Review Article

Behavioural and cognitive sex/gender differences in Autism Spectrum Condition and typically developing males and females

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Abstract

Studies assessing sex/gender differences in autism spectrum conditions (ASC) often fail to include typically developing control groups. It is therefore unclear whether observed sex/gender differences reflect those found in the general population, or are particular to ASC. A systematic search identified papers comparing behavioural and cognitive characteristics in males and females with and without an ASC diagnosis. Thirteen studies were included in meta-analyses of sex/gender differences in core ASC symptoms (social/communication impairments and restrictive/repetitive behaviours & interests) and IQ. Twenty studies were included in a qualitative review of sex/gender differences in additional ASC symptoms. For core traits and IQ, sex/gender differences were comparable in ASC and typical samples. Some additional ASC symptoms displayed different patterns of sex/gender differences in ASC and typically developing groups, including measures of executive function, empathising and systemising traits, internalising and externalising problems, and play behaviours. Individuals with ASC display typical sex/gender differences in core ASC traits, suggesting that diagnostic criteria based on these symptoms should take into account typical sex/gender differences. However, awareness of associated ASC symptoms should include the possibility of different male and female phenotypes, to ensure those who do not fit the 'typical' ASC presentation are not missed.

Keywords

Autism Spectrum Conditions, sex differences, gender differences, diagnosis

Introduction

Autism Spectrum Conditions (ASC) are more commonly diagnosed in males than in females across age groups (Fombonne, 2009; Russell, Steer, & Golding, 2011)[1]. Reliable genetic and/or physiological markers of ASC have not yet been identified, therefore diagnostic criteria rely on behavioural descriptions of the disorder. These criteria have been developed based on the predominantly male populations previously diagnosed or identified as having ASC (Kirkovski, Enticott, & Fitzgerald, 2013; Kopp & Gillberg, 2011; Mattila et al., 2011). However, researchers are increasingly focused on the experiences and characteristics of females with autism to determine whether males and females with ASC display similar behavioural and cognitive profiles (Dworzynski, Ronald, Bolton, & Happé, 2012; Gould & Ashton-Smith, 2011; Kopp & Gillberg, 1992; Lehnhardt et al., 2015; Mandy et al., 2012; Thompson, Caruso, & Ellerbeck, 2003; Werling & Geschwind, 2013). If females with ASC tend to demonstrate different symptom patterns to the majority of ASC males, they may be at greater risk of being missed by clinical services and support options than males (Dworzynski et al., 2012). It is, therefore, important to assess whether there is a need for a broader conceptualisation of ASC to include typically female patterns of this condition. If so, this could have implications for the diagnostic criteria of ASC.

There have been several reviews of the literature on sex/gender differences in the ASC core symptoms of social/communication impairments and restricted/repetitive behaviours and interests (RRBIs) [Note: following Lai, Lombardo, Auyeung, Chakrabarti, & Baron-Cohen (2015), we use the term 'sex/gender' to reflect the awareness that the effects of biological 'sex' and socially constructed 'gender' cannot be easily separated, and that most individuals' identities are informed by both sex and gender]. These generally conclude that females with ASC may display a different phenotype, or different patterns of ASC characteristics, to males with ASC (Kirkovski et al., 2013; van Wijngaarden-Cremers et al.,

2014). While specific sex/gender differences in the severity of social and communication impairments have not been conclusively demonstrated (Koenig & Tsatsanis, 2005; Lai et al., 2011, 2012; Lai, Lombardo, Auyeung, Chakrabarti, & Baron-Cohen, 2015; Van Wijngaarden-Cremers et al., 2014), some have found that girls and women with ASC, on average, display fewer RRBIs (Koenig & Tsatsanis, 2005; Kreiser & White, 2014; Rivet & Matson, 2011). However, it has been argued that RRBI diagnostic criteria fail to reflect the true range of areas under which RRBIs can fall (Mandy et al., 2012). It is possible that many females with ASC experience very extreme interests or behavioural tendencies, but in areas outside the 'typical' ASC interests of systems and machines, therefore excluding them from meeting diagnostic criteria for RRBIs in ASC.

Reviews have also addressed sex/gender differences in additional symptoms associated with ASC, such as internalising and externalising problems and the co-diagnoses that may result from these. Males with ASC and typically developing males with high autism traits are more likely to experience externalising problems such as behavioural problems and hyperactivity, while females are more likely to experience internalising problems such as depression and anxiety hyperactivity (Koenig & Tsatsanis, 2005; Kreiser & White, 2014; Rivet & Matson, 2011). This suggests that the pattern of behaviours associated with ASC symptoms varies between males and females, which may require adjustment of current diagnostic criteria.

In addition to sex/gender differences in ASC symptoms, differences in the diagnostic experiences of males and females with ASC have also been observed. Females with similar levels of ASC symptoms are less likely to be diagnosed with ASC than males (Dworzynski et al., 2012), and it is suggested that females are more likely to be misdiagnosed with other conditions, especially internalising and eating disorders (Kopp & Gillberg, 1992; Mandy & Tchanturia, 2015). Females who do receive an ASC diagnosis do so at a later age than males

on average (Kirkovski et al., 2013). A difference in the ASC symptoms experienced by males and females may partly account for this variation in diagnosis, as the female phenotype may not be viewed as 'typical' ASC symptoms, and so may not immediately point towards an ASC diagnosis.

Reviews have also emphasised that sex/gender differences in ASC are influenced by individual differences. Females with low IQ are more likely to receive a diagnosis than females with high IQ (Rivet & Matson, 2011; van Wijngaarden-Cremers et al., 2014), suggesting that there are additional factors interacting with sex/gender to produce differences in diagnostic rates. Individuals' ages were also found to influence sex/gender differences in core ASC symptoms; for instance, van Wijngaarden-Cremers et al. (2014) found that sex differences in RRBIs only occur from the age of 6 years. There are also likely to be interacting influences from both social and biological factors, such as genetic influences and social/cultural environment, which will contribute to different developmental outcomes for males and females with ASC (Kreiser & White, 2014; Lai et al., 2015). It is, therefore, concluded that future research into sex/gender differences in ASC needs to take into account IQ, age, and other characteristics in order to fully understand how males and females with ASC develop.

Based on the above, males and females with ASC appear to demonstrate somewhat different characteristics, and have different clinical and diagnostic experiences. This would suggest that ASC diagnostic criteria and thresholds should vary for males and females, to ensure that all individuals are able to access the services and support they require. However, the precise ways in which diagnostic criteria might be adapted depend on exactly how and why males and females with ASC differ. One issue with previous research into sex/gender differences in ASC is that typical sex/gender differences have rarely been taken into account. This means that we cannot be certain whether males and females with ASC differ in the same

ways that typically developing males and females differ, or whether having ASC has a differential impact on males and females, and it is this that produces the sex/gender differences described above.

If the first prediction is borne out, then the performance of ASC males and females on diagnostic criteria should also be compared to that of typically developing males and females respectively. Sex/gender differences (or lack thereof) in typically developing populations have been established for a wide range of behaviours related to ASC, therefore it stands to reason that ASC males should be compared to typically developing males, and ASC females to typically developing females when assessing strengths and impairments.

If, on the other hand, ASC does produce different outcomes for males and females beyond those attributed to typical sex/gender differences, adjustments to diagnostic criteria are less straightforward. One outcome might be the development of separate diagnostic criteria for males and females, reflecting differential presentations of ASC in each sex/gender in at least some areas. It has also been suggested that females with ASC may compensate for or mask their ASC-related behaviours to a greater extent than males with ASC, resulting in underestimations of the true extent of ASC and its symptomatology in females (Dworzynski et al., 2012; Lai et al., 2012). Including these behaviours in a female phenotype of ASC would increase identification of females and enable them to access the services and support they need.

Thus, it is important to compare sex/gender differences in the ASC population with those in typically developing groups, in order to establish whether ASC interacts with an individual's sex/gender to produce different outcomes, or whether typical sex/gender differences also exist within in the ASC population. This then has implications for adjustments to diagnostic criteria, and for a broader conceptualisation of ASC in males and females.

This research therefore aims to address the following questions:

What are the sex/gender differences in ASC core and associated symptoms (if any), for ASC and typically developing groups?

Do these sex/gender differences vary between ASC and typically developing groups? In other words, is there an interaction between sex/gender and ASC diagnosis?

Methods

Literature Review

A search of the Psych Info, Pub Med, and Web of Science directories in September 2015 for the terms "autism + sex differences" and "autism + gender differences" produced 3290 initial results. Figure 1 describes the logic used to select studies for inclusion. Eligibility criteria were peer-reviewed papers published in English and comparing males and females with and without an ASC diagnosis, which matched ASC and typically developing groups for IQ and age. Bibliographies of relevant papers, including those of seven recent review and/or meta-analysis papers, were manually searched to find additional papers which may have been missed in the initial search (n = 37). Studies were excluded (n = 3307) if they were duplicates, if they only measured biological sex/gender differences, and if they did not include groups of males and females with and without an ASC diagnosis, matched on age and IQ. Twenty original studies were selected for inclusion in the review of variation in sex/gender differences between ASC and typically developing groups. See Tables 1 and 2 for information about all 20 studies, including summaries of their findings and characteristics of the samples used. Where multiple comparison groups were included, the group most similar to an unrelated, general population sample was selected for inclusion in this review. Several additional authors were contacted to request data on control groups for inclusion in the analysis, but none were able to provide complete datasets. Due to the limited number of

eligible studies, meta-analysis of ASC and typical sex/gender differences was only possible for six studies measuring social/communication impairments, five studies measuring RRBIs, and 13 studies measuring IQ.

Figure 1
PRISMA flow diagram of study identification and selection

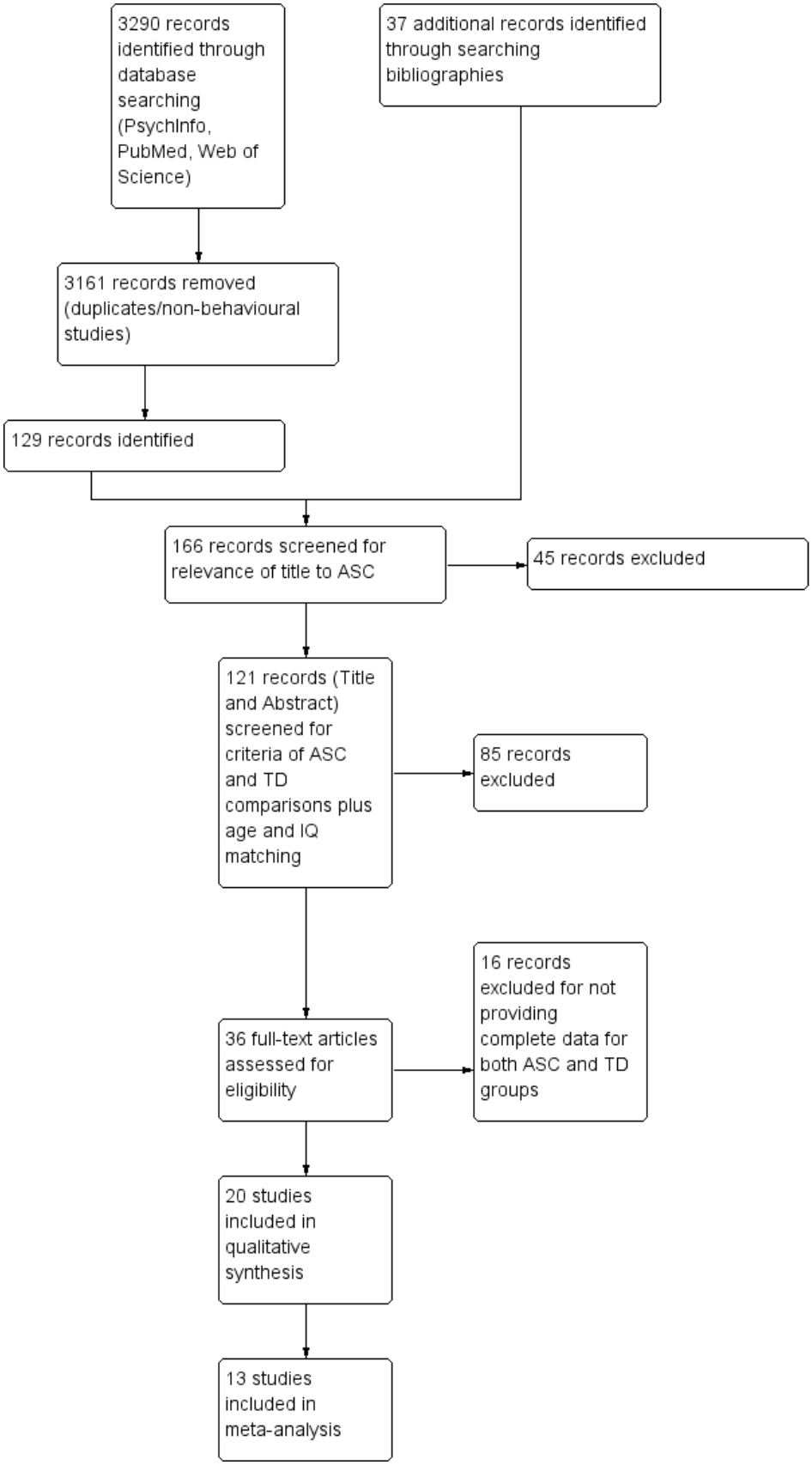

Figure 1. Flow diagram showing identification and selection of studies for inclusion in the review and meta-analysis. ASC = Autism Spectrum Conditions; TD = typically developing

Statistical Analysis

Random-effects meta-analyses were performed using the 'metafor' package in R (R Core Team, 2013; Viechtbauer, 2010) for measures of the core ASC symptoms and IQ. Using a random-effects model accounts for variance between studies caused by sampling error and other artifacts (Hunter & Schmidt, 2004). Mean sex/gender differences in Social/Communication impairments (see Table 3), Restrictive/Repetitive Behaviours and Interests (see Table 4), and IQ (see Table 5) were calculated for ASD and TD groups, then standardised mean differences (SMD) between these differences were calculated, to take into account the variety of test instruments used. Social and communication impairments were analysed separately due to some studies testing these separately or only testing one of these, but are presented and discussed together, to reflect the fact that these autistic symptoms are treated as a unitary domain in DSM-5. Where tests for heterogeneity were significant, a mixed-effects model was used to test for the effect of the moderator 'Age' (Age of participants). ASC groups were entered into the analysis first, therefore positive effect sizes would mean greater sex/gender differences in ASC groups than typical groups, and negative effects sizes would mean smaller sex/gender differences in ASC groups. Where multiple measures of the same symptom were used within one study, the measure most similar to those used in other studies was selected for inclusion in this analysis. R script for all analyses is available on request from the first author.

Results

Meta-Analysis

Figure 2 presents the funnel plots for each of the four meta-analyses conducted. Due to the limited number of studies, it is difficult to draw conclusions about publication bias. However, three of the four plots show some asymmetry, with a positive skew, suggesting there may have been some publication bias in favour of studies reporting statistically significant sex/gender differences in ASC populations. Despite this, Hunter and Schmidt (2004) note that studies of sex/gender difference may be less susceptible to availability bias (the suggestion that studies with significant findings and large effect sizes are more likely to be published, and therefore more available for inclusion in meta-analyses) than other studies. This is because the sex/gender difference is usually a supplementary analysis to the research question of interest and so publication is less likely to be dependent on satisfactory sex/gender difference results.

Figure 2
Funnel plots of studies included in meta-analysis

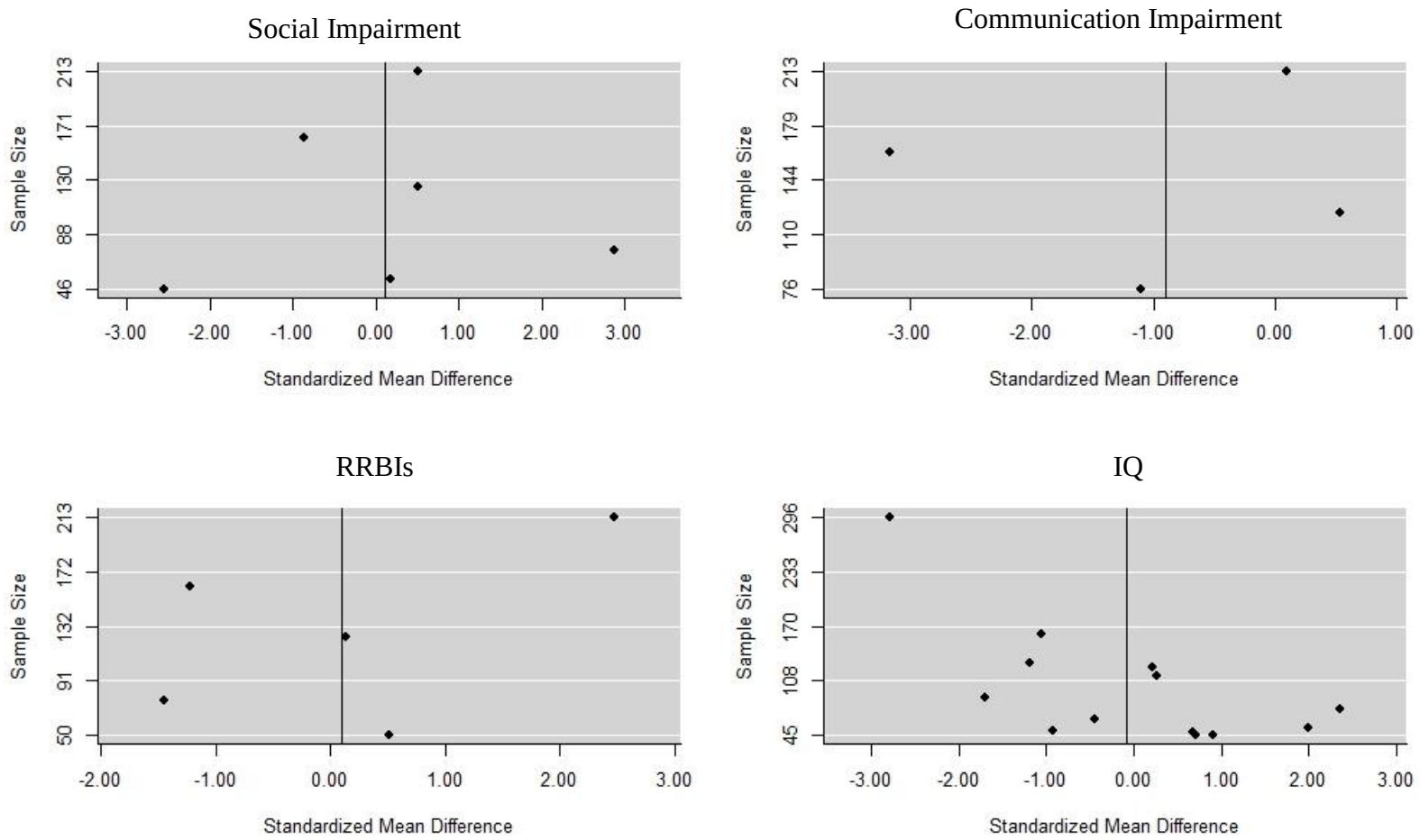

Figure 2. Funnel plot of studies included in meta-analysis of sex/gender differences in ASC and typically developing populations. Studies compared social impairments (n = 6), communication impairments (n = 4), restricted/repetitive behaviours and interests (n = 5) and IQ (n = 13).

Social and Communication impairments. Table 3 displays the mean scores, test used, and sex/gender differences in social and communication impairments for ASC and TD groups. Random-effects meta-analysis found no significant differences between social impairments for ASC males or females across studies, *SMD* = -0.21, 95% CI [-0.44, 0.02]. Typically developing females were found to have significantly lower levels of social impairments than TD males, *SMD* = -0.23, 95% CI [-0.42, -0.04]. Nevertheless, a random-effects meta-analysis revealed no significant difference in the effect of sex/gender between the ASC and TD groups.

Significant heterogeneity was found in this analysis ($Q = 158.76$, $p < .001$), therefore the moderator Age was included in the model and found to be significant, QM ($df = 4$) = 20.53, $p < .001$. The resulting mixed-effects meta-analysis (see Figure 3) found significant variation in sex/gender differences for social impairment between ASC and TD groups for studies including adolescents (n = 2). However, these two studies found different patterns of variation, with the study by Sedgewick et al. (2015) finding smaller sex/gender differences in ASC adolescents than TD, and the study by Solomon et al. (2012) finding the opposite effect. In those studies which only included children or adults (n = 4), no significant variation in sex/gender differences between ASC and TD groups was found. However, the test for residual heterogeneity was significant, QE ($df = 2$) = 43.19, $p < .001$, indicating that other moderators, not included in the model, may still be influencing the effect of sex/gender.

No significant difference in communication impairments was found using meta-analysis for ASC males and females, *SMD* = -0.26, 95% CI [-0.65, 0.12], or typically developing males and females, *SMD* = -0.09, 95% CI [-0.44, 0.26]. A random-effects meta-analysis (n = 4) revealed no significant difference in the effect of sex/gender for the ASC/TD groups, *SMD* = -0.90, 95% CI [-2.52, 0.72]; Figure 4. Significant heterogeneity was found in

this analysis (Q = 174.91, p < .001), therefore, the moderator Age was included in the model but was not found to be significant, QM (df = 1) = 0.01, p = .91. In contrast, the test for residual heterogeneity was significant, QE (df = 2) = 166.56, p < .001, indicating that other moderators not included in the model may still be influencing the effect of sex/gender.

Restrictive/Repetitive Behaviours and Interests (RRBIs). Table 4 displays the mean scores, test used, and sex/gender differences for ASC and TD groups. The extent of RRBIs was not significantly different between males and females with ASC, *SMD* = -0.30, 95% CI [-0.66, 0.07]. Typically developing females had significantly lower levels of RRBIs than typically developing males, *SMD* = -0.29, 95% CI [-0.49, -0.09]. A random-effects meta-analysis (n = 5) revealed no significant difference in the effect of sex/gender for the ASC/TD groups, *SMD* = 0.09, 95% CI [-1.30, 1.48; see Figure 5]. Significant heterogeneity was found in this analysis (Q = 255.24, p < .001), therefore the moderator Age was included in the analysis. However, omnibus testing revealed no significant effect of Age, QM (df = 1) = 0.71, p = .40. In contrast, the test for residual heterogeneity was significant, QE (df = 3) =225.11, p < .001, indicating that other moderators not included in the model may still be influencing the effect of sex/gender.

IQ. Table 5 displays the mean scores, test used, and sex/gender differences for ASC and TD groups. There were no significant differences between ASC male and ASC female IQ scores, *SMD* = -0.05, 95% CI [-0.22, 0.12], or typically developing male and female IQ scores, *SMD* = 0.02, 95% CI [-0.17, 0.21]. A random effects meta-analysis (n = 13) revealed no significant difference in the effect of sex/gender for the ASC vs. TD groups, *SMD* = -0.09, 95% CI [-0.88, 0.71; see Figure 6]. Significant heterogeneity was found (Q = 453.68, p < .001), therefore the moderator Age was included in a mixed-effects meta-analysis but was not found to be a significant moderator, QM (df = 1) = 2.45, p = .12. The test for residual

heterogeneity was significant, QE (df = 11) = 399.72, p < .001, indicating that other moderators not included in the model may still be influencing the effect of sex/gender.

Systematic Qualitative Review

***Executive Functioning*.** Executive functions are a set of abilities which facilitate higher-level cognitive control of behaviour, self-monitoring, and future planning, amongst other tasks (Ozonoff & Jensen, 1999). Individuals with ASC are often reported to have lower levels of executive functions than typically developing individuals (Happé, Booth, Charlton, & Hughes, 2006). There are contradictions in the literature when it comes to performance on specific tasks of executive functioning. All studies examined here found that as a group, individuals with ASC performed more poorly than typically developing individuals. No statistically significant interaction between sex/gender and diagnosis, was found in the Wisconsin Card Sorting Test or the Tower of Hanoi (Bolte, Duketis, Poustka & Holtmann, 2011), or the Go/No-Go task (Lai et al., 2012), suggesting that sex/gender differences may not vary between ASC and typically developing groups (see Table 2). Both studies had medium sample sizes with relatively high proportions of females in each group (compared to many studies examining sex/gender differences in ASC), but had limited power to detect small effect sizes, therefore it is possible that significant interactions were in fact undetected in these studies.

In contrast, the Trail-Making Test was found to produce significantly different sex/gender-relative performances depending on diagnostic status. In the ASC group, males had significantly longer reaction times than females, but in the typically developing group, females took longer to complete the task than males (Bolte et al., 2011). With regards to the Stop task, Lemon et al. (2011) found that ASC females demonstrated significantly longer reaction times than ASC males or typically developing females, while no differences were

found between ASC males' and typically developing males' performance on this task (see Table 2).

***Attention to Detail*.** Some theories of ASC propose that individuals with ASC have a bottom-up, centrally focused processing style as opposed to the typically developing top-down, holistic processing style (Happé & Frith, 2006). Bolte and colleagues (2011) found no significant interaction between sex/gender and diagnosis for the Embedded Figures task (EFT), although a marginal interaction was found by Lai et al. (2012). In the latter study, ASC males demonstrated poorer performance on the EFT than typically developing males, while no differences were found between ASC and typically developing females. As above, it is possible that small effect sizes went undetected in these studies. However, a significant sex/gender and diagnosis interaction was found on the Block Design task (see Table 2). ASC males performed better than ASC females, whereas the reverse pattern was found for typically developing individuals (Bolte et al., 2011).

***Theory of Mind/Emotion Recognition*.** The ability to infer the content of others' mental and emotional states, regardless of whether they are different to one's own, is known as theory of mind. Late or incomplete development of theory of mind abilities is considered a hallmark of ASC (Baron-Cohen, Leslie, & Frith, 1985), with some individuals failing to achieve 'simple' theory of mind abilities, such as recognising emotional expressions, and others struggling only with more complex tests, such as dynamic interactions (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997).

No significant sex/gender and diagnosis interaction was found for either the Reading the Mind in the Eyes task (RMET) or the Karolinska Directed Emotional Faces task (Holt et al., 2014; Lai et al., 2012; see Table 2). However, post-hoc analyses by Holt and colleagues (2014) revealed that ASC males performed more poorly than typically developing males on the RMET, whereas no significant differences were found between ASC and typically

developing females. Again, it should be noted that both studies had limited power to detect small effect sizes. In line with previous research, these studies found that individuals with ASC generally demonstrated poorer Theory of Mind abilities than typically developing individuals.

Memory. No significant sex/gender and diagnosis interaction was found on the Non-Word Repetition Task (Lai et al., 2012) or the Recent/Remote Memory task (Goddard, Dritschel, & Howlin, 2014; see Table 2). The former task is associated with (non-verbal) auditory working memory, as opposed to verbal memory tasks, which may be influenced by individuals' language abilities. The Recent/Remote Memory task measures both short-term and long-term recall memory, and is scored based on the number of details provided in response to each memory cue (Goddard, Dritschel, Robinson, & Howlin, 2014). In this task, individuals with ASC performed more poorly than typically developing individuals; otherwise there were no group differences for these tasks. However, a significant sex/gender and diagnosis interaction was found for the Autobiographical Memory Cueing Task. Males with ASC were found to produce fewer autobiographical memories than females with ASC, whereas no such difference was found between typically developing males and females (Goddard, Dritschel & Howlin, 2014).

Empathising, Systemising and Autistic traits. These traits represent a continuum of abilities reaching from the typical population, through those with an ASC diagnosis. Systemising ability, measured by the Systemising Quotient (SQ), represents an interest and understanding of the mechanisms within a system. High levels of these abilities are associated with more autistic traits in sub-clinical populations as well as with a diagnosis of ASC (Baron-Cohen, Richler, Bisarya, Gurunathan & Wheelwright, 2003). In contrast, higher levels of empathising abilities (measured by the Empathising Quotient [EQ]), such as understanding others' mental states and emotions, are generally found in individuals without

an ASC diagnosis and are associated with lower levels of autistic traits in the general population (Baron-Cohen & Wheelwright, 2004). Autistic traits describe behaviours and cognitive styles associated with autism that also exist in the general population, and are proposed to be more common in typically developing males than females (Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001). Autistic traits are measured by the Autism Quotient (AQ).

An earlier study using smaller samples found no significant differences between ASC males and females on any of these traits, but found higher SQ traits in typically developing males, and higher EQ traits in typically developing females (Baron-Cohen et al., 2003; see Table 2). Interactions were not directly tested in this study, which was underpowered to detect small effect sizes. Baron-Cohen et al., (2001) found a significant interaction between group and sex/gender for AQ scores, with typically developing males scoring higher than females, and no sex/gender difference between ASC males and females. In contrast, a more recent study using a much larger sample and a larger proportion of females with ASC found significant interactions between sex/gender and diagnosis on all three traits (Baron-Cohen et al., 2014). Both ASC and typically developing groups displayed higher SQ and AQ scores for males, and higher EQ scores for females (see Table 2). However, sex/gender differences in these studies were significantly smaller for ASC individuals, suggesting that males and females with ASC may be more similar in their empathising, systemising and autistic traits than males and females without ASC.

The study by Park et al. (2012) did not directly test interactions, but found no significant differences between ASC males and females on the SQ or EQ. Typically developing males had higher SQ scores than equivalent females, while no sex/gender differences were found for the typically developing group on the EQ. ASC males scored higher on the AQ than ASC females, but no significant differences were found between

typically developing males and females on this measure (see Table 2). Similarly, Kirkovski et al. (2016) found that ASC females and males scored lower on the EQ and higher on the AQ than typically developing females and males. Sex/gender differences within diagnosis groups were not reported in this study.

Friendship. No significant interactions between sex/gender and diagnosis were found using either the Friendship Questionnaire (Baron-Cohen & Wheelwright, 2005; Head, McGillivray, & Stokes, 2014) or the Friendships Survey (Dean et al., 2014). Using both measures, ASC individuals were found to perform more poorly than typically developing individuals (see Table 2). However, one study utilizing the Friendship Qualities Scale found that males with ASC reported significantly lower closeness and helping in their best friendship than females with ASC or typically developing children of either sex/gender (Sedgewick et al., 2015).

Internalising and Externalising. As a group, children with ASC experienced more internalising and externalising behaviours than typically developing children. Although interactions were not tested, no sex/gender differences were found for externalising or internalising behaviours, as measured by the Child Behaviour Checklist, in either ASC or typically developing groups (Park et al., 2012). However, this study was limited by a low proportion of females with ASC, which means more subtle differences may have been missed. Similarly, internalising behaviours measured using the Behavioural Assessment System for Children revealed no sex/gender differences in either ASC or typically developing groups (Solomon, Miller, Taylor, Hinshaw, & Carter, 2012). Although this study had a moderate sample size, sex/gender and diagnosis interactions were not directly tested and the results of difference tests were not reported (see Table 2).

Through parent- and self-report, an interaction between sex, diagnosis and developmental stage was found for depressive symptoms, with ASC females demonstrating

higher levels of depressive symptoms than either ASC males or typically developing females in early adolescence (Oswald et al., 2016). However, by late adolescence ASC males and females were found to have similar levels of depressive symptoms, with the change being explained by ASC males alone having a significant increase in depressive symptoms as they got older (see Table 2). The same study also found a marginally significant interaction between sex, diagnosis and developmental stage for anxiety, with ASC females and typically developing males reporting higher levels of anxiety than ASC males and typically developing females in early adolescence, but both ASC males and females reporting higher levels of anxiety than their typically developing peers by later adolescence.

Some significant sex/gender and diagnosis interactions were found when looking at hyperactivity and inattention in particular. The study by May, Cornish, and Rinehart (2012) also looked at the effect of age on ASC-related outcomes. They found that sex/gender differences varied between ASC and typically developing groups, but that this variation depended on the age of the individuals (see Table 2). Younger males with ASC (aged 7-9 years) were more impaired than younger ASC females, compared to typical males and females. By the time these children reached the age of 10-12 years, both ASC and typically developing groups showed similar sex/gender differences, with males having higher levels of ADHD-related behaviours than females. As a group, children with ASC at all ages demonstrated higher levels of inattention and hyperactivity than typically developing children.

***Play Behaviours*.** The study by Knickmeyer et al. (2008) found that ASC females demonstrate significantly less sex-typical pretend play relative to their typically developing peers than ASC males. No such sex/gender differences were found for non-pretend play, where both males and females with ASC demonstrate similar play preferences to typically developing males and females, respectively. In contrast, Harrop and colleagues (2016) found

that ASC males played with sex-typical cars and trucks less than their typically developing peers, whereas no differences in this play behaviour were found between ASC and typically developing females. While typical sex differences were found for other types of play, such as playing with dolls and houses, there were no differences between ASC females and typically developing females, or between ASC males and typically developing males. One possible explanation for these different findings is that the study by Knickmeyer et al. (2008) utilized a sample with a greater range of ages, who were on average older, than the sample used by Harrop et al. (see Table 2).

Discussion

This study aimed to compare sex/gender differences between individuals with Autism Spectrum Conditions (ASC) and typically developing individuals, to determine whether the patterns of difference vary between these groups. A difference in sex/gender variation between groups would suggest diagnostic criteria for ASC should differ for males and females, to reflect separate ASC phenotypes for males and females.

Meta-analyses found no variation in the profiles of sex/gender differences for ASC and typically developing groups for the core ASC symptoms of communication impairments and RRBIs, or for IQ. Sex/gender differences in social impairments were found to vary depending on the age of the participants. Different patterns of variation in sex/gender differences of social impairments were found for two studies including adolescents in their sample. One study found smaller sex/gender differences in ASC than TD groups, whereas the other study found larger sex/gender differences for ASC participants. No variation in sex/gender differences between groups was found for the other four samples, which included either children or adults only. Due to the small number of studies and contradictory findings in each of these studies, a conclusion of either greater or smaller sex/gender differences in

ASC social impairments cannot be drawn. However, these findings raise the importance of comparing sex/gender differences across all ages, as there may be age-related variation in the similarities and/or differences between ASC and TD groups which could not be fully assessed in this limited sample.

These results suggest that typical sex/gender differences in core symptoms and IQ also occur for individuals with ASC, and, therefore, that individuals with ASC are fundamentally similar to typically developing individuals in regard to their sex/gender variation in core ASC characteristics. This reflects the dimensional nature of ASC, such that people above and below the diagnostic threshold for ASC share traits which vary between sexes/genders.

However, the review of sex/gender differences in associated ASC symptoms revealed some degree of variation between ASC and typical populations, suggesting that having an ASC may impact differently on males and females. Males with ASC were found to have significantly more impaired performance on the trail-making task (one measure of executive function, focusing on task switching and cognitive flexibility), to produce fewer autobiographical memories, and have higher levels of hyperactivity (although only at a younger age) than females with ASC, taking into account typical sex/gender differences. In contrast, females with ASC were found to be significantly more impaired on response inhibition, as measured by the stop task, and visual-spatial processing, as measured by the block design task. Play behaviours in both males and females with ASC were found to be different to those of typically developing males and females. However, the differences appear to depend on the age of the individual, with ASC females displaying more sex-typical behaviours than males as young children, but this pattern reversing between childhood and early adolescence. Age-related patterns were also found for internalising and externalising problems. At younger ages, ASC females generally reported higher levels of internalising

problems while ASC males reported higher levels of externalising problems, a similar pattern to the typically developing groups. However, as the ASC children got older their levels of internalising and externalising problems became more similar. In particular, males with ASC demonstrated increased levels of internalising problems as they developed, bringing them to a similar level as their female peers.

Although patterns of sex/gender differences in autism, empathising, and systemising traits were the same in both groups, the differences were smaller for the ASC group, suggesting that males and females with ASC are more similar in these respects. While some of these findings contradict those using other measures of the same characteristics, they raise the suggestion that male and female performance may vary depending on the task used, and encourage further testing of sex/gender differences using a range of measures. The differences that have been found suggest that males and females with ASC are not a homogenous group, but may have distinct patterns of ability and impairment which, so far, have not been thoroughly investigated.

In contrast, no significant interactions between sex/gender and diagnosis were found for the majority of executive function tasks, attention to detail, theory of mind, most measures of friendship, and most memory tasks. These results suggest that any sex/gender differences found in ASC groups here can be attributed to typical sex/gender differences, rather than the specific differences found between males and females with ASC. When evaluating ASC sex/gender differences in these areas, typical sex/gender performance should be taken into account to gain true measures of relative ability and impairment. However, it is also possible that sex/gender variation between ASC and typically developing groups in these areas may have differed in size rather than direction, as was found for some of the cognitive traits associated with ASC. Sex/gender differences in ASC groups may therefore be broadly

similar to those found in typically developing groups for these characteristics, but these differences may be larger within one group than the other.

The smaller sex/gender differences found for ASC groups in systemising, empathising and autism traits suggest that males and females with ASC are more similar to each other than typically developing males and females. This offers some support for recent theories of sex/gender variation in ASC. Baron-Cohen's Extreme Male Brain theory (2002) proposes that ASC individuals are more 'masculinised' than typically developing individuals, displaying cognitive and behavioural patterns more similar to typically developing males than females regardless of the ASC individual's sex/gender. The Extreme Male Brain theory would therefore predict that males and females with ASC are more similar than typically developing males and females, and even that there might be no sex/gender differences within the ASC population.

In contrast, Bejerot and Eriksson (2014) suggest that both males and females with ASC are different to typically developing males and females, with individuals with ASC displaying gender-atypical patterns of behaviours. According to this hypothesis, sex/gender differences in ASC might not be significant, but males with ASC would be different to typically developing males, and females with ASC would be different to typically developing females. Gender-atypicality in ASC would also account for the higher levels of gender dysphoria (incongruence between one's natal sex and experienced gender) found within children, adolescents and adults with ASC than within the general population (Glidden, Bouman & Jones, 2016). Although research into gender dysphoria in ASC is relatively limited, it has been suggested that there are different mechanisms underlying this co-occurrence within males and females (Pasterski, Gilligan & Curtis, 2014), which may reflect the differences in expression of ASC between sexes/genders found in the present study.

Although these two theories both predict males and females with ASC will be relatively similar to each other, they offer different predictions about how individuals with ASC are similar and/or different to typically developing males and females. However, these comparisons were not directly tested in this analysis, therefore conclusions about whether individuals with ASC are more similar to typically developing males, or differ from both males and females, must be left for future research.

The differences found in male and female ASC symptoms may offer some explanation for the differences in diagnostic rates between sexes/genders in ASC. As recently suggested by Lehnhardt et al. (2015), the greater task-switching and cognitive flexibility abilities of females with ASC may explain why they are able to develop compensatory or 'camouflaging' techniques to 'mask' their social and communication impairments. Lehnhardt et al. (2015) also found higher processing speed in females than males in their adult diagnosis sample, suggesting that females with ASC are better able to use explicit cognitive strategies to cope in complex social interactions. It is possible that other cognitive and behavioural abilities found in typically developing females are also utilised by females with ASC when camouflaging, although studies of ASC sex/gender differences with typically developing controls are still limited. Further exploration of the female phenotype in ASC will give us a greater understanding of the tools and techniques used by women and girls, which may result in their being missed by clinical services.

Limitations

A key limitation of this analysis is the small number of studies included, due to a dearth of research comparing ASC and typically developing groups. Meta-analysis based on a small number of studies is more susceptible to second-order sampling errors, because variation in standard deviations is more likely to be influenced by artifacts (Hunter & Schmidt, 2004). Several of the studies included in the qualitative review and meta-analyses

were underpowered to detect small effect sizes, and so it is possible that significant variation in sex/gender differences between groups was not picked up in our analysis. Consequently we echo the calls by many others (e.g., Lai et al., 2015) for future studies to include large enough numbers of males and females from both typical and ASC populations, in order to draw stronger and more consistent conclusions about sex/gender differences.

Another consequence of the limited number of studies is that few potential confounding variables were identified or controlled for. Age was included as a moderator in the meta-analyses and in some of the reviewed studies, and was found to influence sex/gender variation between groups in some areas. Previous studies have also identified IQ, ethnicity, comorbidities, and characteristics of ASC diagnosis, amongst other factors, as interacting with both sex/gender and ASC to produce differential outcomes over time (Brugha et al., 2011; Croen, Grether, & Selvin, 2002; Farley et al., 2009; Holtmann, Bölte, & Poustka, 2007). Consistent measurement and reporting of these characteristics would enable better interpretation of these studies' heterogeneity, which is a significant limitation of the present meta-analyses. Our results should be interpreted with these limitations in mind, although we conclude that the finding of some significant variation in sex/gender differences, despite these limitations, is robust and meaningful.

Although the most recent DSM-5 diagnostic criteria have combined social and communication impairments into one symptom, we analysed them separately. This is because some of the studies included in this analysis only measured either social or communication impairments, therefore scores for both could not be combined for all studies. In addition, hypo/hyper-reactivity to sensory stimulation is a criterion in DSM-5, but was not measured in many of the studies included here. Conclusions therefore cannot be directly applied to the most recent DSM-5 criteria, but still apply to the ICD-10 diagnostic criteria.

A final limitation is that this study was focused on behavioural and cognitive characteristics of ASC only. While these characteristics are of the most relevance to diagnostic criteria (as physiological markers of ASC have not been identified, and therefore diagnosis relies on behavioural information solely), there are many other characteristics of ASC which also display sex/gender variation. This paper lacks the space to offer a full review of sex/gender differences in all areas of research relating to ASC. However, see recent reviews by Kirkovski et al. (2013), Lai et al. (2015), and Werling and Geschwind (2013) for more information on sex/gender differences in neurodevelopmental, biological and genetic factors amongst other characteristics. A comparison of sex/gender differences between ASC and typically developing groups in these characteristics would further broaden our understanding of the expression of ASC in both males and females.

Conclusions

The present results suggest that ASC may have differential impacts on individuals depending on their sex/gender. While differences in core symptoms and IQ reflect typical sex/gender patterns of ability, ASC appears to produce different patterns of some associated ASC characteristics for males and females, beyond typical sex/gender variation. This supports the conclusions of several previous reports, that females with ASC may present different cognitive and/or behavioural phenotypes to most males with ASC, and that clinicians should be mindful of these differences during assessment and diagnosis. We also suggest that there are many individual factors, including age, IQ, and social background, which may interact with an ASC to produce variations in development, and so should not be disregarded in favour of the 'typical' ASC presentation. A significant limitation of this study was the small number of studies available for review. Future research can address this by ensuring all sex/gender comparisons within ASC individuals include a comparison group of

typically developing males and females, to guarantee that sex/gender differences in the general population are accounted for in analyses.

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Notes

[1]Individuals on the autism spectrum have reported that the term 'disorder' is stigmatising and does not reflect the range of strengths and difficulties experienced by those on the spectrum. Following previous researchers (e.g. Lai & Baron-Cohen, 2015), we use the term 'Autism Spectrum Condition' (ASC) in reference to those diagnosed with an autism spectrum disorder.

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Table 1

Sample characteristics of studies included in review

Paper	Authors (Date)	ASC symptom(s) assessed	ASC group diagnoses at time of study	ASC diagnostic criteria used	How diagnosis confirmed	ASC Group			Typically Developing Group		
						Males (n)	Females (n)	Mean age (years)	Males (n)	Females (n)	Mean age (years)
1	Baron-Cohen et al. (2014)	Empathising traits Systemising traits Autism traits	AS (62%) ASD (29%) HFA (5%) PDD (2%) Autism (1%)	Not reported	Not reported	357	454	34.7	1344	2562	34.4
2	Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright (2003)	Empathising traits Systemising traits	AS/HFA (proportions not reported)	DSM-IV criteria for Autism/AS	Not reported	33	14	38.1	114	164	30.9
3	Baron-Cohen & Wheelwright (2005)	Friendships	AS/HFA (proportions not reported)	DSM-IV criteria for Autism/AS	Not reported	51	17	34.4	27	49	40.5
4	Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley (2001)	Autism traits	AS/HFA (proportions not reported)	DSM-IV criteria for Autism/AS	Not reported	45	13	31.6	76	98	37
5	Bölte, Duketis, Poustka, & Holtmann (2011)	IQ Executive functions	Autism (68%) AS (20%) PDD-NOS (13%)	ICD-10 criteria for Autism/AS/PDD-NOS	Clinician assessment & ADI-R /ADOS	35	21	14.2	23	35	14.6

6	Dean et al. (2014)	Friendships	ASD (100%)	Not reported	Clinician assessment & ADOS	25	25	7.5	25	25	7.8
7	Goddard, Dritschel, & Howlin (2014)	IQ Memory	ASD (100%)	DSM-IV-TR criteria for ASD	Clinician assessment & SCQ	12	12	12.9	12	12	12.6
8	Harrop, Green & Hudry (2016)	IQ Play behaviours	ASD (100%)	Not reported	ADI-R /ADOS	14	14	3.8	14	12	2.0
9	Head, McGillivray, & Stokes (2014)	Friendships	ASD (not including LFA or PDD-NOS; 100%)	Not reported	Not reported	25	25	13.7	26	25	12
10	Holt et al. (2014)	IQ Theory of mind	AS/HFA (proportions not reported)	Not reported	ADI-R /ADOS	33	16	14.6	20	20	15.1
11	Kirkovski, Enticott, Hughes, Rossell & Fitzgerald (2016)	IQ Social impairments RRBIs Empathising traits Autism traits	AS (85%) HFA (15%)	DSM-IV-TR criteria for ASD	Viewing of clinician diagnostic report	13	14	30.7	11	12	30.7
12	Knickmeyer, Wheelwright & Baron-Cohen (2008)	Play behaviours	Of those available (91% of total sample): AS (32%) Autism (58%) HFA (3%)	ICD-10 or DSM-IV criteria for ASC	Not reported	46	20	10.2	31	24	5.2

			PDD-NOS (3%) Atypical Autism (2%)								
13	Lai et al. (2012)	IQ Executive functions Theory of mind Memory	AD/AS (proportions not reported)	ICD-10 or DSM-IV criteria for ASC	ADI-R /ADOS /AAA	32	32	27.6	32	32	28.2
14	Lemon, Gargaro, Enticott, & Rinehart (2011)	IQ Executive functions	HFA (70%) AS (30%)	DSM-IV criteria for HFA/AS	Clinician assessment	10	13	11	8	14	11.4
15	May, Cornish & Rinehart (2012)	Social impairment Communication impairment RRBIs IQ Inattention/ hyperactivity	AS (64%) AD (36%)	DSM-IV-TR criteria for AS/AD	Viewing of clinician diagnostic report	32	32	9.9	30	30	9.3
16	Oswald et al. (2016)	IQ Internalising problems	ASD (100%)	Not reported	AQ/ASDS	18	14	14.8	18	14	14.9

17	Park et al. (2012)	Social impairment Communication impairment RRBIs IQ Internalising problems Externalising problems	ASD (100%)	DSM-IV-R criteria for PDDs	Clinician assessment	91	20	8.3	26	25	8.6
18	Sedgewick, Hill, Yates, Pickering & Pellicano (2015)	Social impairment IQ Friendships	Autism (83%) AS (17%)	DSM-IV-TR or ICD-10 criteria for autism/ AS	Clinician assessment and statement of special educational needs indicating autism	10	13	13.9	10	13	13.8
19	Solomon et al. (2012)	Social impairment Communication impairment RRBIs IQ Internalising problems	ASD including HFA, AS & PDD-NOS (proportions not reported)	DSM-IV-TR criteria for AD/AS/ PDD-NOS	ADOS/SDQ	20	20	12.2	17	19	12

20	Zwaigenbaum et al. (2012)	Social impairment Communication impairment RRBIs	Not reported	DSM-IV-TR criteria for ASD	Viewing of clinician diagnostic report & ADI-R/ ADOS	57	28	3.3	64	64	3.3
		IQ				55	25	3.3	63	63	3.3

Note. RRBIs = Restricted, Repetitive Behaviours & Interests; AS = Asperger Syndrome; ASD = Autism Spectrum Disorder; HFA = High Functioning Autism; PDD = Pervasive Developmental Disorder; PDD-NOS = Pervasive Developmental Disorder, Not Otherwise Specified; LFA = Low Functioning Autism; AD = Autistic Disorder; ADI-R = Autism Diagnostic Interview (Revised); ADOS = Autism Diagnostic Observation Schedule; SCQ = Social Communication Questionnaire; AAA = Adult Asperger Assessment; DSM-IV = Diagnostic & Statistical Manual of Mental Disorder (4th Edition); ASDS = Asperger Syndrome Diagnostic Scale; AQ = Autism Spectrum Quotient; DSM-IV-TR = Diagnostic & Statistical Manual of Mental Disorder (4th Edition, Text Revision); ICD-10 = International Classification of Diseases (10th Edition)

Table 2
Measures and key findings of papers included in review

Paper	Authors (date)	Outcome measures	Key findings
1	Baron-Cohen et al. (2014)	EQ SQ AQ	EQ: significant interaction between Sex and Diagnosis found smaller sex differences in ASC than TD group (F [df = 1, 4351] = 14, $p < .001$, $\omega = .06$); ASC Female > ASC Male (F [df = 1, 4351] = 33.4, $p < .001$, $d = .40$); TD Female > TD Male (F [df = 1, 4351] = 455, $p < .001$, $d = .76$). SQ: significant interaction between Sex and Diagnosis found smaller sex differences in ASC than TD group (F [df = 1, 4146] = 11.6, $p < .001$, $\omega = .06$); ASC Male > ASC Female (F [df = 1, 4146] = 15.6, $p < .001$, $d = .27$); TD Male > TD Female (F [df = 1, 4146] = 275.36, $p < .001$, $d = .61$). AQ: significant interaction between Sex and Diagnosis found smaller sex differences in ASC than TD group (F [df = 1, 4713] = 3.94, $p = .047$, $\omega = .02$); ASC Male > ASC Female (F [df = 1, 4713] = 10.97, $p < .001$, $d = .18$); TD Male > TD Female (F [df = 1, 4713] = 133, $p < .001$, $d = .41$).

2	Baron-Cohen, Richler, Bisarya, Gurunathan & Wheelwright (2003)	EQ SQ	EQ: no significant difference between ASC Female and ASC Male (t [df = 18.68] = 1.09, p = .22); TD Female > TD Male (F [df = 1, 269] = 38.6, p < .001). SQ: no significant difference between ASC Female and ASC Male (t [df = 45] = -0.46, p > .65); TD Male > TD Female (F = [df = 1, 270] = 18.1, p < .001).
3	Baron-Cohen & Wheelwright (2005)	FQ	FQ: no significant interaction between Sex and Diagnosis (F [df = 1, 139] = 3.5, p = .06); TD > ASC (F [df = 1, 139] = 51.6, p < .001); Female > Male (F [df = 1, 139] = 16.8, p < .001).
4	Baron-Cohen, Wheelwright, Skinner, Martin & Clubley (2001)	AQ	AQ: significant interaction between Sex and Diagnosis (F [df = 1, 228] = 6.01, p .02); no significant difference between ASC Female and ASC Male (statistical tests not reported); TD Male > TD Female (t = 2.56, p < .01).
5	Bolte, Duketis, Poustka & Holtmann (2011)	WISC WCST ToH TMT EFT BDT	WISC: no significant interaction between Sex and Diagnosis (F = 0.07, p = .79, partial η^2 = .00). WCST: no significant interaction between Sex and Diagnosis (F = 0.09, p = .75, partial η^2 = .00). ToH: no significant interaction between Sex and Diagnosis for number of moves (F = 2.22, p = .07, partial η^2 = .03) or completion time (F = 0.00, p = .96, partial η^2 = .00). TMT: significant interaction between Sex and Diagnosis (F = 3.91, p = .04, partial η^2 = .04); ASC Females were faster than ASC Males (statistical tests not reported); ASC Males were faster than ASC Females (statistical tests not reported). EFT: no significant interaction between Sex and Diagnosis (F = 0.02, p= .88, partial η^2 = .00). BDT: significant interaction between Sex and Diagnosis (F = 5.56, p = .02, partial η^2 = .05); ASC Males performed better than ASC Females (statistical tests not reported); ASC Females performed better than ASC Males (statistical tests not reported).
6	Dean et al. (2014)	Friendships Survey	Friendships Survey: no significant interaction between Sex and Diagnosis for social preferences (F [df = 1, 96] = 1.09, p = .30, ω^2 = 0.2), social acceptance (F [df = 4, 95] = .41, p = .53, ω^2 = 1.35), or social connections (F [df = 3, 96] = 1.35, p = 25, ω^2 = .01).

7	Goddard, Dritschel & Howlin (2014)	WASI BPVS AMCT RRMT	WASI: no significant difference between ASC and TD scores (t = .12, p = .94). BPVS: no significant difference between ASC and TD scores (t = 1.3, p = .24). AMCT: significant interaction between Sex and Diagnosis (F [df = 1, 44] = 4.24, p = .045, η^2 = .09); ASC Females produced more autobiographical memories than ASC Males (statistical tests not reported); no difference between TD Females and TD Males (statistical tests not reported). RRMT: no significant interaction between Sex and Diagnosis (statistical tests not reported).
8	Harrop, Green & Hudry (2016)	Mullen ELC Toy Engagement	Mullen: no significant difference between ASC Female and ASC Male (t [df = 26] = 9.15, p = .37); no significant difference between ASC and TD scores (t [df = 3, 50] = 0.94, p = .96). Toy Engagement: significant interaction between Sex and Diagnosis for garage and cars (F [df = 3, 50] = 20.21, p < .001); TD Males played more than ASC Males (p =.04), or TD Females and ASC Females (p < .001); no significant interactions for other types of play.
9	Head, McGillivray & Stokes (2014)	FQ	FQ: no significant interaction between Sex and Diagnosis (F [df = 1, 101] = 1.00, p > .05, η^2 = .01); ASC Females > ASC Males (t [df = 48] = -3.64, p < .05).
10	Holt et al. (2014)	WASI RMET	WASI: no significant difference between ASC Male and TD Male (statistical tests not reported); ASC Female < TD Female (p = .001). RMET: ASC < TD (p = .002); ASC Male < TD Male (F [df = 2, 61] = 3.39, p = .004); no significant difference between ASC Female and TD Female (F [df = 2, 60] = 2.02, p = .141); no significant interaction between Sex and Diagnosis (statistical tests not reported).
11	Kirkovski, Enticott, Hughes, Rossell & Fitzgerald (2016)	KBIT-2 RAADS-R EQ AQ	KBIT-2: no significant difference between ASC and TD (statistical tests not reported). RAADS-R: ASC > TD on all subscales (statistical tests not reported). EQ: ASC < TD (statistical tests not reported). AQ: ASC > TD (statistical tests not reported).
12	Knickmeyer, Wheelwright & Baron-Cohen (2008)	CPQ	CPQ: Sex-typical play shown by TD Females (t [df = 42] = 11.58, p < .001), TD Males (t [df = 60] = 13.55, p < .001) and ASC Males (t [df = 45] = 11.8, p < .001); Sex-typical play not shown by ASC Females (t [df = 19] = -1.30, p = .21).

13	Lai et al. (2012)	WASI Go/No-Go Task EFT RMET KDEFT NWRT	WASI: no significant difference between Female ASC, Male ASC, Female TD or Male TD groups (statistical tests not reported). Go/No-Go Task: no significant interaction between Sex and Diagnosis (F [df = 2,120] = 0.173, p = .842, Pillai's Trace V = .003). EFT: marginally significant interaction between Sex and Diagnosis (F [df = 1, 122] = 137.40, p < .001); ASC M < TD M (p = .001); no significant difference between ASC F and TD M (p = .83); no significant difference between ASC F and ASC M (p = .04); TD M > TD F (p < .001). RMET: no significant interaction between Sex and Diagnosis (F [df = 1, 122] = 0.42, p = .521, partial η^2 = .003). KDEFT: no significant interaction between Sex and Diagnosis on any emotion (see paper for test results). NWRT: no significant interaction between Sex and Diagnosis (F [df = 1,122] = 0.23, p = .635, Pillai's Trace V = .002).
14	Lemon, Gargaro, Enticott & Rinehart (2011)	WISC Stop Task	WISC: no statistical tests reported. Stop Task: Significant effect of Group (F [df = 3, 19] = 3.87, p = .026); ASC Females were slower than TD Females (p = .002, d = 1.30) and TD Males (p = .025, d = 0.86); no significant difference between ASC Males and TD Males (p = .919, d = 0.05).
15	May, Cornish & Rinehart (2012)	SRS CCC RBQ WISC/WASI SWAN Conners 3 Parent Short Form	SRS: no significant interaction between Sex and Diagnosis (statistical tests not reported); ASC Group > TD Group (F = 229.871, p < .001); no sex differences (F = 0.996, p not reported). CCC: no significant interaction between Sex and Diagnosis (statistical tests not reported); ASC Group < TD Group on all subscales (see paper for test results); Males < Females for some subscales (see paper for test results). RBQ: no significant interaction between Sex and Diagnosis (statistical tests not reported); ASC Group > TD Group (F = 85.397, p < .001); Males > Females for one subscale (see paper for test results). WISC/WASI Full-Scale IQ: TD Group > ASC Group (F = 7.716, p < .001). SWAN: ASC Group > TD Group for hyperactivity (F = 60.08, p < .001) and inattention (F = 83.08, p < .001); Males > Females for hyperactivity (F = 4.51, p < .05) and inattention (F = 4.28, p < .05). Conners 3: significant interaction between Sex, Age and Diagnosis for hyperactivity (F [df = 1, 122] = 4.279, p = .041); no sex differences for inattention (F = 2.981, p not reported); ASC Group > TD Group for inattention (F = 80.089, p < .001).
16	Oswald et al. (2016)	KBIT-2 RCADS MASC CES-D	KBIT-2: no significant difference between ASC and TD scores (F < 0.01, p not reported). RCADS: significant interaction between Sex, Diagnosis, and Developmental Stage (F [df = 2, 54] = 3.30, p = .04, partial η^2 = 0.11); ASC Female > ASC Male and TD Female in early adolescence but no difference between ASC Female and ASC Male by late adolescence (all p's < .01).

			MASC: marginally significant interaction between Sex, Diagnosis, and Developmental Stage (F [df = 1, 55] = 3.79, p = .06, partial η^2 = 0.06; ASC Female > ASC Male and TD Female in early adolescence (all p's < .01). CES-D: marginally significant interaction between Sex, Diagnosis, and Developmental Stage (F [df = 4, 51] = 2.17, p = .09, partial η^2 = 0.15; ASC Female and TD Male > ASC Male and TD Female in early adolescence but ASD Female and Male > TD Female and Male by late adolescence (all p's < .05).
17	Park et al. (2012)	SCQ ASDS ADI-R LIPS CBC AQ EQ SQ	SCQ: ASC Male > ASC Female (t = 2.27, p < .001); no significant difference between TD Male and TD Female (t = 0.62, p = .54). ASDS: no significant difference between ASC Female and ASC Male on any subscale (see paper for test results); no significant difference between TD Female and TD Male on any subscale (see paper for test results). ADI-R: ASC Male > ASC Female for communication impairments (t = 2.34, p = .028) and repetitive, stereotyped behaviours (t = 2.03, p = .045); no significant difference between TD Female and TD Male for any core ASC symptom (see paper for test results). LIPS: TD Group > ASC Group (F = 26.80, p = < .001). CBC: no significant difference between ASC Female and ASC Male on any subscale (see paper for test results); no significant difference between TD Female and TD Male on any subscale (see paper for test results). AQ: ASC Male > ASC Female (t = 2.19, p = .031); no significant difference between TD Male and TD Female (t = 1.76, p = .085). EQ: no significant difference between ASC Female and ASC Male (t = -0.53, p = .605); no significant difference between TD Female and TD Male (t = -1.67, p = .104). SQ: no significant difference between ASC Female and ASC Male (t = 0.87, p = .388); TD Male > TD Female (t = 2.52, p = .016).
18	Sedgewick, Hill, Yates, Pickering & Pellicano (2015)	SRS WAIS FQS	SRS: significant interaction between Sex and Diagnosis (F [df = 1, 42] = 4.79, p = .03, partial η^2 = .10); ASC M > ASC F (t [df = 21] = .242, p = .03, d = 1.03); no significant difference between TD M and TD F (t [df = 21] = .26, p = .12). WAIS: no significant effect of Sex (p > .33) or Diagnosis (p > .18); no significant interaction between Sex and Diagnosis (p > .33). FQS: significant interaction between Sex and Diagnosis for Help (F [df = 1, 42] = 6.21, p = .01, partial η^2 = .13) and Closeness (F [df = 1, 42] = 6.26, p = .01, partial η^2 = .13) subscales; no significant interactions found for other subscales (see paper for test results).

19	Solomon et al. (2012)	SRS CCC RBS WASI BASC	SRS: no significant difference between ASC Female and ASC Male on any subscale (statistical tests not reported); ASC Female > TD Female on all subscales (statistical tests not reported); no difference between ASC Male and TD Male on any subscale (statistical tests not reported); no difference between TD Female and TD Male on any subscale (statistical tests not reported). CCC: no significant difference between ASC Female and ASC Male on any subscale (statistical tests not reported); TD Female > ASC Female on all subscales (statistical tests not reported); TD Male > ASC Male on all subscales (statistical tests not reported); no significant difference between TD Female and TD Male (statistical tests not reported). RBQ: no significant difference between ASC Female and ASC Male on any subscale (statistical tests not reported); ASC Female > TD Female for all subscales but one (statistical tests not reported); ASC Male > TD Male for all subscales (statistical tests not reported); no significant difference between TD Female and TD Male (statistical tests not reported). WASI: TD group > ASC group (statistical tests not reported). BASC: no significant difference between ASC Female and ASC Male on any subscale (statistical tests not reported); ASC Female > TD Female on all subscales (statistical tests not reported); ASC Male > TD Male on depression only (statistical tests not reported); no significant difference between TD Female and TD Male (statistical tests not reported).
20	Zwaigenbaum et al. (2012)	ADI-R Mullen ELC	ADI-R: no significant interaction between Sex and Diagnosis for any subscale (see paper for test results); Males > Females for communication (F = 19.5, $p < .001$) and social impairments (F = 3.95, $p = .049$); ASC Group > TD Group for all subscales (see paper for test results). Mullen ELC: no significant interaction between Sex and Diagnosis for any subscale (see paper for test results).

Note. Degrees of freedom (df) for tests are included where reported in original papers. ASC = Autism Spectrum Condition; TD = Typically Developing; EQ = Empathising Quotient; SQ = Systemising Quotient; AQ = Autism Quotient; FQ = Friendship Quotient; WISC = Wechsler Intelligence Scales for Children; WCST = Wisconsin Card Sort Test; ToH = Tower of Hanoi; TMT = Trail-Making Test; EFT = Embedded Figures Test; BDT = Block Design Test; WASI = Wechsler Abbreviated Scale of Intelligence; BPVS = British Picture Vocabulary Scale; AMCT = Autobiographical Memory Cueing Task; RRMT = Recent & Remote Memory Task; CPQ = Child Play Questionnaire; RMET = Reading the Mind in the Eyes Task; Karolinska Directed Emotional Faces Task; NWRT = Non-Word Repetition Task; SRS = Social Responsiveness Scale; CCC = Children's Communication Checklist; RBS = Repetitive Behaviours Scale; SWAN = Strengths and Weaknesses in Attention-Deficit Hyperactivity Symptoms; SCQ = Social Communication Questionnaire; ASDS = Asperger Syndrome Diagnostic Scale; RBQ = Repetitive Behaviours Questionnaire; ADI-R = Autism Diagnostic Interview – Revised; LIPS = Leiter International Performance Scale; CBC = Child Behavioural Checklist; BASC = Behaviour Assessment System for Children; Mullen ELC = Mullen Early Learning Composite; KBIT-2 = Kaufman Brief Intelligence Test – Second Edition; RAADS-R = Ritvo Autism and Asperger's Diagnostic Scale—Revised; FQS = Friendship

Qualities Scale; RCADS = Revised Child Anxiety & Depression Scale; MASC = Multidimensional Anxiety Scale for Children; CES-D = Centre for Epidemiological Studies Depression Scale

Table 3

Sex/gender differences in social and communication impairments for Autism Spectrum Condition (ASC) and typically developing (TD) groups

Social Impairments

Authors (date)	Test used	Age of participants	ASC			TD		
			Female (SD)	Male (SD)	SMD [95% CI]	Female (SD)	Male (SD)	SMD [95% CI]
Kirkovski et al. (2016)	RAADS-R Social Relatedness subscale	Adult	28.36 (13.87)	28.77 (13.80)	-0.03 [-0.78, 0.73]	3.92 (4.01)	4.36 (4.61)	-0.10 [-0.87, 0.67
May, Cornish & Rinehart (2012)	SRS	Child	97.41 (31.77)	99.97 (22.71)	-0.09 [-0.58, 0.40]	23.17 (16.49)	27.30 (20.42)	-0.22 [-0.73, 0.29]
Park et al. (2012)	ADI-R social subscale	Child	8.55 (4.43)	10.25 (3.83)	-0.43 [-0.92, 0.06]	1.00 (1.22)	1.28 (1.46)	-0.20 [-0.76, 0.35]
Sedgewick et al. (2015)	SRS	Adolescent	72.00 (32.39)	103.00 (27.76)	-0.98 [-1.85, -0.11]	43.00 (13.18)	40.00 (26.16)	0.15 [-0.68, 0.97]
Solomon et al. (2012)	SRS	Child/ Adolescent	103.85 (27.64)	104.60 (32.04)	-0.02 [-0.64, 0.60]	18.11 (18.79)	62.81 (60.81)	-1.00 [-1.69, -0.30]

Zwaigenbaum et al. (2012)	ADI-R social subscale	Child	10.75 (7.00)	11.30 (5.90)	-0.09 [-0.54, 0.37]	2.25 (2.34)	2.70 (2.66)	-0.18 [-0.44, 0.08]
Communication Impairments								
Authors (date)	Test used	Age of participants	ASC			TD		
			Female (SD)	Male (SD)	SMD [95% CI]	Female (SD)	Male (SD)	SMD [95% CI]
May, Cornish & Rinehart (2012)	CCC – global communication subscale	Child	36.75 (15.05)	33.19 (16.00)	0.23 [-0.26, 0.72]	80.60 (22.94)	78.63 (19.78)	0.09 [-0.42, 0.60]
Park et al. (2012)	ADI-R nonverbal communication subscale	Child	17.75 (8.20)	22.31 (6.16)	-0.69 [-1.18, -0.20]	1.80 (2.33)	1.50 (1.90)	0.14 [-0.41, .69]
Solomon et al. (2012)	CCC – global communication Subscale	Child/ Adolescent	76.00 (14.93)	80.95 (24.55)	-0.24 [-0.86, 0.38]	113.05 (16.20)	111.00 (16.37)	0.12 [-0.53, 0.78]
Zwaigenbaum et al. (2012)	ADI-R communication subscale	Child	8.71 (4.54)	10.09 (3.61)	-0.35 [-0.80, 0.11]	1.71 (2.14)	2.85 (2.86)	-0.45 [-0.71, -0.19]

Note. SD = Standard Deviation; SMD = Standardised Mean Difference; CI = confidence interval; SRS = Social Responsiveness Scale; ADI-R = Autism Diagnostic Interview – Revised; RAADS-R = Ritvo Autism and Asperger's Diagnostic Scale—Revised; CCC = Child Communication Checklist; ADI-R = Autism Diagnostic Interview – Revised

Figure 3
Meta-analysis of studies comparing differences in sex/gender variation in social impairment between ASC and TD groups

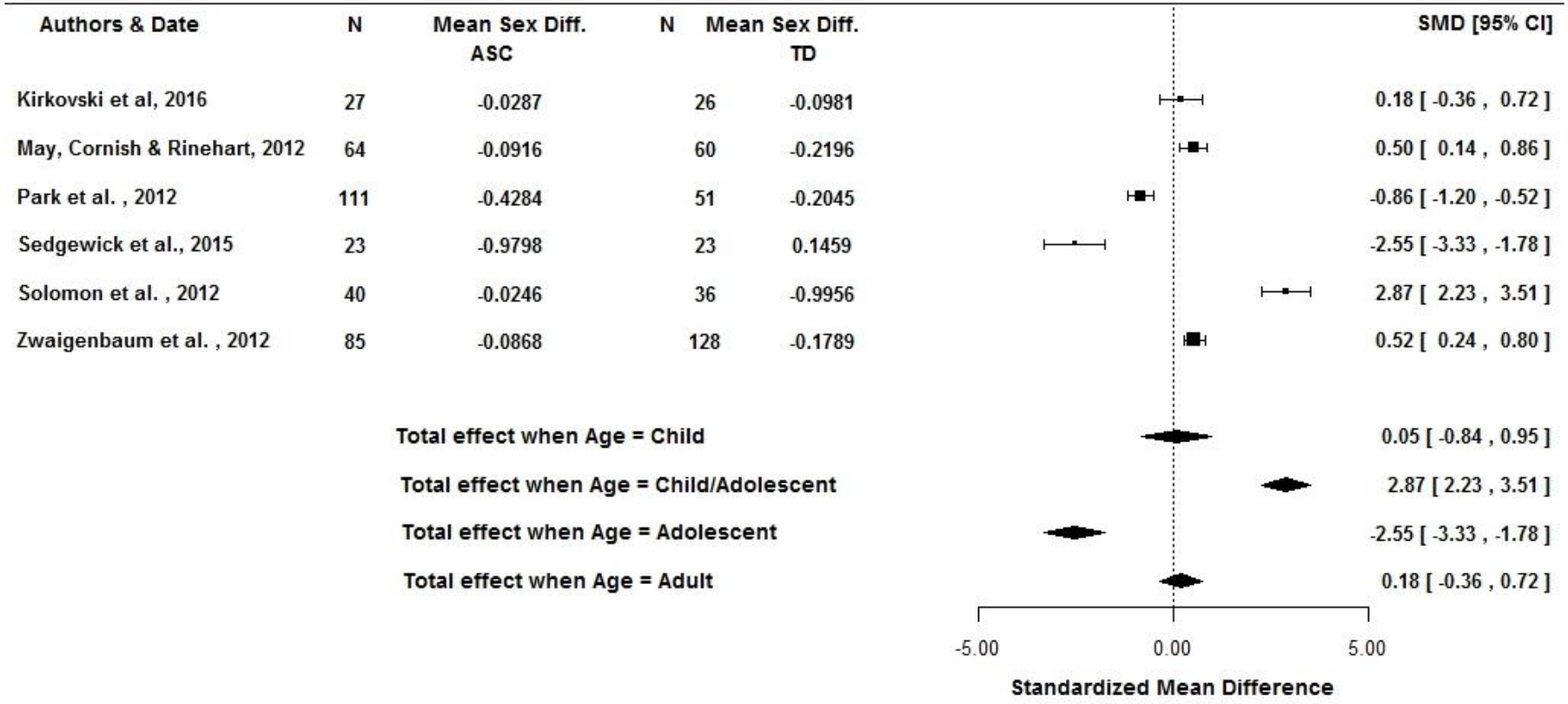

Figure 3. Forest plot of standardised mean differences (SMD) for social impairment in each study and total SMD at each level of moderator 'Age', drawn in R using 'metafor' package (Viechtbauer, 2010; R Foundation for Statistical Computing, Vienna, Austria). Central rectangle indicates mean effect; lines indicate 95% confidence intervals. Negative effects indicate smaller sex/gender differences in ASC groups than in TD groups; positive effects indicate larger sex/gender differences in ASC groups than in TD groups. If lines cross the y axis, effect is not significant. Rectangles indicate the effect size (SMD) in each study, with the size of the rectangle indicating the 'weight' of the study (determined by the sample size and the precision of the confidence intervals). Diamonds indicate the average effect size in each group of studies,

wider diamonds indicating wider confidence intervals of the effect. ASC = Autism Spectrum Condition group; TD = typically developing group; CI = confidence interval.

Figure 4
Meta-analysis of studies comparing differences in sex/gender variation in communication impairment between ASC and TD groups

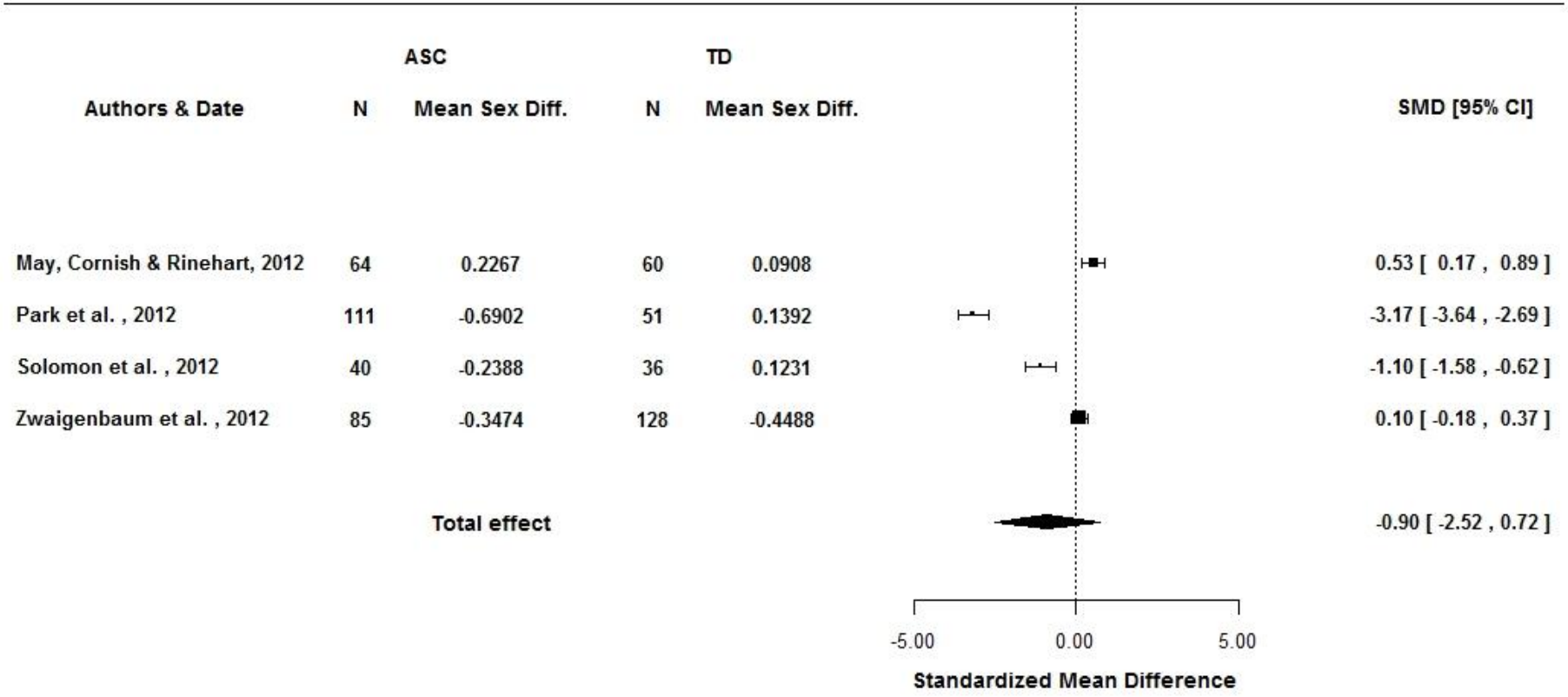

Figure 4. Forest plot of standardised mean differences (SMD) for communication impairment in each study and total SMD from all studies, drawn in R using 'metafor' package (Viechtbauer, 2010; R Foundation for Statistical Computing, Vienna, Austria). Central rectangle indicates mean effect; lines indicate 95% confidence intervals. Negative effects indicate smaller sex/gender differences in ASC groups than in TD groups;

positive effects indicate larger sex/gender differences in ASC groups than in TD groups. If lines cross the y axis, effect is not significant. Rectangles indicate the effect size (SMD) in each study, with the width of the rectangle indicating the 'weight' of the study (determined by the sample size and the precision of the confidence intervals). The diamond indicates the average effect across all studies, with the width of the

Authors (date)	Test used	Age of participants	ASC			TD		
			Female (SD)	Male (SD)	SMD [95% CI]	Female (SD)	Male (SD)	SMD [95% CI]
Kirkovski et al. (2016)	RAADS-R Circumscribed Interests	Adult	53.79 (21.67)	57.00 (12.85)	-0.17 [-0.93, 0.58]	8.42 (5.84)	12.09 (12.00)	-0.38 [-1.21, 0.45]
May, Cornish & Rinehart (2012)	RBQ	Child	35.48 (31.77)	38.34 (9.01)	-0.12 [-0.61, 0.37]	23.23 (4.52)	23.86 (3.42)	-0.16 [-0.66, 0.35]
Park et al. (2012)	ADI-R RSB subscale	Child	4.10 (2.51)	5.48 (2.79)	-0.50 [-0.99, -0.01]	0.36 (0.70)	0.50 (0.81)	-0.18 [-0.73, 0.37]
Solomon et al. (2012)	RBS	Child/ Adolescent	2.47 (1.77)	5.00 (3.16)	-0.97 [-1.62, -0.31]	0.00 (0.00)	0.41 (1.23)	-0.48 [-1.14, 0.19]
Zwaigenbaum et al. (2012)	ADI-R RSB subscale	Child	4.43 (2.60)	4.07 (2.68)	0.13 [-0.32, 0.59]	0.74 (1.26)	1.21 (1.74)	-0.31 [-0.57, -0.05]

diamond indicating the confidence intervals of the effect. ASC = Autism Spectrum Condition group; TD = typically developing group; CI = confidence interval.

Table 4
Sex/gender differences in Restrictive/Repetitive Behaviours and Interests (RRBIs) for ASC and TD groups

Note: CI = confidence interval; RBQ = Repetitive Behaviours Questionnaire; RBS = Repetitive Behaviours Scale; ADI-R = Autism Diagnostic Interview – Revised; RAADS-R = Ritvo Autism and Asperger's Diagnostic Scale—Revised

Figure 5
Meta-analysis of studies comparing differences in sex/gender variation in restricted/repetitive behaviours and interests (RRBIs) between ASC and TD groups

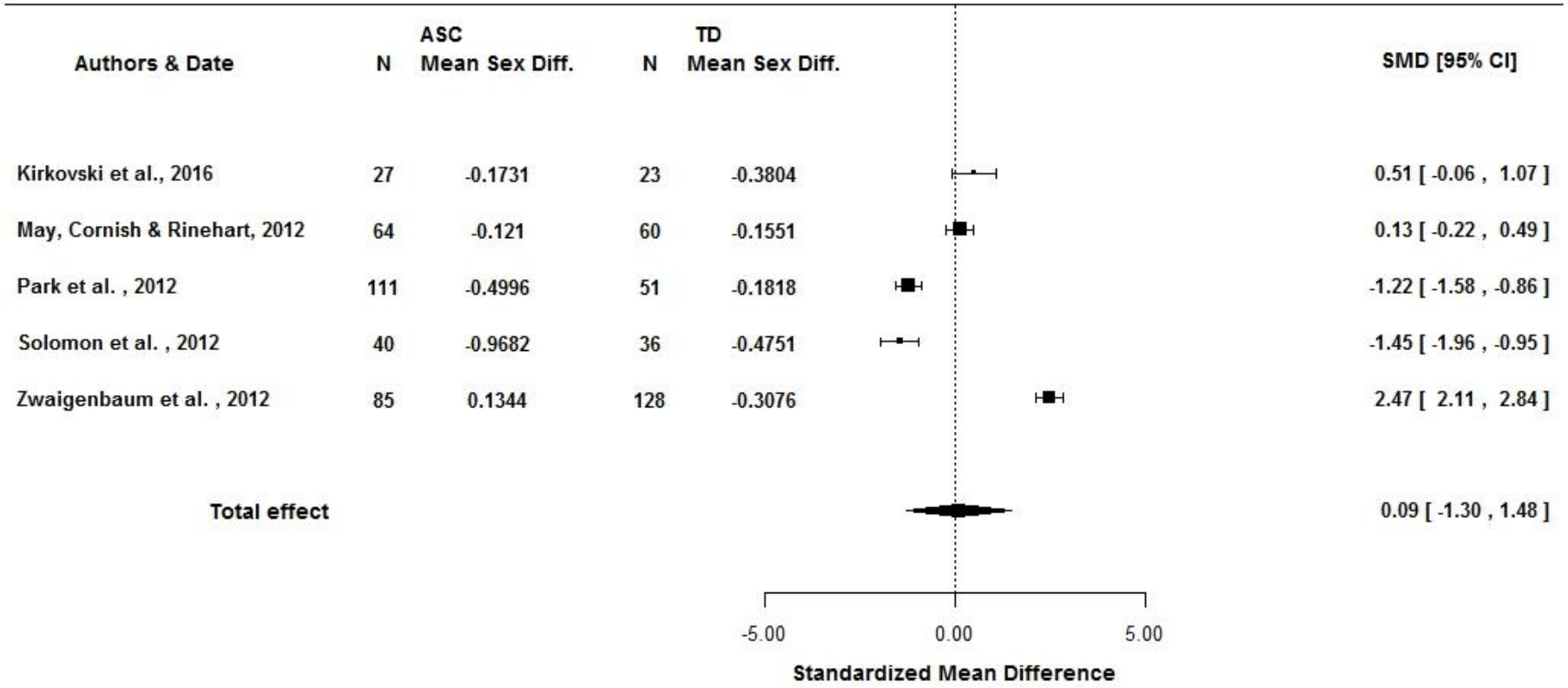

Figure 5. Forest plot of standardised mean differences (SMD) for RRBIs in each study and total SMD from all studies, drawn in R using 'metafor' package (Viechtbauer, 2010; R Foundation for Statistical Computing, Vienna, Austria). Central rectangle indicates mean effect; lines indicate 95% confidence intervals. Negative effects indicate smaller sex/gender differences in ASC groups than in TD groups; positive effects indicate larger sex/gender differences in ASC groups than in TD groups. If lines cross the y axis, effect is not significant. Rectangles indicate the effect size (SMD) in each study, with the size of the rectangle indicating the 'weight' of the study (determined by the sample size and the

precision of the confidence intervals). The diamond indicates the average effect across all studies, with the width of the diamond indicating the confidence intervals of the effect. ASC = Autism Spectrum Condition group; TD = typically developing group; CI = confidence interval.

Table 5
Sex/gender differences in IQ for ASC and TD groups

Authors (date)	Test used	Age of participants	ASC			TD		
			Female (SD)	Male (SD)	SMD [95% CI]	Female (SD)	Male (SD)	SMD [95% CI]
Bolte, Duketis, Poustka & Holtmann (2011)	WISC Non-Verbal IQ	Child/ Adolescent	98.60 (9.80)	99.80 (11.30)	-0.11 [-0.65, 0.43]	102.30 (12.80)	104.70 (13.30)	-0.18 [-0.71, 0.35]
Goddard, Dritschel & Howlin (2014)	Wechsler Full-Scale IQ	Child/ Adolescent	107.40 (13.50)	104.30 (12.40)	0.23 [-0.57, 1.03]	106.00 (11.10)	106.60 (11.20)	-0.05 [-0.85, 0.75]
Harrop, Green & Hudry (2016)	MSEL	Child	27.12 (10.27)	27.20 (10.92)	0.91 [0.13, 1.69]	23.35 (7.86)	22.50 (8.05)	0.10 [-0.67, 0.87]
Holt et al. (2014)	Wechsler Full-Scale IQ	Adolescent	96.44 (11.68)	108.42 (19.47)	-0.68 [-1.29, -0.07]	110.55 (12.66)	112.3 (11.57)	-0.14 [-0.76, 0.48]
Kirkovski et al. (2016)	KBIT-2	Adult	107 (14.48)	112.08 (14.37)	-0.34 [-1.10, 0.42]	113 (11.71)	112.45 (16.20)	0.04 [-0.78, 0.86]
Lai et al. (2012)	Wechsler Full-Scale IQ	Adult	114.10 (15.50)	113.70 (15.10)	0.03 [-0.46, 0.52]	119.70 (8.40)	116.30 (11.80)	0.33 [-0.17, 0.82]
Lemon, Gargaro, Enticott & Rinehart (2011)	Wechsler Full-Scale IQ	Child/ Adolescent	97.30 (16.74)	91.68 (18.40)	0.31 [-0.52, 1.14]	107.00 (10.72)	108.00 (11.00)	-0.09 [-0.96, 0.78]
May, Cornish & Rinehart (2012)	Wechsler Full-Scale IQ	Child	96.19 (12.62)	97.38 (9.01)	-0.11 [-0.60, 0.38]	106.50 (11.25)	108.43 (11.99)	-0.16 [-0.67, 0.34]

Oswald et al. (2016)	KBIT-2	Adolescent	107.64 (18.13	112.11 (11.67)	-0.29 [-1.00, 0.41]	108.79 (16.80)	110.61 (10.60)	-0.13 [-0.83, 0.57]
Park et al. (2012)	LIPS	Child	92.00 (25.61)	93.34 (23.67)	-0.06 [-0.54, 0.43]	123.96 (11.37)	121.68 (9.11)	0.22 [-0.33, 0.77]
Sedgewick et al. (2015)	Wechsler Full-Scale IQ	Adolescent	81.17 (11.50)	78.40 (11.26)	0.31 [-0.52, 1.13]	76.54 (10.25)	76.54 (10.25)	0.00 [-0.82, 0.82]
Solomon et al. (2012)	Wechsler Full-Scale IQ	Child/ Adolescent	104.20 (15.29)	103.95 (16.87)	0.02 [-0.60, 0.64]	113.26 (10.23)	121.65 (11.01)	-0.77 [-1.45, -0.10]
Zwaigenbaum et al. (2012)	Mullen – Receptive Language Subscale	Child	40.20 (13.00)	41.90 (13.40)	-0.13 [-0.60, 0.35]	55.00 (9.60)	51.50 (10.50)	0.35 [0.09, 0.61]

Note. CI = confidence interval; WISC = Wechsler Intelligence Scales for Children; LIPS = Leiter International Performance Scale; KBIT-2 = Kaufman Brief Intelligence Test – Second Edition; MSEL = Mullen Scales of Early Learning

Figure 6
Meta-analysis of studies comparing differences in sex/gender variation in IQ between ASC and TD groups

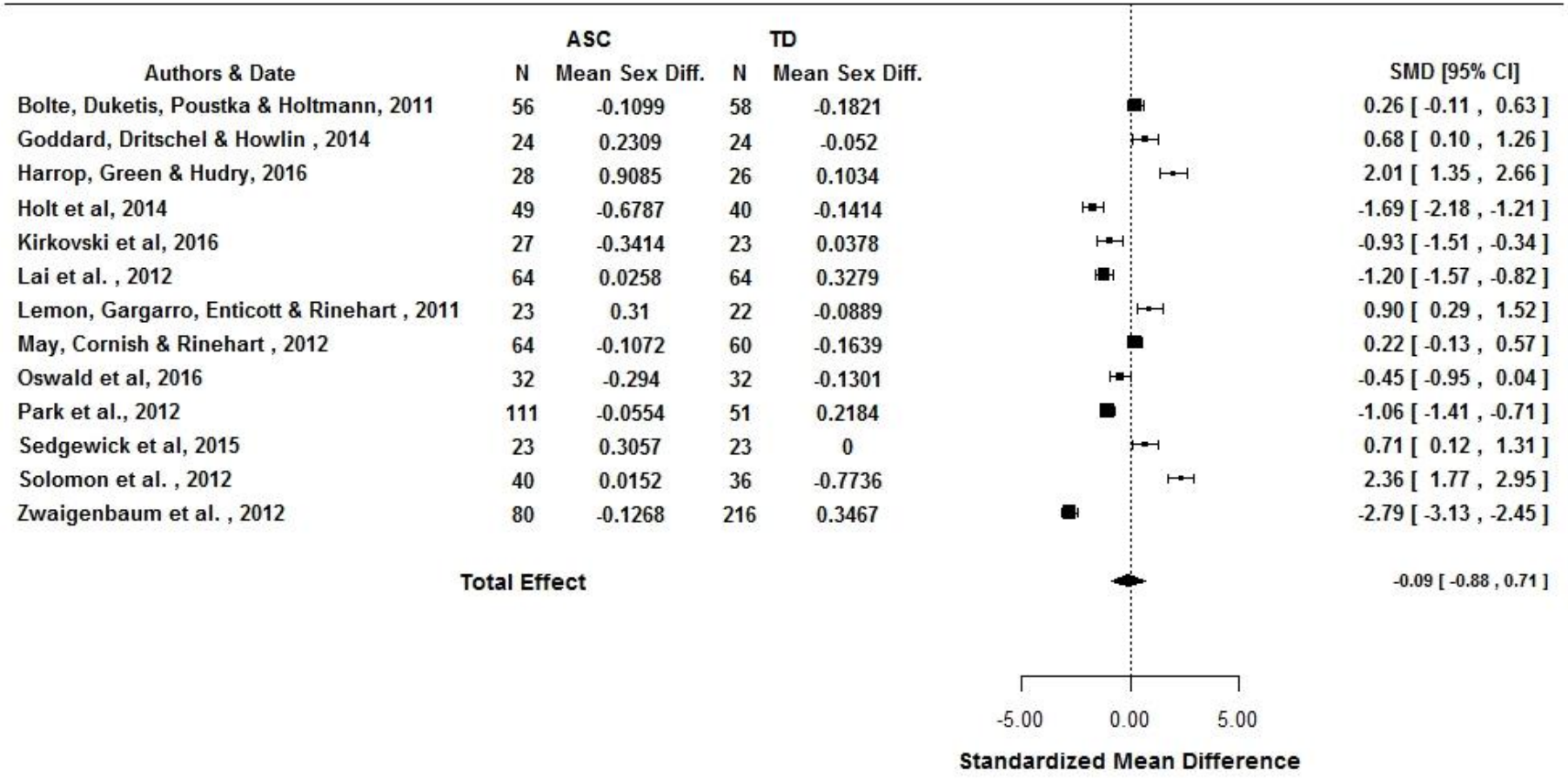

Figure 6. Forest plot of standardised mean differences (SMD) for IQ in each study and total SMD at each level of moderator 'Age', drawn in R using 'metafor' package (Viechtbauer, 2010; R Foundation for Statistical Computing, Vienna, Austria). Central rectangle indicates mean effect; lines indicate 95% confidence intervals. Negative effects indicate smaller sex/gender differences in ASC groups than in TD groups; positive effects indicate larger sex/gender differences in ASC groups than in TD groups. If lines cross the y axis, effect is not significant. Rectangles indicate the effect size (SMD) in each study, with the size of the rectangle indicating the 'weight' of the study (determined by the sample size and the precision of the confidence intervals). The diamond indicates the average effect across all studies, with the width of the diamond

indicating the confidence intervals of the effect. ASC = Autism Spectrum Condition group; TD = typically developing group; CI = confidence interval.