perform worse on intelligence assessments than males with autism. Two of 13 papers assessing intelligence found sex differences on at least one of the subscales, while six studies found no significant sex difference. Finally, five studies reported mixed results, where females performed better on specific subtests while males on others. Thus the results of our thematic analysis showed mixed or no significant differences between males and males with autism. Therefore our hypothesis was rejected.

While the estimation of the sex ratio of females to males with autism diagnosis ranges from 4.3 to 1 (males to females) (Loomes et al. 2017), IQ is often assessed by a ratio that follows a range associate pattern. Here in the low IQ (≤ 70), the ratio is 1.9:1 (males to females), and in the normative range (> 70), the ratio is 5.8:1 (males to females) (Tillman et al., 2018). Similarly, Banach and colleagues (2009) reported that in their study, in the IQ range <50, females with autism

(54,8%) were more precedent compared to males (20.3%). In the IQ range 51-70, the sex ratio was similar, and in the higher range (IQ>70), males were more predominant (56,4%) compared to females with autism (21,4%). Mandy and colleagues (2012) reported that high-functioning autistic boys and girls performed very similarly on both verbal and non-verbal IQ assessments. This would further support the observation of sex difference in the normative IQ range (< 70), where the ratio is more female-dominant (Tillman et al., 2018). Howe and colleagues (2015) used a different approach, but their findings align with the earlier two studies. They used the Modules of the ADOS to investigate the differences between females and males with autism. In the ADOS Module 1, which was used to assess nonverbal participants, no difference was detected between sex. However, on ADOS Module 2, which was used for individuals whose ability included phrase speech, females showed lower Full-Scale IQ scores compared to males with autism on several data sets. On ADOS Module 3, used for verbally fluent individuals, the IQ scores were similar between females and males (except for one dataset, where females had a lower IQ score than males). Their findings suggest several things. First, current criteria may be sensitive to either significantly lower or higher functioning in females with autism. Secondly, that females with autism with fluent speech are less impaired in general, which is in line with the FPE theory. Furthermore, it supports the hypothesis that women with lower IQ are more likely to be diagnosed compared to women with high IQ because lower IQ is associated with more profound impairments, including language-related difficulties (Mandy et al., 2012; Rivet & Matson, 2011b; Van Wijngaarden-Cremers et al., 2014). Potential reasons behind different datasets reporting varying results include slightly different populations. For example, other sex and clinical sample ratios may be heterogeneous concerning the level of symptoms that lead to referral.

Additionally, Carter and colleagues (2007) investigated the sex-based differences in cognitive profiles using the MSEL in a sample of young children. Their findings suggested better performance o on-verbal cognitive skills in girls and better versions of boys in language skills. Hartley and Sikora (2009) reported similar MSEL profiles in boys and girls, which seem to offer additional support to the FPE theory. Ankenman and colleagues (2014) studied the discrepancy between VIQ and NVIQ between females and males with autism. Contrary to the previously mentioned results, their analysis indicated that males and females did not differ in verbal IQ, but males scored significantly higher in nonverbal IQ.

Furthermore, they found that fewer females and more males than expected were represented in the NVIQ >VIQ discrepancy group (higher nonverbal IQ than VIQ). The ability to verbalise may be a great predictor of one's over-cognitive functioning level, in which case further investigation would be beneficial. Alternatively, as mentioned before, current criteria may be sensitive to deficient functioning or significantly higher functioning in females with autism. The standard measurement such as various versions of Wechsler tests (e.g. WASI, WISC; Wechsler, 1981, 1991, 1999), Raven's Progressive Matrices (RPM; Raven et al.,1998) and MSEL (Mullen, 1989, 1995) have been commonly used to assess individuals with autism. However, it is often difficult to utilise these tests as they usually do not consider the difference between typically developing and autistic individuals, such as their level of functioning or verbal abilities. Suppose conventional IQ measures such as the Wechsler Intelligence test underestimate the intelligence level due to their language-demanding assessment methods. In that case, this can lead to faulty conclusions about the functioning level and cognitive profile of individuals with autism (Bodner et al., 2014, Mussey et al., 2017). It has been suggested that some tests are more flexible and can better capture the IQ profile of individuals with autism. For example, the RPM is argued to focus more on general fluid reasoning, which is said to be less intact in persons with autism (Bodner et al., 2014).

Limitations

This study is not without limitations. Studies often use rigorous inclusion criteria, leaving out children with additional challenges. This leads to highly homogenous research samples and results that might need to be more generalisable to the clinical population (Neuhaus et al., 2017; Tillman et al., 2018). This study used the presence of comorbid features as an exclusion criterion, thus potentially missing essential research. Furthermore, studies were not distinguished based on high-functioning samples or low-functioning, which could affect our findings as some evidence suggests that these differences in the social communication symptom cluster are only observed in higher-functioning samples (Amaral et al, 2008).

The assessment used in the studies included also carries limitations. Since autistic traits are measured mainly by self or other reports such as observation, rater bias should be considered a potentially influential factor. Furthermore, the utilisation of several assessments may complicate

the interpretation of results, as the strengths and weaknesses of the assessments and the concept they try to capture might influence the findings significantly.

The analysis conducted also has limitations. Females with autism are very often underrepresented in studies. Consequently, small sample sizes can lead to limited statistical power, which might not be sufficient to detect small to moderate effects (Tillman et al., 2018). Furthermore, IQ has been found to play an influential role in the symptom severity of autism. It would have been beneficial to conduct additional analysis to explore whether IQ explains any of the observed effects.

Recommendations

The studies in the thesis assessed individuals using gold-standard measurements such as ADOS and/or ADI-R. Although studies report a high level of diagnostic accuracy on both, it has been suggested that for better clinical accuracy, both should be used in addition to interviews and reports in a holistic manner (Risi et al., 2006; Kim & Lord, 2012). As mentioned earlier, these gold standard measures may be biased towards male autism as they were developed relying heavily on male-based samples. Thus, while the alteration of classification, namely introducing the dyad of clusters, is well supported by factor analyses and meta-analyses, more qualitative studies are needed to expose the differences in the expression of symptoms. Different criteria and/or new behaviour exemplars need to be established that are more sensitive to female autism. Age and/or IQ-based matching of male and female participants of studies would be beneficial to assist further the more accurate comparison of performances on the standard measurements.

Lastly, evidence indicates differential developmental effects in language related to sex. In the typically developing population, females tend to show more advanced early language development than males and more extensive vocabularies than males. Still, such a difference normalises later in middle childhood and adolescence (e.g., Burton, Henninger, & Hafetz, 2005). Therefore, additional studies exploring language development and skills concerning the autism symptom cluster would be beneficial to see whether these skills play an influential role in the differences in the expression of symptoms observed between females and males with autism.

Conclusion

This thesis aimed to study the sex differences in the core symptom clusters of autism (socio-communication and RRBs) and cognition. The first and second hypotheses were that females with autism perform better than males with autism on the social-communication and interaction core cluster and that females with autism score lower on the RRBs cluster than males with autism. Our third hypothesis was that males perform better on tasks on cognitions skills, such as executive function and working memory. Our final hypothesis was that males with autism perform better on intelligence assessments than females with autism. All results showed some level of contradictions, however, our first three hypotheses found support in the final results. For the fourth hypothesis, the results showed inconsistency; thus contrary to our expectations, most findings indicated no significant difference between males and females with autism. All in all, the findings indicate that different phenotypical features may characterise females compared to males with autism. Therefore, the revision of the standard, rather male-based and culturally influenced assessment methods, are required to establish a realistic sex ratio in the diagnostics of autism.

Appendix

Table 1

Summary of the Descriptive Statistics of the Studies Included in the Quantitative Analysis

Authors	Diagnostics	Assessments	*K*	*N* (ASD_F)	*N* (ASD_M)	*N* (ASD)	*N* (TD)	*X* age (ASD_M) *	*SD* (ASD_M) *	*X* age (ASD_F) *	*SD* (ASD_F) *
Antezana et al,. (2019)	DSM-IV-TR	RSB-R	615	108	507	615	\	10.3	4.2	10.2	4.4
Blote et al., (2011)	ICD-10	ADOS ADI-R	53	21	35	53	\	14.0	3.0	14.3	2.7
Frazier et al., (2014)	DSM-IV DSM-IV-TR	ADOS SRS RBS-R ADI-R	2418	304	2114	2418	\	9.0	3.6	9.3	3.7
Harrop et al., (2015)	n/a	ADOS	58	29	29	58	\	3.0	0.8	3.2	0.7
Hartley et al., (2009)	DSM-IV-TR	ADOS-G	199	42	157	199	\	3.0	0.6	3.0	0.6
Holtmann et al., (2007)	DSM-IV-TR ICD-10	ADI-R ADOS	46	23	23	46	\	11.9	4.6	12.0	4.4
Mandy et al., (2012)	DSM-IV-TR	3Di	325	52	273	325	\	9.7	3.1	10.2	3.5
McFayden et al., (2018)	n/a	RBS SRS-2	125	20	55	75	50	10.3	10.0	17.9	15.9
Park et al., (2012)	DM-IV-R	ADI-R	260	20	91	111	149	8.4	2.8	8.2	3.4
Ratto et al., (2017)	DSM-IV-TR DSM-5	ADOS ADI-R SRS/SRS-2	228	114	114	228	\	10.1	2.2	10.1	2.2
Rodrigues et al., (2019)	n/a	SRS-2 ADI-R	68	34	34	68	\	9.0	1.7	8.9	1.8
Solomon et al.,(2012)	DSM-IV-TR	ADOS-G SRS RBS-R	76	20	20	40	36	12.5	3.7	12.0	3.4
Tillmann et al., (2018)	DSM-IV/-TR DSM-5 ICD-10	ADI-R ADOS-G	2684	464	2220	2684	\	10.1	9.0	11.2	9.5

*Notes:*in years; n/a= information is not available; ADI-R*(Autism Diagnostic Interview- Revised), *ADOS*(Autism Diagnostic Observation Schedule), 3*Di*(Developmental, Dimensional and Diagnostic Interview), *SRS* (Social Responsiveness Scale), *RBS/ RBS-R* (Repetitive Behaviour Scale/ Repetitive Behaviour Scale-Revised).

Table 2

Studies, their Unweighted and Weighted Mean Effect Sizes Used for Social Interaction Core Symptom of Autism in Random Effect Model

Study	Assessment	*Unweighted ES*	*K*	*Weighted Mean ES*
Blöte et al.,(2011)	ADI-R	0.03	53	1.55
Blöte et al.,(2011)	ADOS	-0.18	n/a	-8.94
Frazier et al., (2014)	ADI-R	0.04	2418	96.65
Frazier et al., (2014)	ADOS	0.09	n/a	217.94
Frazier et al., (2014)	SRS	0.06	n/a	145.07
Harrop et al.,(2015)	ADOS	0.02	58	1.05
Hartley et al., (2009)	ADOS-G	-0.95	199	-363,13
Holtmann et al., (2007)	ADI-R	0.02	46	0.86
Holtmann et al., (2007)	ADOS	0.12	n/a	5.18
Mandy et al.,(2012)	ADOS	0.17	325	68.64
Mandy et al., (2012)	3Di	0.21	n/a	55.28
Park et al.,(2012)	ADI-R	0.43	111	49.80
Ratto et al., (2017)	ADI-R	-0.01	228	-2.70
Ratto et al., (2017)	ADOS	0.11	n/a	25.08
Ratto et al., (2017)	SRS	0.73	n/a	208.96
Rodrigues et al., (2019)	ADI-R	-0.13	68	-8.17
Rodrigues et al., (2019)	SRS	0.09	n/a	5.67
Solomon et al.,(2012)	ADOS	-0.21	40	-7.77
Solomon et al.,(2012)	SRS	0.07	n/a	2.56
Tillmann et al.,(2018)	ADI-R	0.05	2684	80.45
Tillmann et al.,(2018)	ADOS	0.03	n/a	134.16

Note. ES = Effect Size; Weighted Mean *ES* is calculated by multiplying the unweighted ES by the inverse variance weight (sample size -3). Where a study was used more than once, the group size (*K*) is only used in the calculation once. Where it was used before, it is marked as n/a.

Interpretation: Positive *ES* (unweighted or weighted) indicates that females performed better than males.

Table 3

Studies, their Unweighted and Weighted Mean Effect Sizes Used for Communication Core Symptom of Autism in Random Effect Model

Study	Assessments	*Unweighted ES*	*K*	*Weighted Mean ES*
Blöte et al., (2011)	ADI-R	-0.07	53	-3.66
Blöte et al., (2011)	ADOS	-0.12	n/a	-5.78
Frazier et al., (2014)	ADI-R	0.02	2418	48.31
Frazier et al., (2014)	ADOS	0.10	n/a	242.31
Frazier et al., (2014)	SRS	0.06	n/a	145.07
Hartley et al., (2009)	ADOS-G	-0.90	199	-283.52
Holtmann et al., (2007)	ADI-R	-0.35	46	-15.71
Holtmann et al., (2007)	ADOS	0.12	n/a	5.18
Mandy et al., (2012)	ADOS	0.17	325	55.28
Mandy et al., (2012)	3Di	0.07	n/a	22.58
Park et al.,(2012)	ADI-R	0.70	111	92.62
Ratto et al., (2017)	ADI-R	-0.09	228	-20.30
Ratto et al., (2017)	SRS	0.73	n/a	208.96

Rodrigues et al., (2019)	SRS	0.09	n/a	5.67
Rodrigues et al.,(2019)	ADI-R	-0.35	68	-23.38
Solomon et al., (2012)	ADOS	0.50	40	20.23
Solomon et al., (2012)	SRS	0.07	n/a	2.56
Tillmann et al., (2018)	ADOS	0.03	n/a	80.45
Tillmann et al., (2018)	ADI-R	0.08	2684	214.94

Note. ES = Effect Size; Weighted Mean *ES* is calculated by multiplying the unweighted ES by the inverse variance weight (sample size -3). Where a study was used more than once, the group size (*K*)is only used in the calculation once. Where it was used before, it is marked as n/a.

Interpretation: Positive weighted Mean *ES* indicates that females performed better than males.

Table 4

Studies, their Unweighted and Weighted Mean Effect Sizes Used for RRBs Core Symptom of Autism in Random Effect Model

Study	Assessments	Unweighted *ES*	*K*	Weighted *ES*
Antezana et al., (2019)	RBS	0,04	615	26.33
Blöte et al., (2011)	ADI-R	-0.40	53	-21.06
Blöte et al., (2011)	ADOS	-0.67	n/a	-40.36
Frazier et al., (2014)	ADI-R	-0.09	2418	-217.94
Frazier et al., (2014)	ADOS	-0.02	2418	-48.31
Frazier et al., (2014)	RBS-R	-0.01	n/a	-24.15
Frazier et al.,(2014)	SRS	-0.02	n/a	-48.31
Harrop et al.,(2015)	ADOS	-0.06	58	-3.41

Hartley et al., (2009)	ADOS-G	-0.41	199	-85.85
Holtmann et al., (2007)	ADI-R	0.10	46	4.31
Mandy et al., (2012)	3Di	-0.32	325	-106.79
Mandy et al., (2012)	RBS	-0.42	n/a	-144.16
McFayden et al., (2018)	RBB	-0.20	75	-14.75
McFayden et al., (2018)	RBS	-0.56	n/a	-45.15
Park et al., (2012)	ADI-R	-0.50	111	-59.76
Ratto et al., (2017)	SRS	-0.63	228	-167.19
Rodrigues et al., (2019)	SRS	-0.08	n/a	-5.08
Rodrigues et al.,(2019)	ADI-R	-0.20	68	-13.11
Solomon et al.,(2012)	RBS	-0.98	40	-94.53
Solomon et al.,(2012)	RSR	-0.08	n/a	-3.08
Tillmann et al., (2018)	ADI-R	-0.17	2684	-460.24
Tillmann et al.,(2018)	ADOS	-0.17	n/a	-460.24

Note. *ES* = Effect Size. Weighted Mean *ES* is calculated by multiplying the unweighted ES by qthe inverse variance weight (sample size -3). Where a study was used more than once, the group size (*K*)is only used in the calculation once. Where it was used before, it is marked as n/a. Interpretation: Positive Mean *ES* (unweighted or weighted) indicates that females performed better than males.

Table 8 - I

Studies Included in the Thematic Analysis Used for Investigating the Cognitive Differences between Males and Females with Autism

Study	Assessment	Diagnostic criteria	Design	Sample *n*	Age_Male (*SD*)	Age_ Female *(SD)*	IQ
Ankenman et al., (2014)	DAS-II; WISC, WASI, MSEL	ADOS ADI-R	SSC	1954 (F=244)	8.8 (3.5)	8.8 (3.5)	M + F= 90.9 (19.9) ; *X_M*= UNK *X_F*=UNK
Banach et al., (2009)	Leiter (only NVIQ)	DSM-IV-TR ADOS ADI-R	Research recruited	*Simplex*: *1*94 (F=50) *Multiplex:* 202(F=50)	9.4 (5.8)	9.1 (5.6)	Simplex*: *X_M*= 76.2 (29.5); *X_F*: 50.2 (22.8) ;Multiplex: *X_M*= 68.9 (31.8); *X_F*=74.8 (30.4); **FSIQ:***X*= 90.99 (19.95); *NVIQ:X*= 93.06 (18.98); **VIQ:** *X*=89.44 (21.74)
Blöte et al., (2011)	WISC; WCST; ToH,EFT; TMT-B-A	ICD-10	Research recruited	56(F=21)	14.0(3.0)	14.3(2.7)	**NVIQ (Raven/Wechsler):** *X_F*=104.0 (3.0);*X_M*= 99.8 (11.3)
Carter et al., (2007)	MSEL	ADOS ADI-R	Research recruited	88 (F=22)	2,36 (3,5*)*	2.26 (4.8)	Similar MSEL AE scores across domains F > M on adjusted VR*a M > F on language composite* and motor skills composite**b
Frazier et al., (2014)	DAS-II ; WISC-IV	ADOS ADI-R SRS	ATN	2418 (F=304)	9.01 (3.56)	9.32 (3.67)	*X_M*= 82.56 (27.59); *X_F*=74.70 (27.59) **VIQ***:X_M*=79.2 (30.7); *X_F*= 73.4 (32)** **NVIQ:** *X_M*=86 (25.8); *X_F*= 77.4, (26.2)***
Hartley et al., (2009)	MSEL, ADOS-G	DSM-IV-TR ADOS	ATN	199 (F=42)	2.96 (7.1)	3.0 (7.3)	UNK, Visual Reception (VR) used as cognition
Howe et al., (2015)	WPPSI; DAS; WASI; WISC-IV	DSM-5	Research recruited SSC; AGRE; AC; ATN	5723(F=872)	**AGRE:** 9.4 (3.5) **AC:**10.1 (4.2) **ATN:** 8.6 (3.0) ***SSC:***9.6 (3.3)	**AGRE:**9.1 (3.3) **AC:** 9.7 (3.6) **ATN:** 8.8 (2.9) ***SSC:*** 9.9 (3.5)	ADOS Module 1 *X_ M+F*= IQ ≤ 70 across all datasets

Kiep & Spek (2016)	WAIS-III; ToH; WCST; Verbal Fluency	DSM-5	Research recruited	199 (ASD_F=40, ASD_M=99, TD_ F=25, TD_M=35)	*X_ASD_M*= 38.03(9.4) *X_TD_M*=39 .16(11.44)	*X_ASD_F*=34.9 2 (10.71) *X_TD_F*=36.14(10.78)	**FIQ:***X_ASD_M*=109.62 (12.44);*X_ASD_F*=107.86 (12.14); *X_TD_M*=112.05 (9.31); *X_TD_F*=108.84 (8.39)
Koyama et al., (2009)	Japanese version WISC-III	DSM-IV-TR ICD-10	Clinically referred	142 (F=22)	*X_M*= 9 (3.0)	8.2 (2.1)	HFA all FSIQ > 70; *X_M*=96.0 (14.2) *X_F*=97.9 (13.6)
Kumazaki et al., (2015)	FIQ; WISC-III; VIQ;	ICD-10	Research recruited	46 (F=20)	7.5(1.14)	7.53(0.93)	**FIQ**:*F_X*=97.5(13.6), *X_M*=97.6(13.5) **VIQ**: X_*F*=97.3(15.2), *X_M*=96.9(18.6); **PIQ:** *X_F*=98.3(12.7), *X_M*=98.5(11.3)
Lai et al., (2011)	ADOS; WASI	ICD-10 DSM-IV -TR	Research recruited	62(F=29)	27.0 (7.1)	26.9 (6.7)	**VIQ**: *X_M*=111.5 (15.3);*X_F*=113.1 (15.4) **PIQ:***X_M*= 111.1 (16.4); *X_F*=109.5 (17.5) **FIQ:** *X_M*= 112.6 (16.3); *X_F*= 112.8 (15.7)
Lai et al., (2012)	F-A-S test, PPT 'assembly' subtask; WASI	DSM-IV-TR ICD-10	Research recruited, MRC AIMS	151 (TD_M_n=3 3, TD_F_n=35, ASD_M_n=4 5, ASD_F_n=3 8)	X_*TD_M*=28 .7 (5.9) X_*ASD_M*=2 7.0 (7.2)	X_*TD_F*= 27.6 (6.3) X_*ASD_F*=28.1 (8.2)	**VIQ :** *X_TD_M* =111.0 (12.2), *X_ASD_M*= 112.5 (14.4), *X_TD_F*= 118.3 (10.1), *X_ASD_F*=114.5 (15.4) **PIQ:** *X_TD_M*=3 118.3 (11.5), *X_ASD_M*= 112.2 (15.3), *X_TD_F*=116.4(9.4),*X_ASD_F*=110.2 (17.0); **FIQ:** *X_TD_M*=3 116.3 (11.8);*X_ASD_M*= 113.7 (15.1); *X_TD_F*=119.7 (8.4); *X_ASD*_F=114.1 (15.5)
Lehnhardt et al., (2015)	ADI-R; WAIS-III;TMT;WCS T	ICD-10 DSM-IV-TR	Research recruited	215 (F=71)	age at diagnosis: 34.7(9.8)	age at diagnosis: 35.8 (8.6)	**FSIQ:***X_F*= 110.2 (14.4); *X_M*=111.7(13.9) **VIQ:** *X*_F=110.0 (13.0); *X_M*=114.7(12.9) **PIQ:** *X_F*=108.3(15.6); *X_M*=106.2 (15.9)
Lemon et al., (2011)	WISC Stop Task	DSM-IV-TR	Research recruited	45 (ASD_F=13, ASD_M=	*X_ASD_M*=1 1.1(3.58)	*X_ASD_F*=11(3) *X_TD_F*=10.7(2 .3)	**FIQ:** *F_X*=97.3(16.7);*X_M*=91.68(18.4); *X_VF*=107(10.7); *X_CM*=108(11.0)

				10,TD_F= 14, TD_M= 8)	*X_TD_M*=12 .1(4.17)		
Mandy et al., (2012)	WASI; WISC-III;WISC-IV	ICD-10 DSM-IV-TR	Clinically referred	325(F=52)	9.7 (3.1)	10.2 (3.5)	**VIQ:** *X_M*=92.7 (19.5); *X_F*=92.5 (18.5); **PIQ:** *X_M*= 94.8 (19.7); *X_F*=91.4 (19.6)
Memari et al., (2013)	WCST, Daily activities	DSM-IV-TR ADI-R	Research recruited	123 (F=29)	9.6 (1.9)	9.6(1.9)	**NVIQ** (Raven/Wechsler): *X*=93.3(11.1)
Mussey et al., (2017)	FIQ VIQ ;NVIQ	ADOS	Clinically referred	792 (F=113)	age range (1.75 − 5.63)	age range (1.75 − 5.63)	*X_M*= 85.6 (22.1); *X_F*=86 (21.8) **VIQ:** *X_M*=92.3 (20.8); *X_F*= 90.7 (21.4) **NVIQ:** *X_M*= 94.7 (19.8), *X_F*=89.7 (20.8)
Reinhardt et al., (2015)	MSEL	ADOS	Research recruited	288 (F= 54)	19.99 (2.25)	20.61 (2.32)	**NVDQ:** *X_M*=26.07(9.09); *F_X*= 25.64 (8.85) **MVDQ:** *X_M*=70.05(28.78); *F_X*= 22.67 (11.66)

Notes: n=sample size; *X*=average; *SD*=Standard Deviation; M=Male; F=Female; TD_F=typically developing female; TD_M= typically developing male; ASD_F= females with autism; ASD_M=males with autism; UNK= unknown; Simplex*= families with one autistic child; Multiple*= families with multiple autistic children

FSIQ: Full-Scale Intelligence Quotient; VIQ: Verpal Intelligence Quotient; NVIQ: Non-Verbal Intelligence Quotient; PIQ: Performance Intelligence Quotient; MSEL:Mullen Scales of Early Learning;, WCST: Wisconsin card sorting test; WASI: Wechsler Abbreviated Scale of Intelligence; , WISC: Wechsler Intelligence Scale for Children; WPPSI: Wechsler Preschool and Primary Scale of Intelligence; ToH: Tower of Hanoi; TMT: Trail Making Test; DAS-II: Differential Ability Scales; EFT: Executive Function Test; PPT 'assembly' subtask.

DSM-IV-TR,: Diagnostic and Statistical Manual of Mental Disorders fourth edition, text revision; DSM-5: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition; ICD-10: International Classification of Diseases 10th Revision; ADI-R: Autism Diagnostic Interview- Revised (ADI-R); ADOS: Autism Diagnostic Observation Schedule; SRS: Social Responsiveness Scale.

ATN: Autism Treatment Network, recruited SSC: Simons Simplex Collection; AGRE: Autism Genetic Resource Exchangehttps://www.autismspeaks.org/agre; AC:

Table 8 - II

Studies Included in the Thematic Analysis Investigating the Cognitive Differences between Males and Females with Autism – Executive Functioning

Study	Executive Functioning
Bölte et al., (2011)	**WCST:** *X_F*=17.6 (8.1),*X_M*=8.6; **ToH moves:** *X_F*=22.9(8.7), *X_M*=25.7(10.9); **ToH time in second :** *X_F*=97.4)53.9), *X_M*=93.4(47.3); **TMT-B-A:** *X_F*=15.9(8.8); *X_M*=20.6(15.5); **EFT (in second):** *X_F*=52.2(28.6); *X_M*=46.8(18.9**); BD:** *X_F*= 10.8(4.8), *X_M*= 12.1 (4.9)
Kiep & Spek (2016)	**ToH (number of moves):** *X_F*=54.65(20.56); *X_M*=57.89(27.11); **ToH (total time):** *X_F*=286.92 (188.93), *X_M*=275.54(195.42); **Preservative errors:** *X_F*=12.12(17.71), *X_M*=11.26(13.51); **Non-preservative erros:** *X_F*=11.65(12.16),*X_M*=17.48(14.93); **Completed strategies:** *X_F*=4.92(2.13), *X_M*=4.15(2.49); **Digit Span:** *X_F*=10.81(2.3), *X_M*=10.3(3.29); **Letter-number sequencing:** *X_F*=10.88(2.83), *X_M*=11.15(3.24). **Semantic fluency-animals**: *X_F*=25.62(5.92), *X_M*=24.80(6.13); **Semantic fluency-professionals**: *XX_F*=20.31(5.08), *X_M*=18.74(5.3); **Phonemic fluency - letter K:** *X_F*=14.15(4.31), *X_M*=14.85; **Phonemic fluency - letter M**=*X_F*=14.19(4.72), *X_M*=12.96(4.48).
Kumazaki et al., (2015)	**Verbal subtest Information:** *X_F*=10.4(3.7, *X_M*=10.7(4.0); **Verbal subtest Similarities:** *X_F*=10.2(3.3), *X_M*=9.0(3.9); **Verbal - Arithmetic:** *X_F*=9.1(3.2), *X_M*=10.2(4.2); **Verbal - Vocabulary** : *X_F*=9.4(2.8), *X_M*=9.2(3.7); **Verbal - Comprehension**: *X_F*=8.8(3.0), *X_M*=8.6(3.2); **Verbal - Digit span:** *X_F*=10.5(3.6), *X_M*=10.2(3.1). **Performance - Picture completion** : *X_F*=10.5(3.1), *X_M*=10.6(2.8), **Performance - Coding:** *X_F*=9.9(2.7), *X_M*=8.5(2.6); **Performance - Picture arrangement:** *X_F*=10.1(3.2), *X_M*=9.5(3.0); **Performance -block design :** *X_F*=10.3(3.5), *X_M*=11.6(3.1); **Performance s-object assembly:** *X_F*=8.1(3.4), *X_M*=10.8(2.6).
Lai et al., (2012)	**F-A-S main effect of sex:** $F(1,121)=6.51$, $p=.012$, $\eta^2=.51$; **NWR main effect of sex:** $F(1,121)=1.35$,$p=.248$, $\eta^2=..011$.
Lehnhardt et al., (2015)	**WCST(PE):** *X_F*=50.7(13.4), *X_M*=50.2(13.2); **WCST(CLR):** *X_F*=49.6(9.3), *X_M*=47.8(9.9); **TMT-A:** *X_F*=52.2(29.3), *X_M*=35.2(27.9); **TMT-B:** *X_F*=44.0(31.6), *X_M*=37.7(31.2); **Verbal fluency (LF):** *X_F*= 13.3(3.4), *X_M*=11.5(3.6); **Verbal fluency (SC):** *X_F*=28.8(7.9), *X_M*=25.2(8.6)
Lemon et al., (2011)	**SSRT:** *X_F*=350(72), *X_M*=270(86); **ZRFT-gradient:** *X_F*=0.28(0.25), *X_M*=0.34(0.13)
Memari et al., (2013)	**WCST (PE) :** *X_F*=22.37(9.23), *X_M*=14.83(83); **WCST (CA):** *X_F*=0.08(0.28), *X_M*=0.83(0.88).

Notes. WCST: Wisconsin Card Sorting Test: PE: preservative error, CA: Category Achieved, Conceptual level responses (CLR); ToH: Tower of Hanoi; TMT: Trail Making Test; EFT: Embedded Figures Test; BD: Block Design Test; Non-Word Repetition (NWR); Word generativity (F-A-S); Stop signal reaction time (SSRT);, Z-scores of the relative finishing times gradient (ZRFT-gradient)

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