THE IMPACT OF GENDER AND DEVELOPMENT ON THE CLINICAL, ACADEMIC AND NEUROPSYCHOLOGICAL PROFILES OF CHILDREN WITH AUTISM SPECTRUM DISORDER

Submitted by

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Abstract

A person's sex or gender can contribute to the susceptibility of being diagnosed with some psychiatric conditions. For example, in childhood, boys are more frequently diagnosed with learning disorders, speech disorders, Attention Deficit Hyperactivity Disorder (ADHD) and Intellectual Disability, whereas girls are more frequently diagnosed with anxiety disorders such as separation anxiety disorder and selective mutism (American Psychiatric Association, 2000). Autism Spectrum Disorder (ASD) is another condition which affects many more males than females (Fombonne, 2003, 2009). ASD impacts on an individual's ability to socially relate and communicate and is accompanied by patterns of restricted interests and repetitive behaviours (American Psychiatric Association, 2000). On average four males to every one female are diagnosed with ASD (Fombonne, 2003). Seminal early gender research in ASD found females were more cognitively impaired and had fewer repetitive behaviours than males (Lord, Schopler, & Revicki, 1982; Wing, 1981). Despite these findings there has been limited research on the ASD gender profile with particular gaps in the examination of neuropsychological factors and functional outcomes such as academic achievement. The current thesis therefore presents a series of papers that systematically investigate gender difference in the clinical symptoms, neuropsychological functioning and academic performance of children with ASD and explores inter-relationships between these domains. This was achieved by comparing a group of normally intelligent children aged 7-12 years with ASD (N=64) and typically developing children (N=60); clinically (through use of behavioural rating scales), academically (through the use of standardized individual academic achievement tests) and neuropsychologically (through the use of experimental computerised tasks investigating executive functioning). The children were tested over two time points one year apart to map developmental trajectories. Results from clinical measures indicate gender similarity in core ASD symptoms, with more hyperactive behaviours in boys and more social

anxiety in girls, a robust finding across two time points. These findings are presented in Chapter 2 and 3. Chapter 4 further explores the clinical profile of boys and girls by examining sleep behaviour over time and how this may inter-relate with clinical symptoms. Chapters 6 and 7 reveal results from neuropsychological and academic studies where gender similarities in objective tests of reading, mathematics and executive functioning were identified. These chapters also revealed that attention switching difficulties predicted concurrent and also later poorer mathematics attainment in children with ASD. The integrated findings reveal gender similarity across a range of objective academic and neuropsychological tests. Although gender differences in parent-reported hyperactivity and social anxiety were found, these differences were also present in typically developing children and not specific to ASD. These findings have implications for the identification of female cases of ASD in that less hyperactive girls may not be ascertained. These subjectively reported differences in associated symptoms, rather than differences in core ASD symptoms, neuropsychological and academic profiles, may help explain why more males than females are diagnosed with ASD. Findings are explored using a biopsychosocial model considering biological, cognitive-psychological-behavioural, and social factors including gender role stereotypes and gender bias which together might contribute to gender difference in ASD.

List of Publications and Presentations during Candidature

Publications

May, T., Cornish, K., & Rinehart, N.J. (In press). Does gender matter? A one year follow-up of autistic, attention and anxiety symptoms in high-functioning children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders.*

May, T., Cornish, K., Conduit, R., Rajaratnam, M.W., & Rinehart. N.J. (In Press). Sleep in High-Functioning Children with Autism: Longitudinal Developmental Change and Associations with Behaviour Problems, *Behavioral Sleep Medicine*.

May, T., Rinehart, N.J., Wilding, J. & Cornish, K. (2013 published online). The role of attention in the academic attainment of children with autism spectrum disorder. *Journal of Autism and Developmental Disorders.*

May, T., Cornish, K., & Rinehart, N.J. (2012 published online). Gender profiles of behavioural attention in children with autism spectrum disorder. *Journal of Attention Disorders.*

Conference Presentations

May, T., Cornish, K., & Rinehart N. (2013, October). Key Clinical Issues Across the Autism Spectrum: ADHD, Learning, and Gender *Australian Psychological Society Conference*, Cairns, Queensland (Oral Presentation).

May, T., Rinehart, N., & Cornish, K. (2013, August). Gateways to literacy and numeracy in children with Autism Spectrum Disorder: The role of attention subfunctions. *Asia Pacific Autism Conference,* Adelaide, South Australia (Oral Presentation).

May, T., Cornish, K., & Rinehart N. (2013, August). Gender profiles in children with Autism Spectrum Disorder over time: A comprehensive comparison of clinical and academic outcomes. *Asia Pacific Autism Conference,* Adelaide, South Australia (Oral Presentation).

May, T., Cornish, K, & Rinehart, N. (2012, December). Difficulties disengaging attention from threatening faces in children with Autism Spectrum Disorder. *Australasian Society for Autism Research*. Sydney (Oral presentation)

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May, T., Cornish, K, & Rinehart, N.J. (2011, December). Autistic Symptoms, Anxiety and Attention: Gender Profiles in Children with ASD. *Australian Psychological Society Women In Psychology Conference,* Wollongong, New South Wales (Oral Presentation).

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Anxiety in Autism Spectrum Disorders: Does gender matter? *Australian Psychological Society Conference*, Canberra, (Oral Presentation).

May, T., Rinehart, N.J., & Cornish, K. (2011, September). Clinical symptoms and academic functioning in Autism Spectrum Disorders; Does sex matter? *Asia Pacific Autism Conference*, Perth, Western Australia (Oral Presentation).

General Declaration

Monash University

Declaration for thesis based or partially based on conjointly published or unpublished work

In accordance with Monash University Doctorate Regulation 17 Doctor of Philosophy and Research Master's regulations the following declarations are made:

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes 3 original papers published in peer reviewed journals and 2 unpublished publications. The core theme of the thesis is gender in Autism Spectrum Disorder. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the candidate, working within the School of Psychology & Psychiatry under the supervision of Nicole Rinehart and Kim Cornish.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research.

In the case of Chapters 2, 3, 4, 6, 7, my contribution (70%) to the work involved the following: Project design (in consultation with supervisors), review of relevant literature, acquisition of ethics approval, recruitment and testing of participants, data analysis using statistical techniques, and writing of papers. Supervisors provided input at the final draft stage of manuscripts.

Thesis chapter	Publication title	Publication status*	Nature and extent of candidate's contribution
2	Gender Profiles of Behavioral Attention in Children with Autism Spectrum Disorder	Published Online	See previous page
3	Does gender matter? A one year follow-up of autistic, attention and anxiety symptoms in high-functioning children with Autism Spectrum Disorder	In Press	See previous page
4	Sleep in High-Functioning Children with Autism: Longitudinal Developmental Change and Associations with Behaviour Problems	In Press	See previous page
6	The role of attention in academic attainment of children with Autism Spectrum Disorder	Published Online	See previous page
7	Understanding the role of attentional switching in academic outcomes for boys and girls with Autism	Submitted	See previous page

	Spectrum Disorder: A one-year follow-up study		

[* For example, ‘published’/ ‘in press’/ ‘accepted’/ ‘returned for revision’]

I have renumbered sections of submitted or published papers in order to generate a consistent presentation within the thesis.

Signed:

Date:

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Introduction

Overview

It is still unclear as to why there are gender differences in the prevalence of some psychiatric disorders. For example, females show higher rates of internalising disorders such as anxiety and depression from adolescence onwards, whereas males experience higher rates of neurodevelopmental conditions during childhood (American Psychiatric Association, 2000). Understanding the mechanisms that cause gender difference in psychiatric conditions may inform more broadly of the causes of psychopathology (Crick & Zahn-Waxler, 2003; Rutter, Caspi, & Moffitt, 2003; Thompson, Caruso, & Ellerbeck, 2003). Pervasive Developmental Disorder (PDD) is a neurodevelopmental condition in which many more males than females are diagnosed (Fombonne, 2009). Research into why this gender disparity exists has been limited to date with the bulk of research focusing on males with the condition given their higher prevalence (Thompson et al., 2003). Relatively little is known about the female presentation in PDD and what factors might contribute to females being less frequently diagnosed.

PDD is classified in the Diagnostic and Statistical Manual of Mental disorders Fourth Edition Text Revised (DSM-IV-TR) as a lifelong neurodevelopmental condition, diagnosed based on a triad of behavioural symptoms. Firstly, impairments in social interaction are present such as a lack of nonverbal social behaviours, delayed or absent peer relationships, and deficits in social or emotional reciprocity. Secondly, communication ability shows qualitative impairments including delay or lack of spoken language, difficulties initiating or sustaining a conversation, repetitive language, and deficits in spontaneous make-believe play. Thirdly, patterns of restricted repetitive and stereotyped behaviours and interests are present including preoccupation and intense focus on one or more interests or parts of objects, insistence on sameness of routines, and repetitive mannerisms such as hand flapping. This

condition is first diagnosed in childhood and has a significant sustained impact on the ability to socialise and communicate with others. Around 1 in 160 children are diagnosed with PDD (Fombonne, 2003). Around 30% of these children will have cognitive functioning within the normal range (often referred to as 'high-functioning') and around 70% will have intellectual disability (referred to as 'low-functioning'). The DSM-IV-TR is the classification manual used by the research presented in this thesis. The term Autism Spectrum Disorder (ASD) has been used through this thesis to refer to the DSM-IV-TR PDD subtypes of Asperger's Disorder and Autistic Disorder. Asperger's Disorder differs from Autistic Disorder in that intellectual disability is not present and language and communication development occurs within the usual timeframes.

Many more males are diagnosed with ASD than females, with male to female ratios being on average 4.3:1 (Fombonne, 2003). However, this ratio differs according to cognitive functioning. In the high functioning range the M:F ratio is larger, at around 6-10:1, whereas in the low-functioning range the ratio is greatly reduced, being around 2:1 (Fombonne, 2003, 2009). That there are many more males than females, and that there are fewer high-functioning than low-functioning females has perplexed researchers in the field for over 30 years. Early research into gender in ASD included the seminal work of Tsai, Stewart and August (1981) and Wing (1981) who examined gender ratios and differences in level of functioning in males and females with ASD. Tsai and colleagues (1981) found females had more impaired cognitive function and more brain damage than males. They also found females had more affected relatives. They suggested that females may need greater genetic liability to manifest autism and when affected they are more severely affected. This is also referred to as a threshold model, such that females have a higher threshold than males for manifesting ASD. Wing (1981) similarly found more cognitive impairment in a larger sample of females compared to males with ASD. Wing proposed that females with normal

intelligence may not be detected as having ASD and thus remain undiagnosed. This study also found that males exhibited more stereotyped and repetitive behaviours than females. These early findings prompted a modest body of research which has examined gender difference in the prevalence and manifestation of symptoms in ASD. This work has also generated a number of interesting theories.

Explanations for the gender differences in ASD span biological, behavioural/ psychological and socio-cultural paradigms, although there remains no general agreement on the cause and manifestation of gender difference in ASD. To date biological theories have had the most focus yet a simple biological explanation does not appear sufficient and behavioural and social factors are likely to contribute. In a broader sense, the causes of ASD itself are still being defined with multiple genes involved in this highly heritable and heterogeneous condition, but also a significant role for environmental factors is indicated (Hallmayer et al., 2011). Elucidating both the profile and cause of gender difference in ASD has the broader potential to increase our understanding of the causal mechanisms of ASD and may also have implications for the diagnosis and treatment of males and females with ASD.

The area of gender in ASD most frequently researched outside of IQ is the presence and severity of autistic symptoms. There are many mixed findings in this area, for example some studies have found more repetitive behaviours in males (Hartley & Sikora, 2009; Mandy et al., 2011; Wing, 1981) and more social deficits in females, particularly post-puberty (McLennan, Lord, & Schopler, 1993), while other studies have found no gender differences (Solomon, Miller, Taylor, Hinshaw, & Carter, 2011). These equivocal results are likely due to methodological differences between studies and a particular gap in respect to the consideration of developmental changes over time. The majority of studies to date have examined very few females, have employed cross-sectional designs across wide age bands and included both cognitively high and low-functioning participants. An area yet to be

researched is a restricted sample of high-functioning children in the primary school years. It is well established that the primary school years cover the age range when high-functioning children with ASD are most frequently diagnosed (Ouellette-Kuntz et al., 2009). As previously noted, it is within this high-functioning range that many more males than females are identified. Hence examining high-functioning primary school-aged children may be particularly enlightening for identifying gender differences in presentation. Examining these presentations over time to understand the development of any gender divergence or convergence will also be particularly critical given symptom expression changes with development.

High-functioning children with ASD will usually attend mainstream schooling and learn a curriculum identical with typically developing children. However, children with ASD have underlying deficits in their ability to plan and organise goal directed behaviour, also termed executive functioning (EF), which may underpin core ASD behavioural symptoms. A wealth of research attests to the cognitive impairments in EF found in ASD, which, in combination with ASD behavioural symptoms of communication and social difficulties, sensory sensitivities and resistance to change, may put individuals with ASD at a significant disadvantage in the classroom compared with their typically developing peers. Individuals with ASD who attend mainstream schools are more likely to underachieve academically compared with their typically developing peers (Ashburner, Ziviani, & Rodger, 2010). Yet the relationships between deficits in EF and academic attainment have not been examined in any comprehensive manner in ASD. Overlaying this is the possibility that there may be gender differences in EF in children with ASD, with females potentially showing more impairment consistent with early research indicating more impaired cognition in females (Lemon, Gargaro, Enticott, & Rinehart, 2010). Hence, there are significant gaps in examining critical factors for primary school-aged high-functioning boys and girls with ASD: symptom profiles,

neuropsychological functioning and academic performance and the inter-relationships between these factors.

This current thesis builds on research to date by proposing a study of gender in high-functioning, primary school-aged children with ASD to examine clinical, neuropsychological and academic profiles over time. This research will examine gender differences in the largest sample of high-functioning females in the 7 to 12 year age range to date in this area, using both objective and subjective measures of behaviour, cognition and academic functioning. Clinically, exploring gender differences in the manifestation of behavioural symptoms of ASD will help further validate the diagnostic criteria in females. This thesis will also examine internalising symptoms, specifically anxiety which shows a female preponderance in typical development, and externalising symptoms, specifically aggression and hyperactivity-impulsivity which show a male preponderance in typical development (American Psychiatric Association, 2000). This will provide important information regarding whether any gender differences found in these areas in ASD reflect those gender differences found in typical development or are specific to ASD. From a neuropsychological perspective, examining any gender differences in executive functioning, specifically switching and sustained attention, will fill an important gap in the research. Extending this to examining academic attainment and the interplay with executive functioning will provide critical functional information for use with early academic interventions in girls and boys with ASD. Collectively, this research will contribute a substantial body of knowledge which will help to define the manifestation of any gender differences in high-functioning children with ASD. This research will also describe how gender may impact on the development of these areas over time in children with ASD.

Research Aims

The overarching aim of this research was to systematically define the gender profiles of a large, well defined group of children with ASD using a comprehensive test battery of parent-report clinical measures relating to autistic symptoms (Social Responsiveness Scale, Repetitive Behaviours Questionnaire, Children's Communication Checklist), anxiety symptoms (Spence Children's Anxiety Scale) ADHD symptoms (Conners 3 Rating Scale) and sleep symptoms (Child Sleep Habits Questionnaire), cognitive tests of executive functioning (Wilding Attention Tasks – Visearch dual search attention switching task and Vigilan sustained attention task), cognitive functioning (WISC-IV) and academic performance (Wechsler Individual Achievement Test-II). This was to determine whether there were any gender differences in the manifestation of psychopathology, academic attainment and neuropsychological functioning in ASD. A second aim of this study was to investigate the inter-relationships between gender and these measures over time by assessing children at baseline (Time 1) and one year later (Time 2). This was to determine the role of gender in the developmental course of ASD during childhood.

The primary research questions that are addressed by this thesis include:

Defining the gender profile:

1. Do high-functioning primary school-aged children with ASD manifest unique gender profiles of autistic symptoms as measured using the Social Responsiveness Scale, Repetitive Behaviour Questionnaire and the Children's Communication Checklist?

2. Do high-functioning children with ASD manifest unique gender profiles of anxiety and ADHD symptoms as measured using the Spence Children's Anxiety Scale, and Conners 3 Rating Scale?

3. Do high-functioning children with ASD show unique gender sleep profiles as measured using the Child's Sleep Habits Questionnaire?

4. Are there unique gender profiles in the academic attainment and executive functioning of children with ASD?

5. Do these gender profiles differ over one year of development?

Understanding attention-academic associations:

6. Is there an association between attention difficulties and concurrent and later academic attainment in children with ASD?

Understanding the similarities and differences of gender profiles in children with ASD will contribute to understanding the causes of gender disproportionaity in the prevalence of this disorder. Examining factors which may constrain academic attainment in children with ASD will be important for tailoring early educational interventions. A biopsychosocial model of gender difference will also be proposed to explain the interplay between biological, cognitive and psychological symptoms and the social environment. Ultimately, understanding the timing and nature of any gender differences in ASD may provide insights more broadly into mechanisms involved in the causes of ASD.

Outline

Unlike a traditional thesis, this thesis is presented as a series of manuscripts that have been published or submitted to journals for publication. Additional information in the form of introductory and supplementary chapters has been included where appropriate in order to present the thesis as a comprehensive and cohesive whole study. This thesis begins with

addressing gaps in the literature related to characterising the gender profile of high-functioning children with ASD. Chapters 2, 3 and 4 present three empirical papers focusing on gender differences in autistic symptoms, internalising and externalizing symptoms, and sleep difficulties. Chapter 5 considers cognitive theories of ASD and key domains of particular relevance for high-functioning children: executive functioning, academic outcomes, and inter-relationships between these factors, also in the context of gender. Chapters 6 and 7 present two final empirical papers focusing on gender differences in academic performance and executive functioning; as well as inter-relationships between these factors over time. When reading the current thesis some minor overlap in methodological information will be present across manuscripts, however, this is an unavoidable consequence of a thesis presented by publication. The final chapter provides an overview of the thesis, summarising and integrating results across studies and proposes a model to account for gender differences in ASD. The value of considering gender differences in the presentation of children with ASD and how it may be useful for the identification of girls at risk of ASD will be discussed. The importance of understanding the link between early attention components and academic performance and how this may be a useful for clinical intervention will also be explored.

Chapter 1 – A Review of Gender in Autism Spectrum Disorder

Gender Differences in Psychiatric Disorders

An unexplained finding in psychiatric research is why some disorders differentially affect males and females. Gender differences can exist in the prevalence of some psychiatric disorders, the onset of symptoms, symptom course, symptom expression and treatment response (Rutter et al., 2003). For example, in childhood, boys are more frequently diagnosed with learning disorders, speech disorders, neurodevelopmental disorders like Attention Deficit Hyperactivity Disorder (ADHD), Oppositional Defiant Disorder, and intellectual disability, whereas girls are more frequently diagnosed with separation anxiety disorder and selective mutism (APA, 2000). From adolescence onwards and during adulthood females are diagnosed more frequently with internalising conditions which involve internal emotional states, such as anxiety and mood disorders, whereas males are diagnosed more frequently with substance abuse disorders (such as alcohol dependence) and anti-social personality disorder. In fact, the pendulum swings from males experiencing more psychiatric conditions than females in childhood, to females experiencing twice as many psychiatric diagnoses as males in adulthood (McGrath, Keita, Strickland, & Russo, 1990).

Although there are no gender specific criteria for psychiatric conditions defined in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revised (DSM-IV-TR), there is an increasing awareness that some symptoms may present differently by gender. For example, with regard to aggressive symptoms characteristic of Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD), there is evidence that females engage in more socially related, covert patterns of aggression whereas males engage in more overt physical aggression (Crick & Zahn-Waxler, 2003). It is proposed that these covert symptoms are overlooked which contribute to females being less frequently diagnosed with ODD and CD (Crick & Zahn-Waxler, 2003). Similarly, the age of onset of symptoms shows gender

difference in some disorders. For example, in schizophrenia the onset of the first psychotic episode is around 21-25 years in males and 25-32 years for females, although a similar number of males and females are affected with this condition (Canuso & Pandina, 2007). The response to medication and time course in schizophrenia also appears to differ by gender with premenopausal females experiencing better response and functioning compared with males and post-menopausal females (Canuso & Pandina, 2007). Importantly, the mechanisms which cause these gender differences in the prevalence, onset, course and treatment response in psychiatric conditions may provide clues to the underlying etiologies of these disorders (Rutter et al., 2003). However, these mechanisms are not straightforward with complex inter-relationships between biological, psychological and social factors implicated.

Another psychiatric disorder which affects more males than females is Autism Spectrum Disorder (ASD). ASD is a lifelong condition, evident within the first three years of life, which significantly impairs an individual's ability to socially relate and communicate. Research on gender in this area is only in its infancy and has lagged behind other more prevalent conditions such as ADHD, depression and anxiety, possibly due to the lower prevalence of ASD. Yet given the causes of ASD are still poorly defined, examining gender differences in ASD may provide insight into the factors and mechanisms which mediate the expression of ASD. Ultimately, this may help inform treatments which prevent or reduce the risk of the expression of ASD.

Autism Spectrum Disorder

Autism Spectrum Disorder, or Pervasive Developmental Disorder (PDD), is a condition first diagnosed in childhood which severely impacts on a child's development. The Diagnostic and Statistical Manual of Mental Disorders Fourth Edition Text Revised (DSM-IV-TR), the manual used for diagnostic purposes in the present study, defines three core areas

of impairment in PDD: social difficulties, communication impairment, and patterns of restricted repetitive behaviours. These difficulties severely impact on a child's ability to relate to, and communicate with, others. Impairments in social interaction manifest as a lack of nonverbal social behaviours like gestures, delayed or absent peer relationships, and deficits in social or emotional reciprocity, for example, not noticing the emotions of others. Qualitative impairments in communication include a delay or lack of spoken language, difficulties initiating and sustaining a conversation, repetitive language, and a lack of spontaneous and flexible make-believe play. Patterns of restricted repetitive and stereotyped behaviours and interests manifest as preoccupation or intense focus on one or more interests or parts of objects, insistence on sameness of routines and surroundings, and repetitive and stereotyped mannerisms such as finger twisting and hand flapping.

The DSM-IV-TR specifies five disorders that fit under the category of Pervasive Developmental Disorder. Autistic Disorder (autism; Table 1.1) where symptoms are present in all three areas; Asperger's Disorder (Table 1.2) which differs from autism in that intellectual functioning is within the normal range and no language delays are evident; PDD-Not Otherwise Specified (PDD-NOS) which is also referred to as atypical autism and involves subclinical symptoms; Childhood Disintegrative Disorder where normal development is present in the first two years of life followed by developmental regression; and Rett's Disorder, an X chromosome linked genetic disorder affecting primarily females (male foetuses rarely survive to term) also involving severe regression after a period of normal development. Overall, conservative rates of the prevalence of PDD are around 60-70 cases in 10,000 (Fombonne, 2009). Of this PDD-NOS is the most common, making up around 30 cases, Autistic Disorder contributes 20 cases, and Asperger's Disorder is rarer making up 6 cases (the remainder are made up by Childhood Disintegrative Disorder and Rett's Disorder) (Fombonne, 2009). However, some recent estimates of prevalence indicate that PDD is being

diagnosed much more frequently with rates of around 1 to 2 cases in 100 estimated (Russell et al., 2013). This increase is likely due to broadened diagnostic concepts, improved detection and awareness, service availability and diagnostic substitution, rather than indicating a real increase in prevalence (Elsabbagh et al., 2012). PDD is also frequently classified by the level of intellectual functioning. Around 70% of individuals with PDD will have comorbid intellectual disability (IQ<70), which is often referred to as low-functioning PDD. The remaining 30% of individuals with PDD have IQs within the normal range (IQ>70), which is often termed high-functioning PDD (Fombonne, 2003).

Table 1.1

DSM-IV-TR Diagnostic Criteria for Autistic Disorder (American Psychiatric Association, 2000)

A. A total of six (or more) items from (1), (2), and (3), with at least two from (1), and one each from (2) and (3):

(1) Qualitative impairment in social interaction, as manifested by at least two of the following:
   (a) marked impairment in the use of multiple nonverbal behaviours such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction
   (b) failure to develop peer relationships appropriate to developmental level
   (c) a lack of spontaneous seeking to share enjoyment, interests, or achievements with other people (e.g., by a lack of showing, bringing, or pointing out objects of interest)
   (d) lack of social and emotional reciprocity

(2) Qualitative impairments in communication as manifested by at least one of the following:
   (a) delay in, or total lack of, the development of spoken language (not accompanied by an attempt to compensate through alternative modes of communication such as gesture or mime)
   (b) in individuals with adequate speech, marked impairment in the ability to initiate or sustain a conversation with others
   (c) stereotyped and repetitive use of language or idiosyncratic language
   (d) lack of varied, spontaneous make-believe play or social imitative play appropriate to developmental level

(3) Restricted repetitive and stereotyped pattern of behaviour, interests and activities as manifested by at least one of the following:
   (a) encompassing preoccupation with one or more stereotyped and restricted pattern of interest that is abnormal either in intensity or focus
   (b) apparently inflexible adherence to specific, non-functional routines or rituals
   (c) stereotyped and repetitive motor mannerisms (e.g., hand or finger flapping or twisting, or complex whole-body movements)
   (d) persistent preoccupation with parts of objects

B. Delays or abnormal functioning in at least one of the following areas, with onset prior to age 3 years: (1) social interaction, (2) language as used in social communication, or (3) symbolic or imaginative play.

C. The disturbance is not better accounted for by Rett's Disorder or Childhood Disintegrative Disorder.

Table 1.2

DSM-IV-TR Diagnostic Criteria for Asperger's Disorder (American Psychiatric Association, 2000)

A. Qualitative impairment in social interaction, as manifested by at least two of the following:

   (1) Marked impairment in the use of multiple nonverbal behaviours such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction

   (2) failure to develop peer relationships appropriate to developmental level

   (3) a lack of spontaneous seeking to share enjoyment, interests, or achievements with other people (e.g., by a lack of showing, bringing, or pointing out objects or interests to other people)

   (4) lack of social or emotional reciprocity

B. Restricted repetitive and stereotyped patterns of behaviour, interests, and activities, as manifested by at least one of the following:

   (1) Encompassing preoccupation with one or more stereotyped and restricted patters of interest that is abnormal wither in intensity or focus

   (2) Apparently inflexible adherence to specific, non-functional routines or rituals

   (3) Stereotyped and repetitive motor mannerisms (e.g., hand or finger flapping or twisting, or complex whole-body movements)

   (4) Persistent preoccupation with parts of objects

C. The disturbance causes clinically significant impairment in social, occupational or other important areas of functioning.

D. There is no clinically significant general delay in language (e.g., single words used by age 2 years, communicative phrases used by age 3 years).

E. There is no clinically significant delay in cognitive development or in the development of age-appropriate self-help skills, adaptive behaviour (other than in social interaction), and curiosity about the environment in childhood.

F. Criteria are not met for another specific Pervasive Developmental Disorder or Schizophrenia.

In May 2013 the fifth version of the DSM was released (DSM-5) which has removed the term PDD and replaced it with Autism Spectrum Disorder (ASD) (American Psychiatric Association, 2013). The DSM-5 version of ASD has a new set of diagnostic criteria, removing the subcategories of Autistic Disorder, Asperger's Disorder, PDD-NOS, Childhood Disintegrative Disorder and Rett's Disorder. The DSM-5 criteria require symptoms in two domains: a combined communication and social deficits domain, and repetitive and restricted behaviours domain, Table 1.3. There has been much discussion on the reclassification of autism in the DSM-5, for example, there is concern that high-functioning cases previously classified as Asperger's Disorder or PDD-NOS may no longer met criteria (Mattila et al., 2011; McPartland, Reichow, & Volkmar, 2012; Ritvo & Ritvo, 2013). There has also been concern regarding the impact on girls, particularly high-functioning girls, in that they may be of higher risk than boys of no longer meeting the new criteria (Lai, Lombardo, Chakrabarti, & Baron-Cohen, 2013). Some of these concerns will be discussed in the general discussion section of this thesis in the context of findings from the present research. Importantly, the present thesis refers to DSM-IV-TR Autistic Disorder and Asperger's Disorder as Autism Spectrum Disorder (ASD) throughout, rather than referring to the DSM-5 version of ASD. All references to ASD throughout the chapters and papers in this thesis are referring to DSM-IV-TR Autistic Disorder and Asperger's Disorder unless otherwise stated.

Table 1.3

DSM-5 Autism Spectrum Disorder, (American Psychiatric Association, 2013).

Must meet criteria A, B, C and D:

A. Persistent deficits in social communication and social interaction across contexts, not accounted for by general developmental delays, and manifest by all 3 of the following:

    1. Deficits in social-emotional reciprocity; ranging from abnormal social approach and failure of normal back and forth conversation through reduced sharing of interests, emotions, and affect and response to total lack of initiation of social interaction.

    2. Deficits in nonverbal communicative behaviours used for social interaction; ranging from poorly integrated- verbal and nonverbal communication, through abnormalities in eye contact and body-language, or deficits in understanding and use of nonverbal communication, to total lack of facial expression or gestures.

    3. Deficits in developing and maintaining relationships, appropriate to developmental level (beyond those with caregivers); ranging from difficulties adjusting behaviour to suit different social contexts through difficulties in sharing imaginative play and in making friends to an apparent absence of interest in people .

B. Restricted, repetitive patterns of behaviour, interests, or activities as manifested by at least two of the following:

    1. Stereotyped or repetitive speech, motor movements, or use of objects; (such as simple motor stereotypies, echolalia, repetitive use of objects or idiosyncratic phrases).

    2. Excessive adherence to routines, ritualized patterns of verbal or nonverbal behaviour, or excessive resistance to change; (such as motoric rituals, insistence on same route or food, repetitive questioning or extreme distress at small changes).

    3. Highly restricted, fixated interests that are abnormal in intensity or focus; (such as strong attachment to or preoccupation with unusual objects, excessively circumscribed or preservative interests).

    4. Hyper-or-hypo reactivity to sensory input or unusual interest in sensory aspects of environment;(such as apparent indifference to pain/heat/cold, adverse response to

specific sounds or textures, excessive smelling or touching of objects, fascination with lights or spinning objects).

C. Symptoms must be present in early childhood (but may not become fully manifest until social demands exceed limited capacities).

D. Symptoms together limit and impair everyday functioning

The causes of ASD are heterogeneous and defined for only around 6% of cases which have been associated with genetic conditions including Fragile X Syndrome, Rett's Syndrome and Tuberous Sclerosis Complex (for a review see Moss & Howlin, 2009). A complex etiology for ASD, including multiple biological and environmental factors has been suggested for the remaining cases. Until recently, the heritability of ASD was thought to be around 90% (Steffenburg, Gillberg, Hellgren, Andersson, & et al., 1989). However, a recent twin study, using current gold standard diagnostic assessments (Autism Diagnostic Interview-Revised and Autism Diagnostic Observation Schedule) which was lacking in prior twin studies, found that genetic heritability for autism was 37%, with a shared environment component of 55% (Hallmayer et al., 2011). Hence, environmental factors appear to explain a considerably higher component of autism than previously thought.

One of the most consistent findings in epidemiological research in ASD is that males are much more frequently affected than females (Fombonne, 2009). On average across all PDD, males outnumber females with ASD at around 4 to 1 (Fombonne, 2003). An average M:F ratio of 4.3:1 has been found in Autistic Disorder (Fombonne, 2009). Separate gender ratio figures for PDD-NOS and Asperger's Disorder based on population samples have not been systematically collated, but in clinical samples of these conditions males outnumber

females by a factor of anywhere from 3 up to 27:1 (Howlin & Asgharian, 1999; Volkmar, Szatmari, & Sparrow, 1993). Proportionally more females with ASD exist in the lower intellectual functioning range, where the M:F ratio is 1.9:1, compared with the high-functioning range, where the M:F ratio is around 5-10:1 (Fombonne, 2003). The cause of the gender disparity in prevalence in ASD has been the focus of a modest body of research over the last 30 years.

Early research on gender in ASD included the seminal work of Tsai, Stewart and August (1981) and Wing (1981) who examined gender ratios and differences in level of functioning in males and females with ASD. Tsai, Stewart and August (1981) found females had more impaired cognitive function and more brain damage than males. They also found that females had more affected relatives and suggested that females may need more genetic liability to manifest autism, also when affected they are more severely affected. This is also referred to as a threshold model, such that females have a higher threshold than males for exhibiting ASD. Wing (1981) also found more cognitive impairment in a larger sample of females. They proposed that girls with normal intelligence may be missed and then remain undiagnosed. They also found that males exhibited more stereotyped and repetitive behaviours. Lord, Schopler and Revicki (1982) also examined a large sample of females and similarly found more impaired cognitive function in females, also suggesting a threshold model. McLennan, Lord and Schopler (1993) then extended this research by focusing on cognitive high-functioning individuals (aged 6 to 36 years) with ASD, although with a relatively small sample (21 males and 21 females). They found better early play and social skills in girls, but revealed that older females had poorer peer relationships than males, using a cross-sectional design. They raised the possibility of diagnostic bias for identifying males, and that parents may also show gender bias when rating symptoms, for example, rating girls more harshly for social deficits given the expectation that females are more socially

competent than males. This early researched prompted a modest research effort examining gender difference in the prevalence and manifestation of symptoms in ASD. Table 1.4 summarises the gender-focused studies in ASD over the last 30 years reporting the sample size, age range, IQ levels, tools used, gender differences found and explanations proposed for any gender differences. This research has produced mixed findings which may relate to methodological and sample differences and the varied diagnostic criteria employed. The remainder of this chapter will examine these findings in more detail, including proposed causes for the gender differences found to date.

Gender and the manifestation and severity of autism symptoms

Collectively, studies examining whether there are gender differences in the severity of ASD symptoms reveal mixed findings. Some of the most well-characterised gender samples in regards to restricted age ranges have been pre-schoolers with ASD. Yet even these studies have reported inconsistent findings. Toddler studies have found either poorer social and communication skills in girls (Carter et al., 2007; Hartley & Sikora, 2009) or better social skills in girls (Zwaigenbaum et al., 2012). More repetitive behaviours in toddler boys (Hartley & Sikora, 2009) and fewer repetitive behaviours in girls with normal development but similar rates of repetitive behaviours in developmentally delayed toddlers (Sipes, Matson, Worley, & Kozlowski, 2011) have been reported, as have no gender differences in repetitive behaviours (Carter et al., 2007) or any core ASD symptoms (Rivet & Matson, 2011a).

In studies of *low-functioning* individuals with ASD spanning childhood through adulthood, studies have reported no gender differences in core symptoms (Rivet & Matson, 2011a), or more repetitive behaviours in males (Hattier, Matson, Tureck, & Horovitz, 2011; Lord et al., 1982; Wing, 1981), or poorer social ability in females (Lord et al., 1982). One of

the most frequent findings in early studies was lower IQ in females with ASD (Lord et al., 1982; Pilowsky, Yirmiya, Shulman, & Dover, 1998; Volkmar et al., 1993; Wing, 1981).

In studies limited to *high-functioning children*, few gender differences emerge. An early cross-sectional study showed females had fewer social difficulties pre-puberty and poorer social functioning post-puberty (McLennan et al., 1993). However, study limitations included a small sample (21 females), broad age range (6-36 years), and the inclusion of some participants with lower-IQ (nonverbal IQ>=60). Holtman and colleagues (2007) examined 23 high-functioning females (aged 7-20 years) similarly finding more social difficulties, particularly in older girls. However, the sample was also relatively small and spanned a wide age range. Solomon and colleagues (2011) examined 20 high-functioning girls aged 8-18 years and reported no gender differences in autistic symptoms. Similarly, Rivet and Mason (2011a) found no gender differences in the triad of autistic symptoms in 37 boys and 37 girls, aged 3-17, with ASD. Hence, in high-functioning children and adolescents there exists some mixed findings for social difficulties, but little evidence of differences in repetitive behaviours and communication. In *high-functioning* adults, one study found more sensory and autistic behaviours but fewer socio-communication symptoms in females (Lai et al., 2011). Methodological differences across studies, including varied measures, small samples and wide age ranges, may all contribute to these inconsistencies.

What is evident from the research to date is that generally only small samples of females have been studied and few samples have examined discrete age and IQ ranges. Researchers also face the challenge of recruiting females from a smaller population than that which exists for males.

Gender and co-occurring conditions in ASD

ASD frequently co-occurs with high rates of other psychiatric conditions including anxiety disorders and Attention Deficit Hyperactivity Disorder (ADHD). Whether having

ASD "over-rides" or reflects the typical gender trends in prevalence in these conditions is unclear. For example, if there were higher rates of ADHD in males compared to females with ASD this would reflect the pattern seen in typical development. Similarly, if there were higher rates of anxiety disorders in females compared to males with ASD this would also reflect the typical gender finding. Understanding how gender may interact with internalising and externalising disorders in ASD may therefore provide important information regarding the etiology of these disorders. Determining whether boys with ASD are at increased risk for experiencing ADHD symptoms, and similarly, understanding whether females with ASD have an elevated risk of anxiety symptoms, will inform whether there is a "double hit" conferred by gender and diagnosis (Solomon et al., 2011). This will also provide clinically important information regarding the potential need for gender specific interventions.

In the DSM-IV-TR, ADHD cannot be dually diagnosed in ASD, however there is a high incidence of inattentive and hyperactive behaviours in this population. This has resulted in the DSM-5 allowing a comorbid diagnosis of ADHD and ASD. Combined rates of the three ADHD subtypes (inattentive; hyperactive-impulsive; combined) in ASD have been estimated at up to 68 percent (Yoshida & Uchiyama, 2004). Most of the research on ADHD symptoms in ASD has combined genders; however, a few studies have reported female results separately. Generally the prevalence of ADHD appears to be similar in males and females with ASD in childhood and adulthood (Gadow, Devincent, Pomeroy, & Azizian, 2005; Tonge, Brereton, Gray, & Einfeld, 1999). Using parental reports on the Child Symptom Inventory in cognitively high and low functioning children (284 males, 43 females), aged 6-12 years, Gadow and colleagues (2005) found 59.2% of boys and 66.7% of girls screened above the cut-off for ADHD. The inattentive subtype was found in 35.8% of boys versus 33.3% of girls, hyperactive-impulsive type in 5% of boys and 7.1% of girls, and combined type in 18.3% of boys and 26.2% of girls. Interestingly, corresponding teacher ratings

reported fewer hyperactive symptoms in girls than did parent reports, with this discrepancy not present for boys. A recent study by Kopp, Berg and Gillberg (2010) involving a large number of girls with ASD, found 80 percent had comorbid ADHD. Studies to date have shown no gender differences in ADHD symptoms in cognitively low-functioning children (Brereton, Tonge, & Einfeld, 2006) or combined samples of low and high functioning individuals with ASD (Gadow et al., 2005; Mandy et al., 2011; Simonoff et al., 2008).

Samples of strictly high-functioning children have not been assessed in respect to gender differences in ADHD symptoms in ASD. Importantly, studies which do not consider the interaction between age, hyperactive-impulsive symptoms and gender may overlook important developmental findings. Hyperactive-impulsive symptoms have been found to be more frequent in males than female with ADHD and show a decline during childhood and into adolescence (Biederman, Mick, & Faraone, 2000). In fact, the ADHD M:F ratio is around 3:1 in children, but thought to be 1:1 in adulthood, with the decline in hyperactive-impulsive symptoms in males possibly accounting for this pattern. Research in ASD is yet to adequately address this potential interaction between age and gender using longitudinal studies.

For internalising symptoms such as anxiety and mood disorders, most studies in ASD have only reported combined gender prevalence rates. Estimates ranging from 11-84% of children with ASD meeting the criteria for an anxiety disorder such as generalized anxiety disorder, specific phobia, separation anxiety disorder and social phobia have been reported (Muris, Steerneman, Merckelbach, Holdrinet, & Meesters, 1998; van Steensel, Bogels, & Perrin, 2011; White, Oswald, Ollendick, & Scahill, 2009). Low-functioning males and females with ASD across childhood, adolescence and adulthood have generally shown similar levels of anxiety symptoms (Brereton et al., 2006; Gadow et al., 2005). Some studies have found females to be more anxious than males, for example, toddler girls with autism were found to be more anxious than boys (Hartley & Sikora, 2009). One cross-sectional study

found more anxiety in high-functioning girls with ASD during adolescence but not childhood (Solomon et al., 2011), suggesting that the typical gender developmental trajectory of anxiety may be present. Longitudinal studies are needed to confirm this finding. Another study combining high and low functioning individuals aged 1-17 years found no gender differences in anxiety (Mayes, Calhoun, Murray, & Zahid, 2011). However, not considering interactions between age, gender and anxiety symptoms may obscure real differences.

Another important area of functioning for children with ASD and their families is sleep behaviour. Sleep difficulties are common in Autism Spectrum Disorder (ASD) with 40 to 80% of individuals experiencing sleeping behaviour which disturbs the child and/or their family (Liu, Hubbard, Fabes, & Adam, 2006). In contrast, around 25% to 40% of typically developing children experience sleeping difficulties (Meltzer & Mindell, 2008). Given anxiety and hyperactivity are both associated with sleep difficulties and also show gender differences in prevalence, how these might then overlap in ASD is an important area which is yet to be thoroughly examined. A recent study indicated that males with ASD traits may experience more sleep disturbance than females with ASD traits. Sivertsen and colleagues (2012) found fewer sleep problems in the 6 females compared with the 22 males examined. However, this study did not examine individuals diagnosed with ASD and the small sample of females means the findings may not be robust. Hence, examining inter-relationships between sleep, anxiety, hyperactivity and gender in ASD may provide important information regarding causal mechanisms and indicate clinical direction for sleep interventions.

Gender differences over development in ASD

Symptom severity and expression may change throughout development due to changing demands in the social environment, brain development, pubertal biological changes and the impact of psychological and behavioural factors. For example, complex interactions between brain development, social functioning and behaviour occur as children develop and

become more socially adept. Gender could interact with these factors to produce different developmental pathways and outcomes for boys and girls with ASD.

There have been very few longitudinal studies which have tracked gender profiles over development in ASD. Some longitudinal studies have shown better social ability in samples of mostly cognitive low-functioning girls prior to puberty but poorer functioning post-puberty (Gillberg & Steffenburg, 1987) and into adulthood (Billstedt, Gillberg, & Gillberg, 2005). Generally females with ASD appear to have poorer outcomes than males, but most females examined have been low-functioning (Burd et al., 2002; Gillberg & Steffenburg, 1987; Howlin, Goode, Hutton, & Rutter, 2004). Howlin and colleagues (2004) found poorer outcomes in seven females followed into adulthood, including both cognitively low- and high-functioning, with regard to schooling, employment and independent living, compared with males. Collectively, a poorer outcome for females with ASD is indicated, yet very few high-functioning females have been longitudinally followed.

Table 1.4

Summary of gender specific studies in ASD

Authors & Year	**Participants**	**Measures**	**Females**	**Males**	**Proposed explanations**
Tsai, Stewart & August, 1981	24F, 78M 3-20 years Range of IQs (most low functioning)	IQ EEG Motility, brain damage, bladder/bowl control	More epilepsy, abnormal EEGs, brain damage Poorer bladder/bowl control Higher incidence of ASD in siblings		Multifactorial / polygenic model: Higher 'dose' of genes needed in females to manifest autism, resulting in fewer female cases but with more severe impairments
Wing 1981	56F, 102M 0-14years Low functioning	Gould or Reynell IQ measures	Lower IQ	Higher visuo-spatial strengths More stereotyped & repetitive behaviours	High-intelligence girls may be missed in the sample. Higher early mortality among females. Different pathologies in males and females Typical female sex strengths compromised (social/verbal), male strengths maintained (visuo-spatial)
Lord, Schopler, & Revicki, 1982	91F, 383M 3-8 years Range of IQs	CARS Various IQ tests Psychoeducational Profile (PEP) Peabody Picture Vocabulary Test (PPVT)	Lower overall IQ, nonverbal IQ, social quotients, receptive vocabulary, eye-hand integration, perceptual/visuo-spatial skills	More stereotypic play	Lateralisation – more in males, less in females, so females more impaired by broad bi-lateral brain damage. Support for polygenetic threshold model.

Lord, & Schopler, 1985	136F, 487M 3-8 years Mostly low functioning but some IQ > 70				No trend for more males in HF range than in LF range.
Volkmar, Szatmari, & Sparrow, 1993	142F, 346M Mean age 10.1 years (children & adults) Most low IQ	Autism Behaviour Checklist Vineland ICD-10 criteria	Lower IQ		Polygenic model Different etiologies for males & females Females are more vulnerable to the underlying pathogenic process
McLennan, Lord and Schopler 1993	21F, 21M 6-36 years High functioning Nonverbal IQ > 60	ADI-R	Older females more impaired peer relationships. Better early social play skills	More impaired early social & communicative behaviour	Older female peer interactions are more demanding than males. Females in the sample were in special classes with mostly boys so females for friendships may not have been available so those social skills may not have developed. Diagnostic bias towards male symptoms. Parental bias - Parents may expect more social aptitude from their daughters than sons. Did not find males were more 'autistic' and so does not support polygenic inheritance model but there may be different modes of transmission.

Pilowsky, Yirmiya, Shulman, & Dover, 1998	18F, 18M 20months – 34 years Low functioning	CARS ADI-R	Lower mental age		No difference in gender for CARS or ADI-R Clinical picture similar for males and females. Females may have different symptoms and behaviours than males which are not currently accounted for in ASD diagnostic tools.
Holtmann, Bolte, & Poustka, 2007	23F, 23M 5-20years High functioning IQ > 70	ADI-R ADOS Child Behaviour Checklist	More social difficulties (particularly older females), attention and thought problems. More pre, peri and post-natal difficulties		More social demands on female peer relationships post-puberty. Potential bias in parental report of higher social expectations for females
Carter, et al., 2007	22F, 68M Average age 2.3 years Included developmental delayed sample	ADOS (except comm), ADI VABS, Mullen Scales of Early Learning Infant-Toddler Social and Emotional Assessment, (ITSEA)	Poorer social & communication skills Better visual reception	Better language & motor abilities	Similarities with boys & strengths in girls found do not support multiple threshold genetic theory. Differing underlying genetic mechanisms suggested
Hartley & Sikora, 2009	42F, 157M 1.5 – 3.9 years Both high and low functioning	Mullen Scales of Early Learning ADOS-G CBCL	Poorer social & communication skills More sleep problems More anxious/ depressed affect	More stereotyped & repetitive behaviours	Mostly similar but subtle differences

Solomon, Miller, Taylor, Hinshaw, & Carter 2011	Girls ASD 20 Boys ASD 20 TYP girls 19 TYP boys 17 8-18 years High functioning IQ>75	SRS CCC ADOS RBS-R WASI BASC2 CDI	More internalizing symptoms in adolescence Overall, no differences in autistic symptoms between boys and girls with ASD		Socialisation differences between boys and girls may lead to more internalizing symptoms in girls with ASD than boys.
Hattier, Mason & Horovitz, 2011	Adults 63F, 77M Severe or Profound ID	Diagnostic Assessment for the Severely Handicapped-Second Edition		More sterotypies in males	Nil
Kozlowski & Mason, 2011	17-36 months of age Autism: 46 M, 46 F PDD-NOS: 57M, 57 F Developmentally delayed	BISCUIT	No gender differences in challenging behaviour (aggression, stereotypic, self-injuring)		
Lai et al. 2011	Adults High functioning 33M, 29F	ADI-R ADOS WASI AQ, SQ, EQ Reading the mind in the eyes	More sensory symptoms More self-reported autistic traits (AQ)	More socio-communicative symptoms (ADOS)	High-functioning females with ASD may be more motivated to develop compensatory social skills as they age. Females may camouflage their symptoms and go “under the radar” Females may have less eccentric interests

Mandy et a. 2011	3-18 years 52F, 273M Approximately 10% LFA	3Di (ADI-R) SDQ ADOS		More repetitive & stereotyped behaviours (parent report & ADOS) More teacher reported externalizing (hyperactivity/inattention) & social problems	
Rivet & Mason, 2011	Toddlers with developmental delay 33F, 30M & TYP 3-17 year olds 37F, 37M – HFA Adults with ID 58F, 58M, controls	Parent report	No gender differences in toddlers in symptoms No gender differences in 3-17 year olds in symptoms No gender differences in symptoms.		Nil
Sipies et al. 2011	Toddlers 17-36 months Developmental delay in females 70F, average development in 26F	BISCUIT	Females with normal development had fewer repetitive behaviours. No gender differences, but those with lower dev had more symptoms regardless of gender		Nil
Mayes & Calhoun, 2011	1-17 years LFA & HFA N=770 (655M, 115F)	Checklist for Autism Spectrum Disorder (CASD)	No gender differences in autistic symptoms No differences in IQ		Nil

Zwaigumbaum et al. 2012	3 years 57M, 29F, controls Low & higher functioning	ADI-R ADOS Vineland Stanford-Binet Mullen Scales	Females better fine motor, daily living skills & socialization but not specific to ASD group. No IQ differences.	Gender differences in ASD mirrored control group. Girls may be more likely to be identified using current tools.

M=Male, F=Female; ASD, Autism Spectrum Disoder; LFA, Low-Functioning Autism; HFA, High-Functioning Autism, ADI-R, Autism Diagnostic Interview Revised; ADOS, Autism Diagnostic Observation Schedule; TYP, Typically Developing; ID, Intellectual Disability; PDD-NOS, Pervasive Developmental Disorder Not Otherwise Specified; CARS, Child Autism Rating Scale; SRS, Social Responsiveness Scale; SDQ, Strengths & Difficulties Questionnaire; AQ, Autism Quotient; EQ, Empathizing Quotient; SQ, Systematizing Quotient; CBCL, Child Behaviour Checklist;

Proposed cause of gender differences in ASD

The search for the causes of gender difference in ASD have largely focused on exploring underlying biological factors including differences in genetics, hormones, brain maturation and morphology. However, biological processes are constantly interacting with the environment to shape behaviour. There are few models which describe the emergence and expression of neurodevelopmental features which incorporate multidisciplinary perspectives. One such model is Beauchamp and Anderson's (2010) SOCIAL model which proposes a developmental biopsychosocial model for the development of social skills, Figure 1.1. This model considers aspects including biological underpinnings, socio-cognitive skills (attention/executive function, communication, socio-emotional skills) and internal and external environmental factors. This model provides a useful framework for understanding the origins of social dysfunction. This model can be adapted as a framework to understand the emergence of gender difference in ASD by examining aspects of gender difference across biological, behavioural and social domains and considering their interactions.

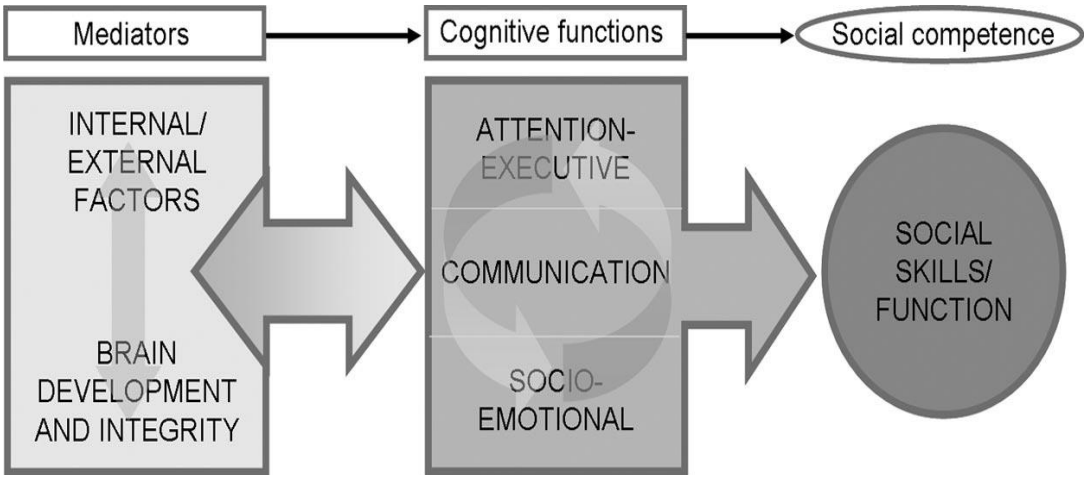

Figure 1.1. The social-cognitive integration of abilities model (SOCIAL) (Beauchamp & Anderson, 2010, p.47).

Biological Contributions to Gender Difference in ASD

A range of biological causes of ASD have been proposed to explain both the higher prevalence of males, and that females when affected tend to be more cognitively impaired. The threshold model posits that females would require more risk factors (genetic, shared, and non-shared environment factors) to manifest an ASD. Females would have some protective mechanisms resulting in them having a higher threshold for ASD than males. This theory predicts that females are less frequently, but more severely affected as they require more loading of risk factors to manifest ASD. This is known as the 'gender paradox' hypothesis (Eme, 1992). If females require a higher genetic load to exhibit ASD then they should theoretically have more relatives affected with ASD than males. However, studies have generally found no difference between the number of ASD-affected relatives in males and females with ASD (Goin-Kochel, Abbacchi, & Constantino, 2007 but see also; Szatmari et al., 2012 who recently found the relatives of females with ASD had more repetitive behaviours). The genetic liability for ASD also appears to be similar in both sexes (Hallmayer et al., 2011). By contrast, the constitutional variability model proposes that different causes would exist for each gender, which may produce more damage in female cases of autism than in male cases, and could account for the more severe presentation of females in the low functioning range (Wing, 1981).

Other biological gender differences could also explain the male preponderance in ASD. Boys have slower brain maturation making them more vulnerable to brain damage during early development (Lenroot et al., 2007). Male brains had been thought to be less lateralized than females (Springer & Deutsch, 1981) leading to the proposal that female brains can withstand more insult before exhibiting autism (Lord et al., 1982). This theory was proposed to account for both fewer but more impaired cases of ASD in females. However, the notion of the female brain being more bilateral in function than a male brain has been

disproven with meta-analytic and functional brain imaging studies indicating similar lateralization in male and female brains (Medland, Geffen, & McFarland, 2002 functional MRI studies ; Sommer, Aleman, Bouma, & Kahn, 2004; Sommer, Aleman, Somers, Boks, & Kahn, 2008).

The sex chromosomes are an area of difference between males and females which could explain the disparity in prevalence and severity. Yet no obvious mechanisms have been found, such as a mutation on the Y chromosome which would account for male cases, or a mutation on the X chromosome which would affect females less often due to their second X chromosome which would dampen any affects. One mechanism for reduced female liability to ASD has been proposed by Skuse (2007) which relates to genetic imprinting in relation to social cognition. Skuse proposed that females, because they have an X chromosome from each parent, have a paternally imprinted genetic locus for social cognition which is not present in males who have a maternally derived X chromosome. Skuse and colleagues studied females with Turner's syndrome, where one of their two X chromosomes is deleted or partially deleted (Skuse et al., 1997). They found that females who inherit the paternal X chromosome had better social abilities than those who inherited the maternal X chromosome. Skuse and colleagues theorised that this indicated paternal imprinting, such that certain paternal X chromosome genes are always expressed instead of one X chromosome being randomly made active in any cell. This paternally imprinted X-linked gene may contribute to social ability via verbal ability and executive functioning which were superior in the females with a paternally derived X chromosome (Skuse et al., 1997). Skuse and colleagues argued that this mechanism would explain why males, who have a maternally derived X chromosome, would be more vulnerable to ASD compared to females. However, the notion that some genes escape X inactivation and are always expressed has been questioned by the finding of no major X-linked genes which escape inactivation (Gong et al., 2008).

Hormonal factors could also be involved. Differences in social and communicative behaviours have been associated with specific hormones, such as androgen (Knickmeyer et al., 2006). For example, higher levels of testosterone during the prenatal period have been linked with communicative and social impairment (Hollier et al., 2013a; Whitehouse, Mattes, Maybery, Dissanayake, et al., 2012; Whitehouse, Mattes, Maybery, Sawyer, et al., 2012). This finding emerged from the Extreme Male Brain theory of ASD (Baron-Cohen, 2002). This theory was derived from the observations of Hans Asperger who first described the condition now known as Asperger's Disorder as being an "extreme form of maleness" (Asperger, 1944). The theory contends that individuals with autism, both males and females alike, have an 'extreme male brain' which has skills in systematizing (understanding the rules of systems) and weaknesses in the typical female strength of emphasizing (understanding and responding to people's thoughts and emotions). A possible mechanism for this theory is suggested to be an atypically high level of testosterone during peri-natal development, yet the specific mechanism causing vulnerability in social/communication development has not been determined (Hollier et al., 2013a). Supporting evidence is also a later age of menarche in females with ASD (Knickmeyer, Wheelwright, Hoekstra, & Baron-Cohen, 2006; Whitehouse, Maybery, Hickey, & Sloboda, 2011b). Naturally higher levels of oxytocin in females have also been associated with nurturance and social cohesion which might act to improve the social ability of females and act as a protective factor (Carter, 2007; Insel, O'Brien, & Leckman, 1999).

The biological research into gender differences in ASD to date has been inconclusive. There are presently no generally accepted biological explanations for the preponderance of males with ASD. Many theories only have indirect evidence and others have not established empirical support. Hence other factors are likely involved in the gender difference in ASD.

Behavioural Contributions to Gender Difference in ASD

Differences in the behaviours of males and females, which could be biologically or socially determined, could also contribute to gender disparity in ASD. It is possible that males may manifest different ASD behavioural symptoms than females. For example, the notion that aggression is less frequent in females has been questioned by findings that boys display physical aggression, whereas girls display relational aggression, but at similarly high rates (Crick & Zahn-Waxler, 2003). The present ASD diagnostic criteria may contain the male prototype behavioural symptoms, given most research to date has focused on male subjects, and may overlook unique female symptoms. For example, circumscribed interests could be more socially related in girls than boys resulting in them being less obvious to carers and clinicians (Kopp & Gillberg, 1992; Rinehart, Cornish, & Tonge, 2011; Wolff & McGuire, 1995). This area has had limited empirical research. Recently a common screening instrument, the Autism Spectrum Screening Questionnaire (ASSQ), was revised by the authors in an attempt to incorporate items thought to be more representative of females with ASD (Kopp & Gillberg, 2011). This task proved difficult with very little gender difference found. Although a small number of items differentiated males and females there were no overall gender differences on the total score of the revised ASSQ-Girl. In the gold-standard tools for diagnosis of ASD, the Autism Diagnostic Interview – Revised (ADI-R) and the Autism Diagnostic Observation Schedule (ADOS), no significant gender differences have been noted in studies, although many more males than females have been examined (Lord et al., 2000). Overall, there is a lack of empirical evidence to suggest that the behavioural symptoms of ASD differ in quality for males and females.

Other behavioural differences, not diagnostic for ASD, could result in more males being identified. For example, boys generally engage in more overt active, oppositional and aggressive behaviours than girls, who are generally more passive and internalising. These

behaviours could result in male difficulties being more obvious and problematic for parents and teachers, resulting in them being more frequently referred for clinical assessment. This referral bias towards males because of externalising behaviours has been similarly proposed to contribute to their excess representation in ADHD (Biederman et al., 2002). There may also be other social factors, unrelated to autistic symptoms which differentially influence diagnosis in boys and girls.

Some studies have investigated which behavioural factors other than ASD may impact on whether a diagnosis is made and whether this differs by gender. Dworzynski, Ronald, Bolton and Happe (2012) examined differences between boys and girls who scored highly on a screening instrument for autistic traits (Childhood Autism Spectrum Test; CAST) and those who later were diagnosed with ASD. They found the difference between high scoring girls who were diagnosed included higher rates of teacher reported hyperactivity, lower IQ and more overall behavioural problems than girls who had high levels of ASD symptoms but were not diagnosed. This difference was not significant in high scoring boys, who experienced similar levels of IQ and behavioural problems as boys with high levels of ASD symptoms who did not fulfil ASD diagnostic criteria. The authors suggested that girls may need to exhibit higher levels of other behavioural difficulties to be diagnosed with ASD. They also indicated alternatively, that girls with high levels of autistic traits without comorbid difficulties may be able to compensate for their autistic difficulties and not meet diagnostic criteria.

The suggestion that girls need to exhibit more difficulties to be identified with a disability is neither new nor specific to ASD. For example, Cullinan and colleagues (2003) examined characteristics of elementary school aged students receiving funding for emotional disturbance. They found that girls with emotional disturbance had higher levels of physical symptoms/fears (anxiety) than boys with emotional disturbance, but there were no gender

differences in students without emotional disturbance. They proposed that females may need to exhibit higher levels of anxiety than boys to receive funding. Importantly, they found no gender difference in the teacher reported overall competence (strengths and developmental assets) in students *with* emotional disturbance. However, in students *without* emotional disturbance, girls were reported by teachers to have higher overall competence than boys. The authors hypothesised that teachers may be reluctant to identify females as having emotional disturbance unless they have significantly fewer strengths and resources than girls without emotional disturbance. Collectively, this research indicates that girls with ASD symptoms appear to require additional behavioural problems to be diagnosed with ASD but this is not required for boys whose ASD symptoms are recognised regardless of whether they exhibit other behaviour problems.

Sociocultural Contributions to Gender Difference in ASD

ASD, like all psychiatric disorders, is diagnosed based on observable behaviours rather than objective biological criteria. Diagnosis is therefore subjective and based on clinical impression and the use of clinical tools such as observation, questionnaires and clinical interviews. Some studies in ASD have proposed that gender differences in prevalence and severity of symptoms may be due to interpreting biases of informants such as clinicians, teachers and parents (Giarelli et al., 2010; Kopp & Gillberg, 1992; McLennan et al., 1993). It has been well-established that clinicians' diagnostic judgements can be influenced by their beliefs about gender. For example, in a seminal gender study psychiatrists were given identical fictional case studies describing symptoms of schizophrenia or depression varying only by the gender of the subject (Loring & Powell, 1988). Psychiatrists were more likely to diagnose schizophrenia when the case was described as being male and depression when the case was described as female (Loring & Powell, 1988). Teachers, too, can be influenced by

gender in their referral decisions for students. This was highlighted in a study of Attention Deficit Hyperactivity Disorder (ADHD). Teachers were given an identical case study varying only by gender (John or Jennifer) and ADHD symptom type and were asked if they would refer the child for assessment (Sciutto, Nolfi, & Bluhm, 2004). Teachers were more likely to refer when the case was described as male compared with when described as female. This difference was particularly marked when the symptom type was hyperactivity, indicating girls' hyperactive symptoms are less likely to prompt referral by teacher than are boys.

In ASD, studies have not yet directly assessed whether there is a clinician or teacher bias towards categorizing males with ASD or referring males more often than females for symptoms characteristic of ASD. In an early seminal study, Koop and Gillberg (1992) reviewed six cases of girls with autism whose PDD diagnoses were overlooked by a range of expert clinicians, raising the possibility that PDD difficulties in girls may not be as readily recognized in girls, or that clinicians were less likely to diagnose ASD in girls.

There are some indirect indications that female symptoms may be viewed differently than males from validation studies of screening instruments often used in ASD prevalence studies. A study of the Autism Spectrum Screening Questionnaire (ASSQ) in children aged 7 to 9 years found that teachers were more likely to identify boys as having higher levels of autistic behaviours than girls, at a ratio of 6:1 (Posserud, Lundervold, & Gillberg, 2006). In contrast, parent reports for the same children were more similar with the boy-to-girl ratio of high scorers being 2.1:1. Although the authors suggest that *parents* could over-report girls' autistic symptoms, they also noted their findings may indicate that *teachers* may overlook autistic difficulties in girls. Regardless, there was less agreement between teachers and parents regarding girl's autistic symptoms than there were for boys, which may indicate that there is more variation in the interpretation of female behaviour than male behaviour.

There also exists some evidence that girls with ASD may not be identified in childhood or that they may be misdiagnosed. Studies have reported females with ASD have been misdiagnosed with anxiety disorders (Bolte & Boschb, 2005), eating disorders (Gillberg, Rastam, Wentz, & Gillberg, 2007; Nilsson, Gillberg, Gillberg, & Rastam, 1999), obsessive compulsive disorder, borderline personality disorder (Ryden, Ryden, & Hetta, 2008), schizoaffective disorders (Bolte & Boschb, 2005) and paranoid symptoms (Kopp & Gillberg, 1992). Nilsson et al. (1999) found that in a group of females with anorexia nervosa, 18 percent met the criteria for an ASD compared with 2 percent in their comparison group, using DSM-IV criteria. Ryden and colleagues (2008) found around 15 percent of female patients with Borderline Personality Disorder also met criteria for an ASD. A study of psychiatric inpatients screened for ASD found of those who met ASD criteria, males were more likely to have received psychiatric care in childhood (69%) compared with females (39%) (Ryden & Bejerot, 2008) indicating that female ASD difficulties may go unrecognised and untreated in childhood. A large study (N=2,568) of 8 year old children found that females who met criteria for ASD, based on applying DSM-IV-TR criteria to service file records, were less likely to have been diagnosed with ASD than were males (Giarelli et al., 2010). This was particularly pronounced with IQs in the high-functioning range. These studies suggest that ASD-affected females may indeed be more likely to be missed in childhood (Begeer et al., 2012). A complex interaction between biological, psychological, behavioural, and social factors may be in play which together contributes to more males cases of ASD.

Summary

There has been a call for more empirically-based studies of gender differences in psychopathology, particularly in neurodevelopmental disorders where males have been the focus of research due to their higher prevalence than females (Crick & Zahn-Waxler, 2003;

Goldman, 2013; Rutter et al., 2003; Thompson et al., 2003). ASD studies over the last 30 years have examined gender differences in symptoms and associated behaviours to attempt to understand why more males are diagnosed with ASD and why females are less common by diagnosis when they are cognitively high-functioning. Mixed findings proliferate and may be due to differing study methodologies, measures, age ranges, IQ ranges, small sample sizes, and failure to consider developmental change in symptom presentation. A range of theories have been developed to explain the phenomenon of male predominance in ASD, however, without clearly articulated findings in this area, causal theories may be based on underlying inaccurate premises. For example, the gender difference in ASD could be due primarily to sociocultural factors such as failure to identify and diagnose ASD in girls rather than due to biological differences between males and females. Clearly, more rigorous studies with well-matched samples of boys and girls, across narrower age ranges, with longitudinal study designs are needed to establish a baseline understanding of any gender difference in ASD. Examining gender differences in developmental trajectories is an important area missing in current ASD research which is required to understand the role of gender in the development of ASD through the lifespan. The following chapters of the thesis will present three empirical papers which consider these gaps in the literature and attempt to address them with a study of high-functioning primary school-aged children with ASD and a matched group of typically developing children.

Monash University

Declaration for Thesis Chapter 2

Declaration by candidate

In the case of Chapter 2, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Project design, review of relevant literature, attainment of ethics approval, recruitment and all testing of research participants, analysis of data and writing of manuscript.	70%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	**Nature of contribution**
Prof. Nicole Rinehart	Contributed to project design and provided input during final draft stage of manuscript.
Prof. Kim Cornish	Contributed to project design and provided input during final draft stage of manuscript.

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work*.

Candidate's Signature		**Date**
Main Supervisor's Signature		**Date**

*Note: Where the responsible author is not the candidate's main supervisor, the main supervisor should consult with the responsible author to agree on the respective contributions of the authors.

Chapter 2 Gender differences in clinical symptoms

Preamble to Paper 1

This published paper is the first in a series of five empirical papers which seek to define the gender profile of ASD in relation to clinical and neuropsychological variables. The focus of Paper 1 is on determining any gender differences in the parent reported clinical symptoms of ASD and ADHD, including hyperactivity-impulsivity and inattention, in high-functioning primary school aged children with ASD. Secondly, the paper aimed to examine any age related findings in ADHD symptoms of hyperactivity-impulsivity based on a cross-sectional design. This is one of the first studies to examine high-functioning gender differences in ASD in a sample restricted to childhood. This paper has been published in the Journal of Attention Disorders.

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Gender Profiles of Behavioral Attention in Children With Autism Spectrum Disorder

Tamara May[1,2], Kim Cornish[1], and Nicole J. Rinehart[1,2]

Abstract

Objective: The attention profile of girls with autism spectrum disorder (ASD) is unclear compared with boys with ASD and typical children. This study aimed to investigate parent-reported ASD and ADHD symptoms in a large sample of boys and girls with and without ASD. **Method:** A total of 124 normally intelligent children, half of them girls, 64 with autistic disorder or Asperger's disorder, and 60 age- and gender-matched typically developing, aged 7 to 12 years, were recruited. Parents completed questionnaires regarding autistic and ADHD symptoms. **Results:** No gender differences in social difficulties but more repetitive motor movements, communication difficulties, and inattention were reported in males, regardless of group. Younger boys with ASD had more elevated levels of hyperactivity-impulsivity than younger girls with ASD. **Conclusion:** Gender differences in autistic symptoms and inattention in ASD reflected gender differences in typical children. More pronounced hyperactivity in younger boys with ASD could contribute to higher rates of clinical referral than girls. *(J. of Att. Dis. 2012; XX(X) 1-XX)*

Keywords

autism spectrum disorders, gender, girls, females, ADHD

Many advances in our clinical and neuropsychological understanding of autism spectrum disorders (ASD) have taken place in the last decade. Notably, there is an increasing recognition of the clinical overlap between ASD and ADHD. This will be reflected in the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM-V*; American Psychiatric Association [APA], 2010) proposal to remove the diagnostic rule precluding a comorbid diagnosis of ASD and ADHD. ADHD shows a number of similarities with high-functioning autism and Asperger's disorder: All are complex genetic, neurodevelopmental conditions with male predominance, which involve similar brain regions such as the frontostriatal area. Notably, the last few decades of research have predominately focused on males with these conditions, with comparatively less focus on females. Often this is justified by findings that suggest, on average, four males for every one female are diagnosed with an ASD (Fombonne, 2003) and at least three males for every one female are diagnosed with ADHD (APA, 2000; Graetz, Sawyer, Hazell, Arney, & Baghurst, 2001). In ASD, the gender ratio differs with cognitive ability, with a 2:1 ratio in individuals with intellectual disability compared with around 6:1 in high-functioning populations (Fombonne, 2003). In ADHD, the gender ratio is higher in clinical populations, likely due to males exhibiting more externalizing behavior problems and subsequently gaining clinical attention (Levy, Hay, Bennett, & McStephen, 2005). In contrast, females typically exhibit more covert internalizing behaviors, like anxiety, resulting in fewer girls compared with boys referred to clinics (Levy et al., 2005; Staller & Faraone, 2006). These gender differences in behavior may affect the ascertainment of girls with ASD and ADHD, and contribute to the male predominance found in these conditions. Importantly, gender differences found in the prevalence, symptomatology, and time course of a disorder may provide clues to underlying etiology (Rutter, Caspi, & Moffitt, 2003). Examining gender differences in ASD and ADHD may therefore provide insight into causal mechanisms, as well as aide in the identification and treatment of girls with these conditions if symptomatology and time course do differ by gender. As ADHD is around 5 times more prevalent than ASD, there have been far greater opportunities to study girls with ADHD than girls with ASD (APA, 2000; Graetz et al., 2001). To date, gender differences in the behavioral symptoms of ASD have received the most research attention, yet some inconsistent findings have emerged.

In general, past research suggests males with ASD have higher levels of repetitive and stereotyped behaviors than females; however, social-communicative symptom

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Paper 1: Gender Profiles of Behavioral Attention in Children with Autism Spectrum Disorder

Abstract

Objective: The attention profile of girls with Autism Spectrum Disorder (ASD) is unclear compared to boys with ASD and typical children. This study aimed to investigate parent-reported ASD and Attention Deficit Hyperactivity Disorder (ADHD) symptoms in a large sample of boys and girls with and without ASD.

Method: One-hundred-and-twenty-four normally intelligent children, half girls, 64 with Autistic Disorder or Asperger's Disorder, and 60 age and gender-matched typically developing, aged 7-12 years, were recruited. Parents completed questionnaires regarding autistic and ADHD symptoms.

Results: No gender differences in social difficulties, but more repetitive motor movements, communication difficulties, and inattention were reported in males, regardless of group. Younger boys with ASD had more elevated hyperactivity-impulsivity than younger girls with ASD.

Conclusion: Gender differences in autistic symptoms and inattention in ASD reflected gender differences in typical children. More pronounced hyperactivity in younger boys with ASD could contribute to higher rates of clinical referral than girls.

Key words: Autism Spectrum Disorders, gender, girls, females, attention deficit hyperactivity disorder

Many advances in our clinical and neuropsychological understanding of Autism Spectrum Disorders (ASD) have taken place in the last decade. Notably, there is an increasing recognition of the clinical overlap between ASD and Attention Deficit Hyperactivity Disorder (ADHD). This will be reflected in the Diagnostic and Statistical Manual of Mental Disorders (DSM) proposal to remove the diagnostic rule precluding a comorbid diagnosis of ASD and ADHD (American Psychiatric Association, 2010). ADHD shows a number of similarities with high-functioning autism and Asperger's Disorder: all are complex genetic, neurodevelopmental conditions with male predominance which involve similar brain regions, such as the frontostriatal area. Notably, the last few decades of research have predominately focused on males with these conditions, with comparatively less focus on females. Often this is justified by findings that suggest, on average, four males for every one female are diagnosed with an ASD (Fombonne, 2003) and at least three males for every one female are diagnosed with ADHD (American Psychiatric Association, 2000; Graetz, Sawyer, Hazell, Arney, & Baghurst, 2001). In ASD, the gender ratio differs with cognitive ability, with a 2:1 ratio in individuals with intellectual disability, compared to around 6:1 in high functioning populations (Fombonne, 2003). In ADHD the gender ratio is higher in clinical populations, likely due to males exhibiting more externalizing behaviour problems and subsequently gaining clinical attention (Levy, Hay, Bennett, & McStephen, 2005). In contrast, females typically exhibit more covert internalizing behaviours, like anxiety, resulting in fewer girls compared to boys referred to clinics (Levy, Hay, Bennett, & McStephen, 2005; Staller & Faraone, 2006). These gender differences in behaviour may impact on the ascertainment of girls with both ASD and ADHD and contribute to the male predominance found in these conditions. Importantly, gender differences found in the prevalence, symptomology, and time-course of a disorder may provide clues to underlying etiology (Rutter, Caspi, & Moffitt, 2003). Examining gender differences in ASD and ADHD may therefore provide insight into

causal mechanisms, as well as aide in the identification and treatment of girls with these conditions if symptomatology and timecourse do differ by gender. As ADHD is around 5 times more prevalent than ASD there has been far greater opportunities to study girls with ADHD than girls with ASD (American Psychiatric Association, 2000; Graetz, Sawyer, Hazell, Arney, & Baghurst, 2001). To date, gender differences in the behavioural symptoms of ASD have received the most research attention, yet some inconsistent findings have emerged.

In general, past research suggests males with ASD have higher levels of repetitive and stereotyped behaviours than females, however, social-communicative symptom disturbance is reported as similar across genders. However, the research findings in this area are mixed with some studies reporting more social difficulties in girls, particularly post-puberty (Holtmann, Bolte, & Poustka, 2007; McLennan, Lord, & Schopler, 1993), but also fewer social difficulties in adult females (Lai et al., 2011, Rivet & Matson, 2011). Findings that males tend to exhibit more repetitive behaviours (Hartley & Sikora, 2009; Hattier, Matson, Tureck & Horovitz, 2011; Mandy et al., 2011; Sipes, Matson, Worley, Kozlowski, 2011; Wing, 1981) may reflect a gender difference found in the general population (Leekam et al., 2007). Yet, other studies have found no gender differences in social, communication, or repetitive behaviours in *children* with ASD (Kozlowski & Matson, 2011; Lai et al., 2011; Pilowsky, Yirmiya, Shulman, & Dover, 1998; Rivet & Matson, 2011; Solomon, Miller, Taylor, Hinshaw, & Carter, 2011). Overall, no consistent gender differences in ASD symptom severity exist in the research literature, which could relate to small sample sizes, heterogeneous study methodology, possible changes in symptoms across development, or there may simply be no robust gender differences.

The behavioural symptoms of ADHD also appear to vary across gender in individuals with ADHD, however, findings in this area are also mixed. In clinically referred samples of

individuals with ADHD males exhibit higher levels of hyperactivity, impulsivity and inattention than girls (Gershon, 2002). However, ADHD gender ratios, when taken from non-referred, population based samples, are narrowed compared with clinical samples, and the level of ADHD symptom severity is also similar across genders (DuPaul et al, 2006; Staller & Faraone, 2006). It is plausible that the way in which ADHD symptoms overlap in ASD in regards to gender may be similar to that found in ADHD. Overall, the rates of ADHD symptoms in individuals with ASD have been estimated at up to 70 percent (Yoshida & Uchiyama, 2004; Gadow, Devincent, Pomeroy, & Azizian, 2005; see also Cornish and Wilding, 2010, for a review). In regards to gender differences in ADHD symptoms in ASD, past research has shown the prevalence of ADHD to be similar in males and females with ASD in childhood and adulthood (Brereton, Tonge, & Einfeld, 2006; Gadow, et al., 2005; Hofvander, et al., 2009; Simonoff, et al., 2008). However, most of these studies have examined very few females compared to males, included wide age bands, and not reported whether samples were IQ matched. Recently, Mandy et al. (2011) found more teacher, but not parent, reported ADHD symptoms in boys than in girls with ASD.

In regards to the time course of ADHD symptomatology, a profile of decline in ADHD symptoms with age has been found for both males and females with ADHD, but with some evidence that ADHD may be more persistent in girls than boys (Hinshaw et al., 2007; Mick et al., 2011; Monuteaux, Mick, Faraone, & Biederman, 2010). In contrast to this, Mandy et al. (2001) recently found no age profile of ADHD symptoms in ASD, however, they used a unitary hyperactivity/inattention construct in a sample aged from 3 to 18 years. As hyperactivity tends to decrease with age but inattention may remain persistent, employing a unitary construct for these separate domains may obscure age effects in symptom change. Hence, it is not clear if the timecourse of ADHD symptoms in boys and girls with ASD shows a similar gender profile to that of ADHD.

Finally, when examining gender it is important to examine a typically developing group to determine if any gender differences are specific to a disorder or reflect general population gender differences. Numerous studies of gender in ASD have failed to include a typically developing group of boys and girls (Koenig & Tsatsanis, 2005). If there are gender differences found in ASD that reflect typical gender differences these will require different interpretation than gender differences unique to ASD and will have different implications in regards to causal mechanisms.

The aim of the current study was to firstly examine gender differences in autistic and ADHD symptoms in a well defined IQ and age matched group of boys and girls with ASD. The second aim was to determine whether ADHD symptoms in this group would show a decline with age. Thirdly, our aim was to examine these relationships in the context of typical gender development by including a normally developing comparison group. Our hypotheses were threefold; (1) that boys with ASD would exhibit more repetitive and stereotyped behaviours than girls with ASD, but similar levels of social and communication deficits, and these relationships would be reflected in typically developing children (2), that boys with ASD would show more hyperactive-impulsive and inattentive symptoms than girls with ASD, a pattern which would also be present in the typically developing children; and, (3), that there would be lower levels of hyperactive and inattentive symptoms in older children with ASD than in younger children with ASD, regardless of gender, and this age pattern would also be reflected in the typical group.

Method

Participants

The participants were 124 children aged 7 to 12 years, 64 with Autistic Disorder or Asperger's Disorder including 32 males (16 Autistic Disorder, 16 Asperger's Disorder) and 32 females (7 Autistic Disorder, 25 Asperger's Disorder), and 60 typically developing

children (TYP), 30 female and 30 male. Of the participants, 93.5% were Caucasian, 5.6% Asian and 0.9% other. The clinical group were recruited from the Monash University Centre for Developmental Psychiatry and Psychology register of volunteers, the Autism Victoria 'Get Involved' register of volunteers, and from private clinics in the Melbourne metropolitan area. Only children who had a current diagnosis of ASD from their paediatrician or psychologist were invited into the study. The DSM-IV-TR criteria for Autistic Disorder or Asperger's Disorder was confirmed for all clinical participants using our standard process of confirmation involving reviewing diagnostic reports from registered psychologists and paediatricians with a symptom checklist to ensure the DSM-IV-TR criteria were fulfilled. Only children with Full Scale IQs of 70 and above were included. The TYP group was recruited from a local primary school and had no history of parent reported developmental delay or psychopathology. The groups were matched based on gender and age.

Measures

Cognitive functioning. Cognitive functioning in the clinical group was assessed using the Wechsler Preschool and Primary School Intelligence (WPPSI), or the Wechsler Intelligence Scales for Children IV (WISC-IV) Australian versions. The cognitive functioning of the TYP group was assessed using the Wechsler Abbreviated Scales of Intelligence (WASI).

Parent reported autism symptoms. Clinical symptoms of ASD were assessed using parent reports from the Social Responsiveness Scale (SRS), Children's Communication Checklist (CCC-2), and the Repetitive Behaviours Questionnaire II (RBQ-II). The CCC-2 is a 70 item parent report used to assess children's communication abilities (Bishop, 2003). The device is used to screen for language and pragmatic impairment in children with communication problems. Higher scores indicate less impairment. Subscale reliability estimates from .66 to

.80 have been reported in typical children. The SRS is a 65 item questionnaire used to assess social awareness, social information processing, capacity for reciprocal social communication, social anxiety/avoidance, and autistic preoccupations and traits in children from 4 to 18 years (Constantino, 2002). It has acceptable levels of internal consistency (.93-.97) and test-rest reliability (.77-.85). Parents use a four-point rating scale to rate the severity of symptoms. The RBQ-II is a questionnaire which assesses the presence of repetitive behaviours in children (Leekam et al., 2007). Four subscales are measured in the RBQ-II which closely link to the ICD-10 criteria for autism: unusual sensory interests, repetitive motor movements, rigidity/adherence to routine, and preoccupations with restricted patterns of interest. Parents answer 20 questions using a three point rating scale. Internal consistency for the 20 items was .85 (Leekam et al., 2007).

Parent reported ADHD symptoms. Two measures of ADHD symptomatology were utilised, the Conners 3 and the Strengths and Weaknesses in Attention Deficit Hyperactivity Symptoms (SWAN). The Conners 3 Parent Short form is a 43 item parent-report which identifies ADHD symptoms in a child based on DSM-IV-TR criteria (Conners, 2003). Six items identify hyperactive symptoms, and 5 identify inattentive symptoms. Responses are indicated on a 4 point scale from not true at all, to very much true. Test-retest reliability ranges from .71 to .98 and internal consistency ranges from .77 to .97. The SWAN (Swanston et al., 2006) is an 18 item parent report scale with subscales in the domains of inattention (9 items) and hyperactivity (9 items) based on the DSM-IV ADHD symptoms. Responses are indicated using a 7 point likert type scale from far below (-3), below (-2), slightly below (-1), average (0), slightly above (1), above (1), far above (3). This allows for a normal distribution of data and also provides more sensitivity in assessing symptoms. The scale asks for ratings in

comparison to the participant's peers and so can be used across a range of age groups. Reliability using Cronbach's alpha has been reported to be .98 (Wilding & Burke, 2006).

Procedure

The study was approved by the Monash University Human Research Ethics Committee and the Victorian Department of Education and Early Childhood Ethics Committee. Parents received an explanatory statement and provided written informed consent. Participation was voluntary and participants did not receive any monetary reward for participation other than reimbursement for travel costs.

Parents of participants were invited to participate via email or letter and follow-up telephone call. Participants were tested at a home visit, at the Monash University Clayton campus, or at their primary school. Cognitive assessments were administered according to standardized instructions. Parents completed the questionnaires as per their standard instructions. Age-based standardized scores were utilized for the IQ tests. Raw scores were used for the SRS, RBQ-II, CCC-2, Conners 3, and SWAN. All data was entered into Statistical Package for the Social Sciences (SPSS) version 18.0 for statistical analyses.

Results

The data were assessed for outliers. An outlier in each of the SWAN inattention and Conners 3 hyperactivity scale was detected and corrected with the next most extreme score plus one, as per Tabacknich & Fidell (2007). A one-way Analysis of Variance (ANOVA) revealed there was no difference in age between the groups (Table 1). ANOVA revealed a group difference in Fullscale IQ (FSIQ), Verbal Comprehension Index (VCI) and Perceptual Reasoning Index (PRI). The boys and girls with ASD were matched on FSIQ, VCI and PRI. Post-hoc Bonferroni tests showed the TYP group had higher FSIQ scores than the ASD

group, TYP boys had higher VCI scores than the ASD girls and boys, but there was no difference in the four groups on PRI despite the significance of the main ANOVA. Consequently, FSIQ was used as a covariate in the analyses. For the main analyses two-way multiple ANOVA's were conducted with group (TYP and ASD) and gender (Male and Female) entered as independent variables and the SRS, CCC, RBQ, C3 and SWAN subscales as dependent variables, with FSIQ used as a covariate.

Table 1

Summary Age, and IQ Characteristics for the Autism Spectrum Disorder and Typically Developing Groups

Characteristic	ASD Girls (N=32)	ASD Boys (N=32)	TYP Girls (N=30)	TYP Boys (N=30)	*F*	*P*
Age in months, M (SD)	117.9 (21.50)	119.6 (22.84)	115.8 (21.86)	107.9 (18.67)	1.799	.151
FSIQ, M (SD)	96.19 (12.62)	97.38 (13.86)	106.50 (11.25)	108.43 (11.99)	7.716a	.000***
VCI, M (SD)	99.12 (13.42)	98.66 (14.34)	106.47 (9.14)	107.60 (10.24)	4.768b	.004**
PRI, M (SD)	97.31 (14.09)	104.84 (15.10)	106.27 (14.34)	106.43 (14.47)	2.949c	.036*

FSIQ, full-scale IQ; VCI, verbal comprehension index; PRI, perceptual reasoning index; ASD, Autism Spectrum Disorder Group; TYP, Typically Developing Group

*p<.05; **p<.01; ***p<.001; a TYP > ASD; b TYP boys > ASD; c No group differences in post hoc tests

Social ability. A two-way MANOVA revealed the ASD group had higher scores than the TYP group across all subscales and for the total SRS score, Table 2. There were no gender differences in any of the SRS subscales or total score, and no group X gender interactions, Table 2.

Repetitive Behaviours. The two-way MANOVA revealed the ASD group had higher levels of repetitive behaviours across all subscales than the TYP group, Table 2. There was a main effect of gender on the Repetitive Motor Movements subscale, with males exhibiting more of these behaviours than females (p=.006). There were no group X gender interactions.

Communication ability. A two-way MANOVA revealed the ASD group had lower scores than the TYP group across all subscales (on this measure lower scores indicate poorer performance), Table 2. There was a main effect of gender on the inappropriate initiations (p=.033) and unusual interests (p=.004) subscales, where males had lower scores indicating more inappropriate initiations and autistic interests than females. Males also scored lower on the social interaction deviance composite (SIDC; p=.033) which indicates their language structure was better than their pragmatic language ability, compared to females. There were no group X gender interactions.

Table 2

Differences between SRS, RBQ, and CCC by Group and Gender

Variable	ASD Girls (N=32) M (SD)	ASD Boys (N=32) M (SD)	TYP Girls (N=30) M (SD)	TYP Boys (N=30) M (SD)	*F ratio group*	*F ratio Gender*
Social Responsiveness Scale						
Social Awareness	15.56 (11.26)	12.78 (3.36)	4.43 (2.51)	5.10 (2.77)	51.083*** ASD>TYP	.729
Social Cognition	20.81 (13.83)	19.75 (5.41)	4.10 (2.98)	4.77 (3.23)	90.856*** ASD>TYP	.000
Social Communication	33.06 (15.35)	33.53 (8.76)	8.00 (6.09)	9.17 (7.79)	133.045*** ASD>TYP	.417
Social Motivation	17.16 (15.23)	14.38 (4.63)	4.60 (3.66)	4.83 (3.86)	35.526*** ASD>TYP	.523
Autistic Mannerisms	20.44 (14.89)	19.81 (6.26)	2.83 (3.09)	3.17 (3.91)	90.671*** ASD>TYP	.001
Total score	97.41 (31.77)	99.97 (22.71)	23.17 (16.49)	27.30 (20.42)	229.871*** ASD>TYP	.996
Repetitive Behaviours Questionnaire						
Repetitive Motor Movements	1.54 (.54)	1.84 (.60)	1.04 (.16)	1.16 (.22)	40.069*** ASD>TYP	7.855** M>F
Rigidity, Adherence to Routines	1.99 (.60)	2.00 (.59)	1.19 (.35)	1.15 (.21)	68.821*** ASD>TYP	.003
Autistic Preoccupations	1.78 (.46)	1.96 (.47)	1.12 (.34)	1.26 (.22)	63.623*** ASD>TYP	2.893
Sensory Sensitivities	1.63 (.59)	1.73 (.53)	1.14 (.36)	1.13 (.22)	33.530*** ASD>TYP	.295
Total score	35.48 (8.53)	38.34 (9.01)	23.23 (4.52)	23.86 (3.42)	85.397*** ASD>TYP	2.232
Children's Communication Checklist~						
Speech	5.94 (3.65)	6.56 (3.91)	9.50 (3.40)	9.83 (3.03)	13.629*** ASD<TYP	.307
Syntax	5.91 (3.24)	5.78 (3.87)	9.33 (3.60)	9.13 (3.60)	12.231** ASD<TYP	.280
Semantics	5.16 (2.53)	4.59 (3.26)	9.70 (3.98)	10.17 (3.98)	40.341*** ASD<TYP	.097
Coherence	4.34 (2.44)	3.78 (2.17)	10.43 (3.08)	9.97 (3.12)	113.382*** ASD<TYP	1.723

Inappropriate Initiations	5.50 (2.46)	3.94 (1.87)	10.90 (3.20)	10.50 (2.93)	120.987*** ASD<TYP	4.659* M<F
Stereotyped Language	4.38 (3.00)	3.78 (2.66)	10.50 (3.48)	9.87 (2.97)	93.717*** ASD<TYP	1.525
Context	2.97 (2.67)	2.31 (2.46)	9.67 (3.84)	9.60 (2.54)	131.995*** ASD<TYP	.765
Nonverbal Communication	2.56 (2.43)	2.44 (2.46)	10.57 (2.84)	9.57 (2.94)	193.622*** ASD<TYP	1.816
Social Relations	3.06 (2.50)	2.13 (2.66)	10.30 (2.95)	9.40 (3.08)	158.165*** ASD<TYP	3.925
Autistic Interests	4.78 (2.14)	3.63 (2.35)	10.53 (3.67)	8.87 (2.49)	98.072*** ASD<TYP	8.814** M<F
Global Communication Composite	36.75 (15.01)	33.19 (16.00)	80.60 (22.94)	78.63 (19.78)	129.936*** ASD<TYP	1.274
Social Interaction Deviance Composite	-5.44 (9.14)	-8.59 (10.23)	3.33 (8.23)	-0.77 (7.44)	40.311*** ASD<TYP	4.657* M<F

*p<.05; **p<.01; ***p<.001; ~ higher scores indicate better performance; ASD, Autism Spectrum Disorder; TYP, Typically Developing; SRS, Social Responsiveness Scale; CCC-2, Children's Communication Checklist; RBQ, Repetitive Behaviours Questionnaire

Relationship between inattention, hyperactivity, group, and age. Data for inattention and hyperactivity scores was missing for 2 control girls and 1 control boy. To understand the interaction between age, sex and group, the sample was divided in two based on the median age in the total sample of 116 months. There were 58 participants in the younger group (84-116 months of age; ASD: 12 males, 15 females; TYP: 12 females, 19 males) and 63 participants in the older group (117-155 months of age; ASD: 20 males, 17 females; TYP: 16 females, 10 males). A three-way MANOVA was used with group (ASD and TYP), gender (male and female) and age (older and younger) as the independent variables, and Conners 3 inattention and hyperactivity, and SWAN inattention and hyperactivity as the dependent variables. There were significant main effects of group, gender and age, Table 3. The combined ASD group had higher levels of hyperactivity and inattention on both the SWAN

and Conners 3 than the TYP group. The main effects of gender showed that boys had high levels of hyperactivity/impulsivity than girls on both the Conners 3 (p=.004) and the SWAN (p=.036). There was no gender difference in levels of inattention on the Conners 3, but boys had higher levels of inattention on the SWAN scale compared to girls (p=.041). There was also a main effect of age for Conners 3 (p=.005) and SWAN (p=.025) hyperactivity scales, with inspection of means revealing there was more hyperactivity in the younger age group. There was a significant interaction between group and gender for Conners 3 hyperactivity, $F(1,122)=4.598$, p=.034. Inspection of Figure 1 indicated that males with ASD had higher levels of hyperactivity than females with ASD which was not reflected in the TYP group. There was also a significant interaction between group, gender and age, for Conners 3 hyperactivity, $F(1,122)=4.279$, p=.041. Inspection of Figure 2 and the means indicated that the level of hyperactivity was similar in young TYP boys (M=3.00) and young TYP girls (M=3.08), with older TYP boys (M=2.50) having slightly higher levels of hyperactivity than older TYP girls (M=1.38). In contrast, younger boys with ASD (M=13.25) had much higher levels of hyperactivity than younger girls with ASD (M=7.47). Older boys with ASD (M=8.15) had more similar levels of hyperactivity than older girls with ASD (M=6.82), reflecting the gender relationship in older TYP children.

Table 3

Differences between Conners 3 and SWAN Inattention and Hyperactivity scales by Group and Gender and Age

Variable	ASD Girls (N=32)	ASD Boys (N=32)	TYP Girls (N=28)	TYP Boys (N=29)	*F ratio group*	*F ratio Gender*	*F ratio Age*
Conners 3 Inattention	7.81 (3.17)	9.39 (3.67)	2.64 (2.25)	2.69 (2.44)	80.089*** ASD > TYP	2.981	.933
Conners 3 Hyperactivity	7.13 (4.74)	10.06 (5.06)	2.11 (2.25)	2.83 (2.80)	64.729*** ASD > TYP	8.660** M>F	8.267** Y>O
SWAN Inattention	-7.84 (8.64)	-11.41 (9.33)	8.68 (8.67)	5.72(6.25)	83.080*** ASD > TYP	4.280* M>F	.232
SWAN Hyperactivity	-4.38 (10.98)	-9.50 (8.27)	8.64 (9.50)	6.79 (8.22)	60.078*** ASD > TYP	4.508* M>F	5.197* Y>O

* P<.05, **p<.01; p<.001

M = male, F= female, Y=younger, O=older, ASD=Autism Spectrum Disorder group, TYP = Typical Group

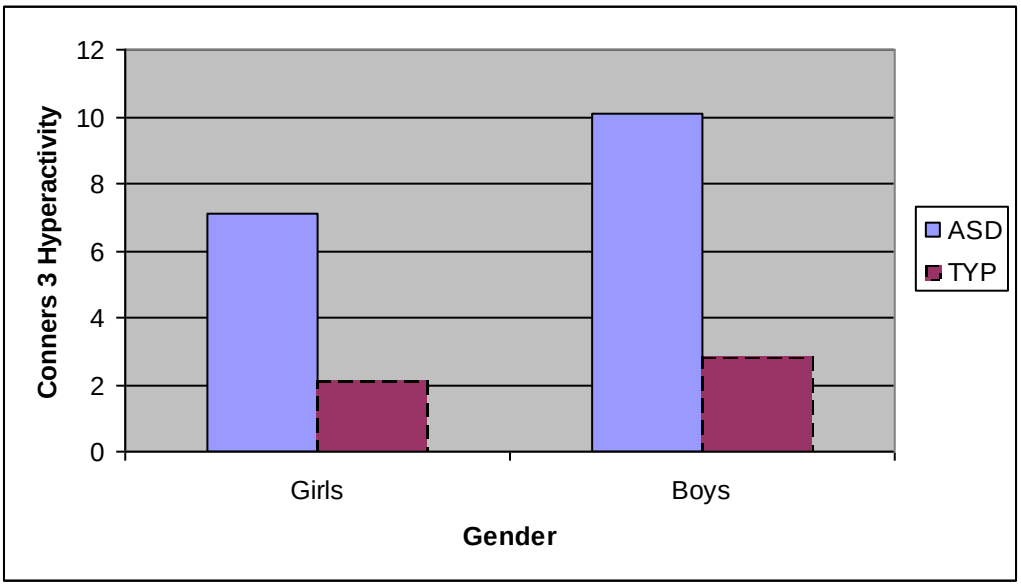

Figure 1. Gender by Mean Conners 3 hyperactivity raw score for the Autism Spectrum Disorder and Typical groups.

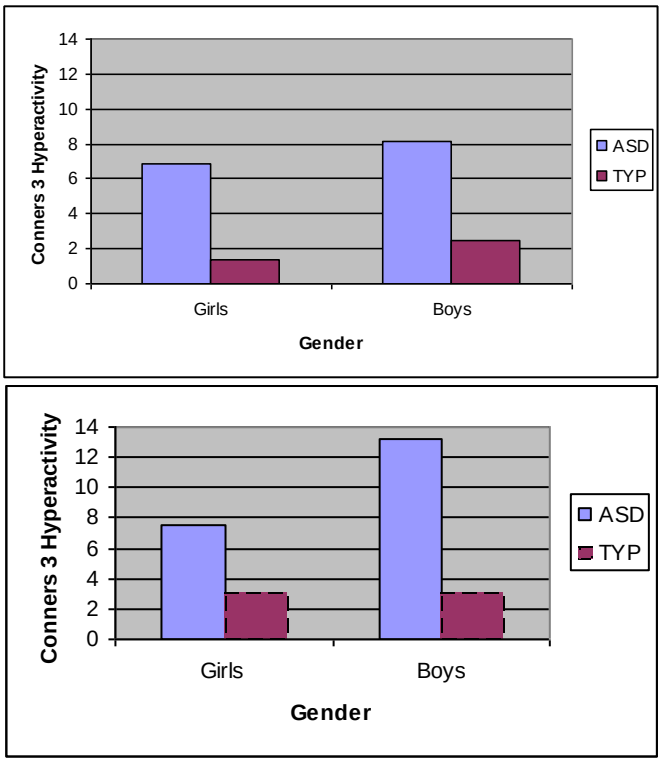

Figure 2. Gender by Mean Conners 3 Hyperactivity raw score for the Autism Spectrum Disorder (ASD) and Typical (TYP) group by age group. In the younger group (84-116 months), bottom panel, boys with ASD had higher levels of hyperactivity than girls. In the older group (117-155 months), top panel, hyperactivity levels were similar for boys and girls with ASD, and typical boys and girls.

Discussion

The last decade of ASD research has led to changes in our clinical conceptualization of ASD, for example, it is presently proposed for the DSM 5 that ADHD and ASD can be dually diagnosed. Apropos of this, we know very little about girls with ASD and less about the ASD-ADHD profile in girls and boys. This study examined an age and IQ matched group of primary school aged boys and girls with ASD on parent reported behavioural symptoms of ASD and ADHD. The study also included a typically developing group to examine how gender differences may be unique to ASD or reflect gender differences found in the general population. Overall, our findings were that males with ASD showed more difficulties with

repetitive motor movements, communication and inattention, which were reflected in the typically developing children. Younger boys with ASD also had higher levels of hyperactivity than younger girls with ASD, a gender finding unique to the ASD group, which could contribute to the difficulties of boy's with ASD being more obvious than girls with ASD.

As hypothesised, there were no significant gender differences in level of social responsiveness in boys and girls with ASD or between typical boys and girls, suggesting that girls and boys with ASD present similarly regarding this core deficit of autism in this age group. This finding mirrors recent findings of similar social impairments in boys and girls with ASD (Mandy et al,, 2011; Sipes et al., 2011; Solomon, et al., 2011). In older adults, females have been reported to show better social abilities (Lai et al., 2011, Rivet & Matson, 2011) which may indicate improvement in social abilities with age in females with ASD. Longitudinal studies of well matched samples of high functioning girls are needed to understand whether gender differences in social ability (and other autistic symptom domains) show a specific trajectory across development.

Contrary to our hypothesis, the present study found gender differences on the communication measure. Boys showed more inappropriate initiations than girls which involves talking repetitively about things that no-one else is interested in. Boys also had more unusual interests relating to autism than girls on the CCC-2. Boys were also reported to have a lower Social Interaction Deviance Composite scores on the CCC-2 than girls, which indicates that girls had better pragmatic language relative to language structure than boys, regardless of group. Hartley and Sikora (2009) also found more communication deficits, and Carter et al. (2003) found more social and communication deficits, in girls compared to boys, although both of these studies examined younger children (1.5 to 3.9 years). The finding of more inappropriate verbal initiations, more autistic interests, and poorer pragmatic language skills in boys than in girls with ASD provides some evidence that impairment in boys with

ASD may be more behaviourally obvious than in girls. These gender findings in relation to communication were not specific to the ASD group, but were also reflected in the TYP group, indicating that these gender differences may reflect differences present in the general population.

As hypothesised, boys exhibited more repetitive motor movements than girls with ASD. This gender difference was also present in the TYP group, again indicating this finding was not unique to the ASD phenotype. Importantly, having more repetitive motor movements could make boys impairment more behaviourally noticeable than girls with ASD. There were not significant differences on the other repetitive behaviour scales or on the total score, and potentially the sample size lacked power to detect more subtle differences, given findings of more repetitive and stereotyped behaviours in other studies (Hartley & Sikora, 2009; Hattier, Matson, Tureck & Horovitz, 2011; Mandy et al., 2011; Sipes, Matson, Worley, Kozlowski, 2011; Wing, 1981). Overall, in regards to autistic symptoms, the present findings indicate similar levels of social symptoms in girls and boys with ASD, but with some specific aspects of communication and repetitive behaviours showing more impairment in boys. These gender differences mirrored that found in the typically developing group and hence were not specific to ASD. Of course, the causes of these differences can only be speculated upon in this study. These differences could be due to genetic or biological differences in the development of girls and boys. However, these differences could equally be due to the different socialization of boys and girls.

The hypothesis that boys would exhibit more hyperactive-impulsive behaviours than girls was also supported. This finding is consistent with other studies which have found more hyperactive behaviours in boys than in girls with ASD (Mandy et al., 2011) but not others (Brereton, Tonge, & Einfeld, 2006; Gadow, et al., 2005). This finding mirrors the gender profile often observed in referred ADHD samples (Biederman, et al, 2000; Gershon, 2002)

where girls present with less hyperactive-impulsive symptoms and therefore may be underrepresented in clinical settings, and hence, under diagnosed. However, there have also been findings of *more* difficulties in cognitive inhibition in girls than in boys with ASD (Lemon, Gargaro, Enticott & Rinehart, 2011). Hence, behaviourally reported symptoms may not correspond to cognitive deficits, and factors such as rater bias needs to also be considered.

When the relationship between age and ADHD symptoms was examined it was found that younger boys with ASD had much higher parent reported levels of hyperactivity-impulsivity than younger girls with ASD. This difference was not reflected in the TYP group with the younger boys showing similar levels of hyperactivity to the younger girls. Older boys and girls with ASD had more similar levels of hyperactivity, with boys exhibiting slightly more symptoms. This was similar to the older TYP group. This finding indicates that boys with ASD may show a decrease in hyperactivity symptoms with age, which is typically found in boys with ADHD (Biederman, et al., 2000; Monuteaux, et al., 2010). However, this relationship was not found for girls with ASD which indicates levels of hyperactivity-impulsivity may remain more persistent, but at lower levels for girls than boys, across this age range. The finding of more hyperactivity in younger boys was in contrast to Mandy et al (2011) who found no age changes, however, they used a combined inattention and hyperactivity construct which may obscure age related changes, given inattention may not be as remittent as hyperactivity. Boys were also found to show more inattention on the SWAN scale, but not the Conners 3 scale. The different findings between the measures may relate to the SWAN being more sensitive with a 7 point scale and based on a normal distribution compared with the Conners 3. The finding of more inattention in boys was not dependent on group, again indicating a more general population difference. There was no decline with age for inattention symptoms in the sample, indicating persistent levels of difficulties with inattentive behaviours in children with ASD over this age range.

A limitation of this study is the sample size of approximately 30 in each group, as there may not have been enough statistical power to detect subtle differences between groups. However, this sample of girls is still larger than a number of prior studies (Holtman et al., 2001; McLennon et al., 1996; Lai et al. 2011, Solomon et al., 2011; Pilowsky et al., 1998) and has employed a narrower age range. It is also important to note the large number of comparisons in the current study which were not corrected with Bonferroni adjustments, therefore, some findings may be Type II errors. Hence, our findings should be interpreted with caution and we have included *p* levels to indicate the strength of the findings. Children in this study were also clinically referred and hence may be more severely impaired and show a different pattern of difficulties than a non-referred sample. Furthermore, this sample is cross-sectional, therefore, the changes with age need to be confirmed in a longitudinal study. Finally, this study has used parent reports of symptoms which may be biased by parental expectations based on gender stereotypes. For example, parents may rate girls as having fewer repetitive behaviours and better social-communication ability, in line with common gender expectations of these behaviours in girls (McLennon, et al., 1996).

In summary, girls and boys with ASD showed similar social difficulties but boys were reported to have more repetitive motor movements, and communication impairments. These differences reflected typical population differences rather than being unique to the autism phenotype. This highlights the importance of including a typically developing comparison group when conducting research into gender differences in this field. Hyperactivity-impulsivity appears to show an age-gender profile in ASD: younger boys were significantly more hyperactive than younger girls, a pattern not present in younger typically developing boys and girls. Inattention levels were persistent in both boys and girls with ASD across this age range. Clinicians need to be aware of the particularly high levels of hyperactivity in younger males with ASD and appropriately treat and manage these symptoms. The proposed

change in the DSM-5 to allow a comorbid diagnosis of ADHD in ASD may assist in this regard. Notably, high levels of hyperactivity in younger males may prompt clinical assessment. Combined with the subtle gender differences in communication and repetitive behaviours found in this study, these factors could partially contribute to more high-functioning early school-aged boys than girls being referred and subsequently diagnosed with an ASD. These findings call for future work on gender differences in ASD to move beyond core autistic symptomology, to more fully elucidate other factors like attentional profiles, that may result in gender-based referral bias and the under representation of girls with ASD.

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Monash University

Declaration for Thesis Chapter 3

In the case of Chapter 3, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Project design, review of relevant literature, attainment of ethics approval, recruitment and all testing of research participants, analysis of data and writing of manuscript.	70%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	**Nature of contribution**
Prof. Nicole Rinehart	Contributed to project design and provided input during final draft stage of manuscript.
Prof. Kim Cornish	Contributed to project design and provided input during final draft stage of manuscript.

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work*.

Candidate's Signature		**Date**
Main Supervisor's Signature		**Date**

*Note: Where the responsible author is not the candidate's main supervisor, the main supervisor should consult with the responsible author to agree on the respective contributions of the authors.

Chapter 3 – Gender differences in symptoms over time

Preamble to Paper 2

Chapter 2 considered gender differences in ASD and ADHD symptoms, revealing few gender differences in autistic symptoms. Boys with ASD experienced higher levels of hyperactivity than girls, particularly younger boys, based on a cross-sectional design. The focus of this paper is on determining any gender differences in ASD symptoms, and internalizing and externalizing symptoms *over two time points* one year apart in high-functioning children with ASD. This longitudinal approach will provide important information regarding the developmental trajectories of symptoms over time and whether these may differ by gender. Secondly, the paper aimed to examine any gender differences in school placement and school support in high-functioning children with ASD. This is an area that has received little attention in the literature but may provide indications as to how gender might interact with behaviour to impact on access to educational support. This paper has been published in the Journal of Autism & Developmental Disorders.

May, T., Cornish, K., & Rinehart, N.J. (Submitted) Does gender matter? A one year follow-up of autistic, attention and anxiety symptoms in high-functioning children with Autism Spectrum Disorder.

Paper 2: Does gender matter? A one year follow-up of autistic, attention and anxiety symptoms in high-functioning children with Autism Spectrum Disorder

Abstract

Gender differences in Autism Spectrum Disorder (ASD) symptoms and associated problem behaviours over development may provide clues regarding why more males than females are diagnosed with ASD. Fifty-six high-functioning children with ASD, and 44 controls (TYP), half of the participants female, were assessed at baseline (aged 7-12 years) and one-year later, collecting measures of autism, attention and anxiety symptoms, school placement and support information. Findings indicated no gender differences in autistic symptoms. Males were more hyperactive and received more integration-aide support in mainstream schools, and females were more socially anxious. Overall, similar gender profiles were present across two time points. Lower hyperactivity levels in females might contribute to their under-identification. Implications are discussed using a biopsychosocial model of gender difference.

Key words: gender, autism spectrum disorder, attention, anxiety, girls

Recently there has been an emergence of cross-sectional research focusing on gender differences in Autism Spectrum Disorder (ASD; Mandy et al., 2011; Rivet & Matson, 2011; Solomon, Miller, Taylor, Hinshaw, & Carter, 2011). This research has been driven by the consistent finding that significantly more males are diagnosed with ASD, with an average gender ratio of 4.3 males to 1 female. This ratio varies by IQ with a 5.75:1 ratio in cognitively high-functioning children (full-scale IQ >=70) versus 1.9:1 in low-functioning ASD (full-scale IQ<70; Fombonne, 2003). Although many theories for this disproportionality exist, spanning biological (Baron-Cohen, 2002; 2007; Skuse, 2005), psychological (McLennan, Lord, & Schopler, 1993) and social paradigms (Holtmann, Bolte, & Poustka, 2007; Kopp & Gillberg, 1992), none has provided a definitive answer. With increased agreement on the definition of ASD, and improvement in case detection, recent studies are identifying more high-functioning females (Zwaigenbaum et al., 2012). This gives credence to the notion that females with ASD may have been previously under-identified (Kopp & Gillberg, 1992). Whether this possible under-identification relates to differing gender profiles of symptoms and associated problem behaviours is unclear, given past mixed findings and the small number of females actually examined (Thompson, Caruso, & Ellerbeck, 2003). There is need for further examination in this area using well-defined samples regarding factors like age and IQ.

Past mixed findings of gender differences in autistic symptoms

Most ASD gender studies have investigated differences in core autistic symptoms. ASD is currently diagnosed using observable behaviours in three core areas: communication abnormalities, like stereotyped speech; social deficits including a lack of emotional reciprocity; and patterns of rigid and repetitive behaviours such as stereotyped motor mannerisms (APA, 2000). Symptoms may be more severe when combined with intellectual disability (Matson & Shoemaker, 2009) and may change across development (Seltzer et al.,

2003), hence these factors require consideration when examining gender. In studies limited to *high-functioning* children, few differences emerge. An early cross-sectional study showed females had fewer social difficulties pre-puberty and poorer social functioning post-puberty (McLennan, Lord, & Schopler, 1993). However, study limitations included a small sample (21 females), broad age range (6-36 years), and including participants with lower-IQ (nonverbal IQ>=60). Holtman and colleagues (2007) examined 23 high-functioning females (aged 7-20 years) similarly finding more social difficulties, particularly in older girls. However, the sample was also relatively small across a wide age range. Solomon and colleagues (2011) examined 20 high-functioning girls aged 8-18 years, finding no gender differences in autistic symptoms. Similarly, Rivet and Mason (2011) found no gender differences in the triad of autistic symptoms in 37 boys and girls, aged 3-17, with ASD. Hence, in high-functioning children there exist some mixed findings in social difficulties, but little evidence of differences in repetitive behaviours and communication. Potentially, associated difficulties commonly occurring in high-functioning ASD, like disruptive behaviours, could differ between boys and girls prompting gender differences in clinical referral.

Equivocal findings of gender differences in internalising and externalising behaviour

There are varied findings regarding whether the typical gender differences in rates of internalising and externalising disorders exist in ASD. Boys are more likely to experience externalising disorders such as Attention Deficit Hyperactivity Disorder (ADHD) and Oppositional Defiant Disorder (APA, 2000). Along these lines, studies have shown more hyperactive behaviours in high-functioning boys with ASD (May, Cornish, & Rinehart, 2012), but no gender differences in cognitively low-functioning children (Brereton, Tonge, & Einfeld, 2006) or combined samples of low and high IQ (Gadow, Devincent, Pomeroy, & Azizian, 2005; Mandy et al., 2011; Simonoff et al., 2008). These differences may relate to IQ

or the age range employed given hyperactivity declines in adolescence (Biederman, Mick, & Faraone, 2000). Oppositional behaviour appears to occur at similar rates in low-functioning boys and girls with ASD contrary to the typical gender finding (Gadow et al., 2005), with this area yet to be examined in high-functioning children.

For internalising symptoms in typical development, anxiety disorders affect boys and girls at similar rates during childhood, with females experiencing twice the rate of males from adolescence (APA, 2000). Low-functioning males and females with ASD across childhood, adolescence and adulthood have generally shown similar levels of anxiety (Brereton et al., 2006; Gadow et al., 2005). One cross-sectional study found more anxiety in high-functioning girls with ASD during adolescence but not childhood (Solomon et al., 2011), suggesting that the typical gender developmental trajectory of anxiety may be present. Longitudinal studies are needed to confirm this finding.

Few longitudinal studies of gender differences

Symptom severity and expression may change throughout development due to changing demands in the social environment, pubertal biological changes and the impact of psychological factors. This could contribute to some mixed findings in studies to date and presents a challenge in understanding this area. Unfortunately there have been few longitudinal studies which have tracked gender profiles over development in ASD. Longitudinal studies have shown better social ability in samples of mostly cognitive low-functioning girls prior to puberty but poorer functioning post-puberty (Gillberg & Steffenburg, 1987) and into adulthood (Billstedt, Gillberg, & Gillberg, 2005). Generally females with ASD appear to have poorer outcomes than males, but most females examined have been low-functioning (Burd et al., 2002; Gillberg & Steffenburg, 1987; Howlin, Goode, Hutton, & Rutter, 2004). Howlin and colleagues (2004) found poorer outcomes in seven females followed into adulthood, including both low and high-functioning, in schooling,

employment and independent living, compared with males. Along these lines, Migliore and colleagues (2012) examined employment and post-secondary outcomes in a large sample of youth with ASD (2,455 male, 458 female), finding that being male was associated with achieving employment, being paid more per hour, and working more hours. Collectively, a poorer outcome for females with ASD is indicated, yet few high-functioning females have been longitudinally tracked.

Gender factors in educational placements and support

These findings of poorer life outcomes raise questions regarding whether early educational opportunities for females and males with ASD are equivalent given the association between education and life outcomes. Yet questions such as whether there is gender parity in access to educational support in ASD have rarely been examined (although this question has been asked in special education more generally, see Wehmeyer & Schwartz, 2001). One study found no gender differences in the education placements of 92 boys and 11 girls with ASD (White et al., 2007). Another examined characteristics which influenced placement within regular classes in 66 boys and 11 girls (Yianni-Coudurier et al., 2008). Girls had higher levels of placement in regular classes. This could indicate that girls receive less support. Importantly, these studies examined very few females, hence, whether there is gender equity in access to education placement and support is unclear.

The present study aimed to address a gap in the literature by tracing the developmental trajectories of a well-matched group of elementary school-aged girls and boys with high-functioning ASD over one year. The study builds on cross-sectional findings by employing a one year follow-up of autistic symptoms, internalising and externalising behaviours (May et al., 2012). Firstly, given the few differences in autistic symptoms found in high-functioning children, it was hypothesised that boys and girls with ASD would have similar levels of repetitive behaviours, social difficulties and communication impairment. Secondly, it was

predicted there would be no gender difference in oppositional behaviours or anxiety given the age range of this sample and past findings of parity (APA, 2000; Gadow et al., 2005). It was predicted there would be higher levels of hyperactivity in males than females but that this difference would also be present in typically developing children. Thirdly, given a pattern of females experiencing poorer outcomes over time, it was hypothesised that females with ASD would show a worsening of social symptoms over the year. Finally it was hypothesised that boys and girls with ASD who were matched on age and cognitive functioning would have similar educational placements and funding for integration-aide support.

Method

Participants

At baseline 124 children were recruited, 64 children with ASD (32 male and 32 female) and 60 typically developing children (TYP; 30 male, 30 female), aged between 7-12 years. The DSM-IV-TR criteria for Autistic Disorder or Asperger's Disorder was confirmed for ASD participants using our standard process involving review of diagnostic reports from registered psychologists and paediatricians with a symptom checklist to ensure DSM-IV-TR criteria were fulfilled. In addition, all ASD participants were screened and confirmed to be within the clinical range on the Social Responsiveness Scale (SRS) parent report (Constantino, 2002). ASD participants were recruited through the Monash University Centre for Developmental Psychology and Psychiatry, the Autism Victoria 'Get Involved' volunteer register, and from private clinics in the Melbourne metropolitan area. Only children with a full-scale IQ of 70 and above were included. TYP children were recruited from a Melbourne primary school. No TYP children had prior history of parent or teacher reported developmental disability or psychopathology. Children were excluded if they had a history of brain injury or any genetic disorders (such as Fragile X syndrome).

At Time 2, 56 children in the ASD group were reassessed (28 males and 28 females), a drop-out rate of 12.5%. Fifty-five TYP children were reassessed at Time 2 (29 males and 26 females), a drop-out rate of 8.3% percent. Drop-out was due to inability to contact families, or because parents indicated they were too busy to participate. Complete parent reports were returned for all 56 children with ASD and 45 TYP children.

Measures

Intellectual functioning. For children with ASD the Wechsler Intelligence Scale for Children IV (WISC-IV; Wechsler, 2005) Australian versions was used, and the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) was completed for TYP children. The WASI full-scale IQ is comparable with the WISC-IV full-scale IQ, the WASI Verbal IQ is comparable with the WISC-IV Verbal Comprehension Index, and the WASI Performance IQ is comparable with the WISC-IV Perceptual Reasoning Index (Wechsler, 1999).

Parent-rated Autistic Symptoms. The SRS is a 65-item questionnaire to assess social awareness, social information processing, capacity for reciprocal social communication, social anxiety/avoidance, and autistic preoccupations and traits in children aged 4-18 years (Constantino, 2002). It has acceptable levels of internal consistency (.93-.97) and test-rest reliability (.77-.85). Parents use a four-point rating scale for symptom severity. The Children's Communication Checklist-2 (CCC) is a 70-item parent report which assesses children's communication abilities (Bishop, 2003). The device screens for language and pragmatic impairment. Higher scores indicate less impairment. The General Communication Composite (CCC-GCC) identifies children at risk of language problems. The Social Interaction Deviance Composite (CCC-SIDC) indicates a communication profile characteristic of autism (better developed language structure and syntax compared with pragmatic language). Subscale reliability estimates range from .66 to .80. The Repetitive Behaviour Questionnaire II (RBQ) determines the presence of repetitive behaviours in children based on the ICD-10 criteria for autism (Leekam et al., 2007). Parents answer 20

questions using a three-point rating scale. Internal consistency for the 20 items was reported to be .85.

Parent-rated ADHD Symptomatology. The Conners 3rd Edition (Conners, 2003) is a standardized screening instrument for ADHD. The parent short form consists of 43 items, measuring indices of oppositional/aggressive behaviour problems, hyperactivity-impulsivity, inattention, learning problems, executive functioning difficulties and peer relationships in 3-17 year olds. Test-retest reliability ranges from .71 to .98 and internal consistency ranges from .77 to .97 (Conners, 2003).

Parent-rated Anxiety. The Spence Children's Anxiety Scale is a 38-item questionnaire assessing six anxiety domains using DSM-IV criteria: generalized anxiety, panic/agoraphobia, social phobia, separation anxiety, obsessive compulsive disorder and physical injury fears (Spence, 1998). A four-point rating scale is used. Test-retest reliability has been shown to be satisfactory (Nauta et al., 2004).

Parent-rated Family Psychopathology. The Family Assessment Device questionnaire assesses psychopathology in a family using a four-point rating scale (Epstein, Baldwin, & Bishop, 1983). The general family functioning scale consists of 12 items and was utilised in this study as a measure of family psychopathology. Higher scores indicate greater psychopathology.

Procedure

The study was approved by Human Research Ethics Committees of Monash University and the Ethics Committee of the Victorian Government Department of Education and Early Childhood. Parents received an explanatory statement, provided written informed consent and children provided assent. Participation was voluntary and participants did not receive any monetary reward for participation other than reimbursement of travel costs.

At Times 1 and 2, parents of participants were invited to participate via email or letter and follow-up telephone call. Participant's cognitive functioning was individually assessed at Time 1 only via home visit, at Monash University, or at their primary school. Parents completed questionnaires and were also asked about their child's school placement and

whether they had received funding to access integration-aide support at school over the past year. All data were entered into Statistical Package for the Social Sciences (SPSS) version 21.0 for statistical analyses

Analyses

Data was assessed for outliers and normality of distributions. Where transformations did not improve distributions, raw data was entered into analyses. To reduce the likelihood of Type I errors, an alpha level of .01 was set given the large number of comparisons. Only differences at or below this level were considered significant. Analysis of Variance (ANOVA) and Chi Square tests of independence were used to compare group differences in demographic data. Repeated Measures Analysis of Covariance (ANCOVA) were employed to examine group and gender differences in variables over time controlling for any demographic factors which differed between groups. Pearson correlations were used to examine relationships between variables.

Results

Demographics

ANOVAs indicated higher full-scale IQ, $F(1,96)=19.020$, $p<.001$, and verbal IQ, $F(1,96)=10.268$, $p=.002$, in TYP children, but no gender differences or interactions. The groups were matched on perceptual IQ, age, and months between Time 1 and 2 assessments (ASD, $M=12.96$, $SD=1.11$; TYP, $M=12.67$, $SD=0.89$), with no gender differences or interactions for these analyses. There was no difference in the number of boys and girls medicated at Time 1 (girls, 5/28; boys 4/28) and Time 2 (girls, 9/28; boys, 7/28). There was no significant difference in parent education between males with ASD, females with ASD, TYP females or TYP males, $X^2(12, N=100)=12.521$, $p=.405$. Socioeconomic status was calculated based on postcode using the Australian Bureau of Statistics Socio-Economic Index of Areas data (ABS SEIFA; 2006). ANOVA revealed children with ASD had higher SES

levels than TYP children, $F(3,99)=26.941$, $p<.001$, with no gender differences or interactions. On the Family Assessment Device, there was a significant main effect of time, $F(1,95)=7.692$, p=.007, indicating greater family difficulties over time. The ASD group had higher levels of family psychopathology, $F(1,95)=20.807$, $p<.001$, with no gender differences or interactions.

Table 1

Time 1 Demographic and symptom variables for the TYP and ASD groups by Gender

	ASD		TYP	
	Girls	Boys	Girls	Boys
	N=28	N=28	N=19	N=25
Age (months)	116.5(22.4)	120.6(23.2)	115.4(19.1)	104.2(17.9)
Full-scale IQ	95.6(11.3)	96.7(14.7)	104.8(11.8)	109.7(12.0)
Verbal IQ	99.25(13.3)	98.5(15.3)	104.7(8.9)	109.2(10.0)
Perceptual IQ	95.7(13.1)	104.6(15.8)	104.7(16.4)	106.8(13.3)
Mother's Education				
Some high school	21%	14%	5%	12%
High School Graduate	21%	18%	47%	32%
Some University	25%	32%	21%	24%
Bachelor Degree	18%	10%	21%	24%
Post-Graduate Degree	14%	25%	5%	8%
Father's Education				
Some high school	25%	28%	42%	32%
High School Graduate	21%	14%	10%	12%
Some University	10%	10%	5%	24%
Bachelor Degree	28%	25%	36%	16%
Post-Graduate Degree	14%	21%	5%	16%
SES score	1061(73)	1038(73)	988(33)	990(22)
Ethnicity				
Australian	100%	82%	74%	92%
European	0%	14%	21%	4%
Asian	0%	4%	5%	4%

ASD, Autism Spectrum Disorder; TYP, Typically Developing

Table 2

Symptom variables for the TYP and ASD groups by Gender

Variable	*Time 1*				*Time 2*			
	ASD		TYP		ASD		TYP	
	Girls N=28	Boys N=28	Girls N=19	Boys N=25	Girls	Boys	Girls	Boys
SRS Total	92.75(30.21)	102.93(17.79)	21.21(11.89)	23.48(15.57)	87.04(32.28)	90.25(22.44)	18.59(12.25)	20.60(11.53)
RBQ Total	34.19(8.13)	38.71(8.09)	22.68(4.42)	23.48(3.23)	33.48(8.85)	35.60(6.55)	21.63(2.39)	22.04(1.43)
CCC-GCC	38.93(14.70)	30.50(14.02)	82.63(23.67)	83.79(16.65)	43.30(19.38)	31.61(14.19)	85.26(17.40)	86.92(17.53)
CCC-SIDC	-4.00(8.46)	-8.43(10.03)	3.89(8.81)	-1.25(7.38)	-6.00(10.43)	-7.25(8.98)	2.95(7.44)	0.83(8.40)
Conners-3 Inattention	7.50(2.90)	9.79(3.24)	2.32(2.19)	2.64(2.52)	7.57(3.80)	9.21(3.41)	2.37(2.31)	2.20(2.47)
Conners-3 Hyperactivity	6.14(4.14)	10.32(4.31)	1.79(1.61)	2.64(2.04)	6.50(4.90)	9.00(4.41)	1.12(1.20)	1.76(1.67)
Conners-3 Aggression	1.93(2.29)	2.50(2.78)	0.53(0.84)	0.84(1.68)	2.29(2.99)	2.57(3.67)	0.58(0.77)	0.84(1.40)
Conners-3 Executive Functioning	7.82(3.15)	8.89(3.77)	3.42(2.85)	3.12(2.65)	8.86(3.40)	9.11(3.72)	2.74(1.76)	2.20(1.83)
Conners-3 Learning Difficulty	5.57(3.04)	6.29(3.39)	1.79(1.90)	1.28(2.03)	5.61(3.23)	5.71(3.67)	1.79(2.25)	1.08(1.73)

Conners-3 Peer Relationships	6.04(4.20)	8.07(3.89)	1.11(1.33)	1.12(2.30)	6.18(4.33)	7.54(4.12)	0.89(1.05)	1.48(2.67)
Family Functioning*	1.94(0.69)	2.02(0.48)	1.43(0.45)	1.46(0.34)	2.01(0.68)	2.04(0.56)	1.52(0.54)	1.48(0.39)
SCAS Total	28.86(12.91)	28.36(12.77)	15.68(5.89)	11.69(6.48)	30.29(13.31)	25.61(10.51)	16.16(6.60)	11.50(5.66)

*Significant difference between Time 1 and Time 2

ASD, Autism Spectrum Disorder; TYP, Typically Developing; SCAS, Spence Children's Anxiety Scale; SRS, Social Responsiveness Scale; RBQ, Repetitive Behaviours Questionnaire; CCC, Children's Communication Checklist; GCC, Global Communication Composite; SIDC, Social Interaction Deviance Composite

Autism Symptoms

Repeated measures ANCOVA controlling for full-scale IQ, with time as the repeated measure, and group and gender as between subjects factors were computed for the total scores of the SRS, RBQ and CCC-GCC and CCC-SIDC. For the RBQ and CCC, data were missing for one girl with ASD. Children with ASD had more impairment than TYP children on the SRS, $F(1,95)=47.524$, $p<.001$, RBQ, $F(1,94)=94.770$, $p<.001$, CCC-GCC, $F(1,95)=174.255$, $p<.001$, and CCC-SIDC, $F(1,95)=31.410$, $p<.001$. There were no main effects of gender or time, and no interactions between the factors for the three scales.

Externalising Symptoms

Repeated measures ANCOVA controlling for full-scale IQ, with time as the repeated measure and group and gender as the between subjects factor were computed for the Conners 3 subscales. The ASD showed more impairment than the TYP group for inattention, $F(1,95)=89.454$, $p<.001$, learning problems $F(1,95)=36.146$, $p<.001$, executive functioning, $F(1,95)=100.449$, $p<.001$, aggression, $F(1,95)=11.045$, $p=.001$, and peer relationships, $F(1,95)=71.637$, $p<.001$. There were no main effects of gender or time, and no interactions between the factors. For hyperactivity-impulsivity there was a main effect of group with the ASD group having more impairment, $F(1,95)=74.057$, $p<.001$, $\eta_P^2=0.438$, and as predicted, a main effect of gender, with males having more impairment, $F(1, 95)=10.381$, $p=.002$, $\eta_P^2=0.099$, and no main effect of time or interactions between the factors.

Internalising Symptoms

Repeated measures ANCOVA controlling for full-scale IQ, with time as the repeated measure and group and gender as the between-subjects factor were computed for the SCAS total score and subscales. There were no main effects of time or gender and no interactions, but significant group differences in Separation Anxiety, $F(1,95)=19.041$, $p<.001$, OCD, $F(1,95)=40.101$, $p<.001$, Panic/Agoraphobia, $F(1,95)=28.300$, $p<.001$, Generalised Anxiety

$F(1,95)=32.663$, $p<.001$, and for the Total score, $F(1,95)=44.976$, $p<.001$, with the ASD group having more symptoms than the TYP group. There was a main effect of gender for Social Anxiety, with females reported to have more impairment, $F(1,95)=10.452$, $p=.002$, $\eta_P^2=.099$, (Time 1 females $M=6.04$ $SD=3.55$; males $M=4.47$ $SD=3.00$; Time 2 females $M=6.91$ $SD=3.83$; males $M=4.36$ $SD=2.61$). There was more Social Anxiety in the ASD group, $F(1,95)=11.791$, $p=.001$, $\eta_P^2=.119$, with no interactions. The group difference in Physical Injury Fears only approached significance, $F(1,95)=6.021$, $p=.016$, with no main effects of gender or time and no interactions.

School Placement and Support

The school attendance for the high-functioning children with ASD is shown in Table 3, with most students attending mainstream state or private schools. Two boys with normal IQ attended special schools. A Chi Square test of independence indicated no gender difference in school type attended by children with ASD, $X^2(4, N=56)=3.413$, $p=.491$. Despite a similar profile of school type, there was a significant gender difference in the number of children receiving an teacher/integration-aide in these school settings. Only 4 of 25 girls (16%) compared with 13 of 25 boys (52%) received a teacher's aide which was significant, $X^2(1,N=50)=7.219$, $p=.007$, $\phi=.380$. This disparity was particularly evident in mainstream private schools where 66% of boys with ASD received aide support, compared with 8% of girls.

Table 3

Frequencies of school type and aide support for boys and girls with Autism Spectrum Disorder

	Mainstream State	Mainstream Private	Special School	Behavioural School	Home School
Males (N=28)	13 (5 aided)	12 (8 aided)	2	1	0
Females (N=28)	12 (3 aided)	13 (1 aided)	0	2	1

Pearson correlations were used to determine which factors from Time 1 (SRS, CCC, RBQ, SCAS, Conners 3, IQ, age, and medication) were associated with aide support. Aide support correlated with gender, r=.380, p=.006, r^2=.144, and hyperactivity, r=.363, p=.009, r^2=.132.

Discussion

Recently there has been an increase in the number of studies examining girls with ASD, yet few longitudinal studies track gender differences over time, particularly in high-functioning children. The present study followed elementary school-aged high-functioning girls and boys with ASD at baseline and one year later to compare gender differences in trajectories of symptoms and behaviour problems. The study found boys and girls with ASD were similar over a year of development in parent-reported autistic symptoms, inattention, aggression/defiant behaviour, learning problems, peer relationships, executive functioning and overall levels of anxiety. Males were reported to have higher levels of hyperactivity; females had more symptoms of social phobia. These gender differences were not specific to

ASD and were also present in the TYP group. One disparity was found with regard to integration-aide support at school, with significantly more males than females receiving this service. Collectively, these findings indicate a largely similar trajectory of symptoms in elementary school aged boys and girls with ASD.

Our first aim was to examine gender differences in the core autism symptoms, with predictions being supported given no gender differences in social ability, repetitive and stereotyped behaviours, and communication. This corresponds with other studies which have similarly found no differences in these areas in high-functioning children with ASD (Rivet & Matson, 2011; Solomon et al., 2011). Studies which have found differences in these areas have included low-functioning participants across wider age ranges (Holtmann et al., 2007; Mandy et al., 2011; McLennan et al., 1993; Wing, 1981). Hence, age range and IQ level appear to be important factors regarding gender and autistic symptoms and highlight the importance of longitudinal studies.

Our second aim was to examine gender differences in the development of symptoms over time. Stability over a year was found with no change in autism symptom severity for boys and girls. This stability was not predicted with a worsening of social deficits in females over the period expected as per other studies (Gillberg & Steffenburg, 1987; Holtmann et al., 2007; McLennan et al., 1993). However, as some of the sample was pre-pubescent at Time 2, a longer time interval may be required to observe this decline, or it may not occur in high-functioning females.

Our third aim was to examine gender differences in externalising and internalising symptoms over time. As hypothesised, there was no difference in oppositional behaviours in males and females with ASD over two time points. This is similar to past findings in samples including participants with IQs in the low-functioning range (Gadow et al., 2005). Although oppositional behaviours are more frequent in boys than girls in the general population, this

trend does not appear to be present in ASD. This could be due to social impairment combined with inhibition and communication difficulties having similarly impediment for boys and girls (Guttmann-Steinmetz, Gadow, & DeVincent, 2009). There were also no gender differences in the other areas of inattention, executive functioning, and learning problems over time. However, as predicted, males with ASD were reported to have more hyperactive behaviours than females. This difference was not specific to ASD and reflected a gender difference in the TYP group. Again, this difference in hyperactivity contradicts some past studies (Brereton et al., 2006; Gadow et al., 2005; Simonoff et al., 2008), however, the unique age range of the present study may explain the difference given the other studies have included adolescents and adults and it is well-established that hyperactivity decreases into adolescence (Biederman et al., 2000). Also, past studies have included participants with IQs in the low-functioning range.

Regarding internalising symptoms, as predicted, males and females had similar levels of overall parent-reported anxiety. However, there was more parent-reported social phobia in females. This finding was not specific to the ASD group and reflected a gender difference present in typical children. As some children were entering adolescence by Time 2, this finding may be consistent with the greater emergence of anxiety in females around this developmental period. There were no statistically significant findings regarding a worsening of anxiety over time in females, however, an examination of the mean scores for anxiety shows that females had higher levels after one year with males having similar or fewer symptoms. Hence, a longer time period may reveal that females with ASD also experience the typical female gender trajectory of anxiety increase after childhood (APA, 2000).

The final aim was to examine any gender differences in educational placements and supports. The school setting was similar for boys and girls with ASD with the majority attending state or private mainstream schooling and no gender differences. For students

attending mainstream schooling, significantly fewer girls than boys received integration-aide support, despite similar cognitive profiles and similar behavioural problems including oppositional/aggressive behaviour. We have previously reported no gender differences in the same group of participants for academic measures of reading and mathematics attainment and cognitive measures of sustained attention and attentional switching (May et al., 2013). Hence, different academic performance or executive functioning cannot explain this gender disparity. Hyperactivity, which was more prominent in boys, explained around 13% of aide support, with no other measures being significantly associated. Other unmeasured factors must therefore be involved. One speculative social factor could be a gender bias where females are less likely than males to either apply for or receive, integration aide funding.

The gender differences found in the psychological variables of hyperactivity and social phobia can be explored using a biopsychosocial model. Higher levels of hyperactivity in males and anxiety in females could be due to biological differences. As these variables were based on subjective parent report, differences could be due to sociocultural influences including the gender stereotype of males being more active and strong and females as more passive and anxious (Levy et al., 2005; McLennan et al., 1993). Parents may view and shape their child's behaviour through these stereotypes. For example, children may actually have similar levels of these behaviours but parents could conceivably be more inclined to report their child's symptoms to fit with gender stereotypes. At the psychological/behavioural level, differences in the behaviour of girls and boys, such as males exhibiting more hyperactive behaviour may prompt a referral bias such that more males are referred to clinics than are females, as their problem behaviours are more disruptive to carers and teachers (Levy et al., 2005). This may contribute to more identified cases of males with ASD.

These findings are limited by the clinically-referred sample. It will be important for population-based, non-referred samples of children with ASD to be examined with respect to

factors such as educational placements and supports. Given fewer cognitively high-functioning females are identified than low-functioning, the study purposely explored the characteristics of this group, however, the present findings may not generalise to low-functioning children. The study was also limited by the time between assessments with few changes emerging over one year.

These findings have important implications for clinicians, educators and parents. Potentially, girls without hyperactivity could be overlooked for assessment and educational support in mainstream classrooms despite largely similar cognitive, academic and behavioural profiles to boys. Parents, teachers and clinicians should be cognisant of this possibility when assessing and creating management plans for girls with ASD. Findings indicate that social anxiety may be particularly pronounced in girls with ASD, which requires identification and management. Similarly, hyperactivity in boys with ASD is likely to be pronounced. The new DSM V which allows for dual diagnosis of ASD and ADHD will in part facilitate this awareness and appropriate treatment. Generally however, clinicians and educators should expect the core symptoms of autism to be similarly common and severe in high-functioning elementary school-aged boys and girls with ASD. Perhaps this understanding itself, rather than viewing ASD as a male condition, may contribute to more accurate identification of females with ASD.

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Monash University

Declaration for Thesis Chapter 4

In the case of Chapter 4, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Project design, review of relevant literature, attainment of ethics approval, recruitment and all testing of research participants, analysis of data and writing of manuscript.	70%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	Nature of contribution
Prof. Nicole Rinehart	Contributed to project design and provided input during final draft stage of manuscript.
Prof. Kim Cornish	Contributed to project design and provided input during final draft stage of manuscript.
Dr. Russell Conduit	Contributed to project design and provided input during final draft stage of manuscript.
Prof. Shantha Rajaratnam	Provided input during final draft stage of manuscript.

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work*.

Candidate's Signature		**Date**
Main Supervisor's Signature		**Date**

*Note: Where the responsible author is not the candidate's main supervisor, the main supervisor should consult with the responsible author to agree on the respective contributions of the authors.

Chapter 4 – Gender differences in sleep disturbance

Preamble to Paper 3

The previous two chapters of this thesis have focused on determining any gender differences in ASD symptoms, internalizing and externalizing symptoms, using cross-sectional and longitudinal designs. Comorbid neurological problems including epilepsy (Amiet et al., 2008), motor deficits (Rinehart, Bradshaw, Brereton, & Tonge, 2001; Rinehart et al., 2006) and sleep difficulties (Richdale, 1999) are also present in ASD (Jeste, 2011). For example, epilepsy occurs in around 21% of ASD cases with comorbid intellectual disability and around 8% of cases without (Amiet et al., 2008). Importantly, epilepsy occurs more often in females with ASD than males, with the cause of this gender difference undetermined (Amiet et al., 2008; Saemundsen, Ludvigsson, Hilmarsdottir, & Rafnsson, 2007). Motor difficulties including subtle deficits in gait profiles in children with ASD have also found, although gender differences are yet to be examined (Rinehart et al., 2001; Rinehart et al., 2006). Clinically significant sleep disturbance is also experienced in around 40 to 80% of children with ASD (Liu, Hubbard, Fabes, & Adam, 2006). Few past studies of sleep in ASD have examined the influence of gender; hence, the profile of sleep disturbance in girls with ASD is largely unknown. The trajectory of sleep disturbance over time in ASD is another area yet to be extensively studied. Therefore, the aim of the third paper is to determine any gender differences in the clinical presentation of sleep disturbance in high-functioning children with ASD. The paper also aimed to examine the developmental trajectory of sleep and inter-relationships with behaviour problems over two time points. This paper has been accepted for publication in *Behavioral Sleep Medicine*.

May, T., Cornish, K., Conduit, R., Rajaratnam, M.W., & Rinehart, N.J. (In press). Sleep in High-Functioning Children with Autism: Longitudinal Developmental Change and Associations with Behaviour Problems, *Behavioural Sleep Medicine*.

Paper 3: Sleep in High-Functioning Children with Autism: Longitudinal Developmental Change and Associations with Behaviour Problems

Abstract

Sleep disturbance is common in Autism Spectrum Disorder (ASD) but longitudinal trajectories and poorly defined. This study measured sleep disturbance at baseline and one year later examining change over time and associated problem behaviours. Participants were 84 gender-matched children, aged between 7 and 12 years at baseline, 48 with ASD and 38 typically developing (TYP). Parent reports on a range of scales were collected. The ASD group had more sleep disturbance than the TYP group. Sleep disturbance decreased over the year in ASD but not TYP children. Reduced sleep disturbance was associated with improved social ability. Sleep disturbance at baseline predicted later anxiety. Findings indicated different trajectories of sleep disturbance in ASD and the implications are discussed.

Sleep difficulties are common in Autism Spectrum Disorder (ASD) with 40 to 80% of individuals experiencing sleeping behaviour which disturbs the child and/or their family (Liu, Hubbard, Fabes, & Adam, 2006). In contrast around 25% to 40% of typically developing children experience sleeping difficulties (Meltzer & Mindell, 2008). The cause of the higher rate of sleep disturbance in children with ASD is still being determined. In a comprehensive biopsychosocial model of sleep, Richdale and Shreck (2009) proposed that biological, psychological and environmental factors may predispose or precipitate disordered sleep in ASD. Biological and genetic abnormalities such as the abnormalities in the timing of melatonin secretion, comorbid medical conditions and epilepsy may cause sleep disturbance in ASD (Holloway & Aman, 2011; Richdale, 1999). Sleep difficulties may also relate to environmental factors such as the families sleeping practices and family stress related to having a child with ASD (Richdale & Schreck, 2009). In typical development sleep difficulties are also associated with emotional and behavioural problems such as internalising and externalising symptoms (for a review see Gregory & Sadeh, 2012). Children with ASD experience high rates of these emotional and behavioural symptoms in addition to the core symptoms of ASD and these factors may independently or in combination contribute to sleep disturbance (Richdale & Schreck, 2009).

Studies have shown associations between sleep disturbance and the behavioural symptoms which define ASD: social deficits (Ela et al., 2000; Hoffman et al., 2005; Malow et al., 2006; Schreck, Mulick, & Smith, 2004), communication impairments (Schreck et al., 2004; Taylor et al., 2012; but see also Hoffman et al., 2005) and repetitive and stereotyped behaviours (Gabriels, Cuccaro, Hill, Ivers, & Goldson, 2005; Goldman et al., 2009; Schreck et al., 2004). The direction of the relationships between sleep disturbance and autism symptoms have not been established. Sleep disturbance may be a product of autistic symptoms or both autistic symptoms and sleep problems may have a common etiology. Social

difficulties in particular, have been most frequently associated with sleep difficulties. The sleep-wake cycle is thought to be learnt in part via social cues about sleeping behaviour, something that children with ASD have difficulties intuitively noticing and interpreting (Richdale, 1999). In typical development the sleep-wake cycle follows a developmental trajectory from the polyphasic pattern of sleeping and waking seen in newborns, until gradually more sleep occurs at night with daytime naps usually eliminated at around 4 years of age (Iglowstein, Jenni, Molinari, & Largo, 2003). In ASD, difficulties picking up on the social cues related to the timing of sleep behaviour might impact on the establishment of a stable sleep-wake pattern (Richdale, 1999). Furthermore, internalizing behaviours, such as anxiety, and externalising behaviours, such as aggression and hyperactivity, may be triggered by environmental factors and become intensified by ASD symptoms and also contribute to sleep disturbance in ASD (Hollway & Aman, 2011).

Anxiety is highly prevalent in ASD with estimates between 11-84% of children meeting the criteria for an anxiety disorder (Muris, Steerneman, Merckelbach, Holdrinet, & Meesters, 1998; White, Oswald, Ollendick, & Scahill, 2009). A recent review indicated that around 39% of young people with ASD have a comorbid anxiety disorder (Van Steensel, Bogles, & Perrin, 2011). Anxiety has been shown to consistently overlap with sleep difficulties in children (Allik et al., 2006; Malow et al., 2006; Mayes & Calhoun, 2009). In some studies of typical development sleep disturbance has been found to predict later anxiety but this relationship may not necessarily act in reverse (Gregory & O'Conner, 2002). A recent review of anxiety and sleep in typical development over childhood and adolescence suggested that sleep disturbance may act as a "red flag" for the later development of anxiety (Leahy & Gradisar, 2012). For children with ASD the direction of the relationship between sleep and anxiety is unclear and is complicated by the overlap between anxiety and the core autism symptoms (Sukhodolsky et al., 2008).

Externalising symptoms, such as hyperactive and oppositional behaviour have also been associated with sleep difficulties in typical development (Gregory & Sadeh, 2012) with this pattern also present in ASD. Problems with paying attention, including hyperactivity and impulsivity are highly prevalent in ASD with reports of anywhere between 28% to 70% meeting the criteria for Attention Deficit Hyperactivity Disorder (Gadow, Devincent, Pomeroy, & Azizian, 2005; Simonoff et al., 2008). Most studies have found hyperactive symptoms, rather than inattention problems overlap with sleep disturbance in children with ASD (DeVincent, Gadow, Delosh, & Geller, 2007; Goldman et al., 2011). Oppositional or aggressive behaviours have also been associated with poor sleep in ASD (Mayes & Calhoun, 2009; Patzold et al., 1998). Again, the direction of these relationships in ASD is unclear, and in typical development the relationship with sleep and attention may be bidirectional (Gregory & O'Conner, 2002; Gregory & Sadeh, 2012).

A key limitation of the research to date is the very few studies examining behavioural problems and sleep disturbance in ASD longitudinally. Little is known about how sleep changes over time in ASD and what factors might be associated with change. Only two longitudinal studies of sleep disturbance in ASD were found in the literature. Using actigraphy, Allick et al (2008) found a fairly similar longitudinal trajectory of sleep profiles in high-functioning children with ASD and typical children, mean age 11.1 years at baseline, followed up 2 to 3 years later. A recent longitudinal study (Sivertsen et al., 2012) examining a population sample, found those with parent reported autism spectrum *problems* (but not diagnosed with ASD; 28 participants) showed increased sleep problems from age 7-9 to 11-13. This is in contrast to most studies which find that sleep problems decrease with age in typically developing children (Clarkson, Williams, & Silva, 1986; Gregory & O'Conner, 2002). In ASD some studies of children have found no relationship with sleep difficulties and age (Mayes & Calhoun, 2009), whereas others have found a decline in sleep difficulties with

age similar to typical development (Giannottie et al., 2008), although these studies have been cross-sectional. Sivertsen and colleagues also found concurrent autistic symptoms were associated with sleep problems at Time 2, but did not report longitudinal associations. They found fewer sleep problems in the 6 females compared to the 22 males, which may be important given males greatly outnumber females with ASD (Fombonne, 2003) with no generally agreed cause. However, this study did not examine individuals actually diagnosed with ASD and the extremely small sample of females means the findings may not be robust. In order to understand sleep in ASD, more longitudinal studies are required to trace sleep trajectories in this population and to understand what unique variables may influence change. This information may be important to inform interventions in this population. Sleep interventions which are effective in typical development may not be applicable for children with ASD if autistic symptoms in part underlie or intensify sleep disturbance (Richdale & Schreck, 2009). In fact, there is a growing body of literature which is defining disorder specific sleep profiles across a range of neurodevelopmental conditions such as William's Syndrome (Annaz et al., 2012; Mason et al., 2011; Goldman et al., 2009; Gombos et al., 2011) and Attention Deficit Hyperactivity Disorder (Stein et al., 2012), with each requiring personalised interventions.

In this regard, the aims of this study were threefold. Firstly, the study aimed to understand changes in the range of sleep difficulties as measured by the Child's Sleep Habits Questionnaire (CSHQ; Owens, Spirito, & McGuinn, 2000) over a short period of development in children with ASD and determine if this differed from typical development or by gender. Secondly, the study aimed to understand longitudinal predictive associations between sleep disturbance and behavioural/emotional problems, investigating these relationships in both directions. Finally, the study aimed to investigate the relationships between developmental change in sleep and behavioural problems. Given that sleep

disturbance generally declines with age in children (Clarkson et al., 1986; Gregory & O'Conner, 2002), it was hypothesised that sleep disturbance would reduce over time in TYP and ASD children and gender trajectories would be similar. As sleep disturbance has been found to predict later behavioural/emotional problems in typical development (Gregory &O'Conner, 2002), we predicted that sleep disturbance would predict later anxiety, aggression, and hyperactivity.

Method

Participants

Eighty-four children aged from 7 to 12 years participated at both time points in this study. These children were part of our larger study (May, Cornish, & Rinehart, 2012) with TYP and ASD groups matched on age and gender. The ASD group consisted of 46 children, 22 female, 24 male with Autistic Disorder or Asperger's Disorder. This group of children were taken from our larger study of gender differences in high-functioning children with ASD hence a more equal gender ratio is present in this group compared to the typical 4:1 male to female gender ratio usually found in ASD (Fombonne, 20009; May, Cornish, & Rinehart, 2012). Children with ASD were recruited from the Monash University Centre for Developmental Psychiatry and Psychology register of volunteers, the Autism Victoria 'Get Involved' register of volunteers, and from private clinics in the Melbourne metropolitan area. Only children who had a current diagnosis of ASD from their paediatrician or psychologist were invited into the study. Children were excluded if they had any genetic conditions (such as Fragile X Syndrome) or epilepsy. The DSM-IV-TR criteria for Autistic Disorder or Asperger's Disorder was confirmed for all clinical participants using our standard process of confirmation involving reviewing diagnostic reports from registered psychologists and paediatricians with a symptom checklist to ensure the DSM-IV-TR criteria were fulfilled. Parents were asked to provide clarification regarding the presence of symptoms if this was

unclear from diagnostic reports. All children with ASD scored above the clinical cut-off on the Social Responsiveness Scale (SRS; Constantino, 2002). The TYP group was 38 typically developing children, 14 female, 24 male, recruited from a local Primary School and had no parent or teacher reported history of psychopathology. All TYP children scored below the clinical cut off on the SRS. All children had normal intellectual functioning (full-scale IQ > 70) based on the Wechsler Intelligence Scales for Children IV (WISC-IV) Australian version in the ASD group and the Wechsler Abbreviated Scales of Intelligence in the TYP group.

Materials and Procedure

The study was approved by the Monash University Human Research Ethics Committee and the Victorian Department of Education and Early Childhood Ethics Committee. Parents provided written informed consent. Participation was voluntary and participants did not receive any monetary reward for participation other than reimbursement for travel costs. Parents completed standardised questionnaires for each child, as detailed below, at both time points, baseline (Time 1) and one year later (Time 2).

Parent-rated Autistic Symptoms. The Social Responsiveness Scale (SRS) is a 65 item questionnaire used to assess social awareness, social information processing, capacity for reciprocal social communication, social anxiety/avoidance, and autistic preoccupations in children from 4 to 18 years (Constantino, 2002). It has acceptable levels of internal consistency (.93-.97) and test-retest reliability (.77-.85). Parents use a four-point rating scale to rate the severity of symptoms.

Parent-rated Hyperactivity-Impulsivity and Aggression. The Conners 3 Hyperactive-Impulsive and Aggression subscales were utilised. The Conners 3 Parent short form is a 43 item questionnaire which determines Attention Deficit Hyperactivity Disorder symptoms in a

child based on DSM-IV-TR criteria (Conners, 2003). Test-retest reliability ranges from .71 to .98 and internal consistency ranges from .77 to .97.

Parent-rated Anxiety. The Spence Children's Anxiety Scale (SCAS) is a 38 item questionnaire which assesses six domains of anxiety including generalized anxiety, panic/agoraphobia, social phobia, separation anxiety, obsessive compulsive disorder and physical injury fears based on the DSM-IV anxiety disorders (Spence, 1998). A four point rating scale is used. Test-rest reliability has been shown to be satisfactory (Nauta et al., 2004).

Parent-rated Sleep Disturbance. The Child's Sleep Habits Questionnaire (CSHQ) contains 33 scoring items using a three point scale, and is used to screen for the most common types of sleep difficulties in 4 to 12 year old children (Owens, Spirito, & McGuinn, 2000). Parents report on their child's sleep during the last month. It contains 8 subscales: bedtime resistance (6 items), sleep onset delay (1 item), sleep duration (3 items), sleep anxiety (4 items), night wakings (3 items), parasomnias (7 items), sleep disordered breathing (3 items), and daytime sleepiness (8 items). Reliability and validity have been shown to be acceptable, including test-retest reliability (range 0.62 to 0.79; Owens, Spirito, & McGuinn., 2000). The total CSHQ score can be used as a screening device with scores above 41 indicate sleep disturbance, with this cut off point found to have sensitivity of .80 and specificity of .72 (Owens et al., 2000).

Data Analyses

Outliers greater than 3 standard deviations above the mean in each group were assessed and corrected with the next most extreme score to retain the maximum number of cases (Tabachnick & Fidell, 2007). Repeated Measures Multiple Analysis of Covariance (MANCOVA) was used for time and group comparisons for the dependent variables of interest. When significant interactions were found these were interpreted using analysis of simple main effects.

Hierarchical Regression Analysis was employed to determine which behavioural factors (SCAS total score, SRS Total score, Conners 3 Aggression and Hyperactivity-Impulsivity subscales) from Time 1 predicted Time 2 sleep disturbance (measured using the CHSQ total score). The regression analyses used an interaction term to determine whether any relationships between the dependent variable and the predictor of interest were moderated by group (ASD or TYP). This was achieved by first centering the behavioural variable (by subtracting the group mean from each individual mean) then calculating the interaction term by multiplying group by the centered variable. This interaction term allowed the assessment of whether group (moderator variable) affects the direction and/or strength of the relationship between the independent variable of interest and the dependent variable (Baron & Kenny, 1986). If the interaction term was significant in the predictive model, further post-hoc probing using simple slopes analysis was conducted. The second hierarchical regression model examined whether Time 1 CSHQ total score predicted any of the Time 2 behavioural factors similarly employing an interaction term to determine if group membership moderated the relationship. Finally, change scores were calculated and Pearson correlations used to understand any relationships between change in the behavioural factors and change in sleep over the 1 year period. Bonferroni corrections for multiple-comparisons were employed.

Results

Demographic and behavioural characteristics

Means and standard deviations for the demographic variables assessed in this study are presented in Table 1. The TYP group had significantly higher full-scale IQ than the ASD Group, $t(83)=-4.91$, $p<.001$. Although recruited using the same age range the TYP group were significantly younger than the ASD group at Time 1, $t(83)=2.065$, $p=.042$, and Time 2 $t(83)=2.157$, $p=.034$, Table 1. Chi Square tests of independence showed there was no significant difference in the number of males and females in each group, $X^2(1, N=84)=1.025$,

p=.311. There were no group differences in parental education level between the TYP and ASD groups, for mothers, $X^2(4, N=84)=6.224$, *p*=.183, and fathers, $X^2(4, N=84)=3.810$, *p*=.432. There was no significant difference in the number of months between the Time 1 and Time 2 assessments for the ASD (M=13.00, SD=1.01) and TYP (M=12.6, SD=0.85) groups, *t*(83)=1.88, *p*>.05. None in the TYP group were medicated. At Time 1, 7 children with ASD were medicated (SSRIs, stimulants, risperidone, and melatonin). At Time 2, 14 children with ASD group were medicated. Independent t-tests showed no difference in the CSHQ total score between medicated and non-medicated children with ASD at both Time 1, *t*(44)=-1.195, *p*=0.238, and Time 2, *t*(44)=-.856, *p*=0.396. Over the one year period parents of the children with ASD reported that 56.5% had received psychotherapy, 8.7% had received speech interventions, and 15.2% had attended a social skills group. There were no significant Pearson correlations between any of these interventions and Time 2 CSHQ score, or change between Time 1 and Time 2 CSHQ total score.

A series of repeated measures ANCOVAs, with time as the repeated measure, group as the between subjects factor, covaried for full-scale IQ and age, were calculated to determine any changes over time and group differences in the other factors, Table 1, with Bonferroni corrections for 4 comparisons (.05/4=.012). There was no significant change symptoms over time, but as expected, there a significant group difference with the ASD group having higher levels on the Conners 3 hyperactivity-impulsivity scale, *F*(1,80)=68.986, *p*<.001, Conners 3 aggression scale *F*(1,80)=12.151, *p*=.001, SCAS Total anxiety score, *F*(1,80)=44.320, *p*<.001, and SRS Total score, *F*(1,80)=165.485, *p*<.001.

Table 1

Demographic, Behaviour Problems and Child's Sleep Habits Questionnaire scores for the ASD and Typically Developing Children at Time 1 and Time 2

Variable	ASD Group (N=46) M (SD)	TYP Group (N=38) M (SD)	ASD Group (N=46) M (SD)	TYP Group (N=38) M (SD)
	Time 1		Time 2	
Age (months)	118.11 (22.70)	108.53 (19.49)	131.1 (22.46)	121.15 (19.60)
Full-scale IQ	95.14 (12.76)	108.26 (11.06)	NA	NA
Mother's Education				
Some high school	13%	11%		
High School Graduate	22%	37%		
Some University	30%	18%	NA	NA
Bachelor Degree	15%	26%		
Post-Graduate Degree	20%	8%		
Father's Eduction				
Some high school	26%	39%		
High School Graduate	22%	13%		
Some University	11%	18%	NA	NA
Bachelor Degree	22%	16%		
Post-Graduate Degree	19%	14%		
Spence Children's Anxiety Scale Total Score	28.52 (13.01)	13.24 (6.63)	28.48 (12.44)	12.76 (5.71)

Variable	ASD Group (N=46) M (SD)	TYP Group (N=38) M (SD)	ASD Group (N=46) M (SD)	TYP Group (N=38) M (SD)
Conners 3 Hyperactivity-Impulsivity	8.50 (4.79)	2.37 (2.01)	8.07 (4.84)	1.55 (1.55)
Conners 3 Aggression	2.37 (2.66)	0.66 (0.96)	2.47 (3.18)	0.71 (1.08)
SRS Total Raw Score Social Difficulties	96.24 (24.68)	22.39 (13.53)	87.26 (27.90)	19.05 (11.08)
Child's Sleep Habits Questionnaire				
Bedtime Resistance	8.22 (2.66)	6.61 (1.42)	7.30 (1.72)	6.74 (1.55)
Sleep Onset Delay	2.02 (0.88)	1.32 (0.57)	1.91 (0.86)	1.37 (0.63)
Sleep Duration	4.93 (1.79)	3.55 (1.01)	4.54 (1.41)	3.45 (0.92)
Sleep Anxiety	6.13 (2.24)	4.76 (1.24)	5.13 (1.64)	4.76 (1.34)
Night Wakings	4.02 (1.37)	3.66 (1.05)	3.72 (1.07)	3.74 (1.00)
Parasomnias	9.80 (1.96)	8.21 (1.04)	9.17 (1.76)	8.55 (1.35)
Sleep Disordered Breathing	3.54 (0.96)	3.32 (0.53)	3.48 (0.78)	3.32 (0.77)
Daytime Sleepiness	13.37 (3.56)	10.68 (2.54)	12.74 (3.47)	10.53 (1.98)
Total CSHQ score	49.22 (8.79)	39.89 (4.47)	45.70 (7.19)	40.03 (4.55)

ASD, Autism Spectrum Disorder, TYP, typically developing; CSHQ, Child's Sleep Habits Questionnaire; SRS, Social Responsiveness Scale

Change in sleep disturbance over time

Means and standard deviations for the CSHQ are found in Table 1. At Time 1 78.3% ASD participants had total CSHQ over the cut off of 41 indicating sleep dysfunction, compared to 28.9% in the TYP group. Chi square tests indicated this was significantly different, $X^2(1, N=84)=20.533$, $p<.001$. At Time 2, 65.2% of participants with ASD had scores above 41, compared with 31.6% in the TYP group, which remained a significant group difference, $X^2(1, N=84)=9.419$, $p=.002$.

Correlations between age, full-scale IQ and CSHQ subscales are found in Table 2. There were no correlations with age and any of the CSHQ subscales in the TYP or ASD group. Full-scale IQ was correlated with the Time 1 Total CSHQ score and Daytime Sleepiness in TYP children and therefore was used as a covariate. Multicolinearity was assessed by examining correlations between the Time 1 and Time 2 CSHQ subscales. Values were generally within the range of .03 to 0.7 and hence appropriate for MANOVA. A repeated measures MANOVA with time as the repeated measure, group and gender as the between subject factors, full-scale IQ as the covariate, and Time 1 and Time 2 CSHQ subscales and total score as dependent variables was calculated. The assumption of sphericity was violated hence Greenhouse-Geisser corrections were used. There was no main effect of gender nor interactions between gender and the other factors. There was no main effect of time. There was a significant main effect of group, $F(1,79)=16.910$, $p<.001$, $\eta_P^2=.176$, with the ASD group scoring higher on the CSHQ subscales than the TYP group. There were significant interactions for the following: CSHQ subscales X group, $F(1,79)=13.410$, $p<.001$, $\eta_P^2=.145$, time X group, $F(1,79)=10.871$, $p=.001$, eta=.121, and a CSHQ subscale X time X group interaction $F(1,79)=5.312$, $p=.002$, $\eta_P^2=.063$.

To understand the interactions simple main effects were employed. Children with ASD had significantly higher levels of difficulties than TYP children for the following CSHQ

subscales: Bedtime Resistance [$F(1,82)=7.605$, $p=.007$], Sleep Onset Delay [$F(1,82)=20.685$, $p<.001$], Sleep Duration [$F(1,82)=25.346$, $p<.001$], Sleep Anxiety [$F(1,82)=6.682$, $p=.012$], Parasomnias [$F(1,82)=12.425$, $p=.001$], Daytime Sleepiness, [$F(1,82)=15.950$, $p<.001$], and more overall difficulties on the Total CSHQ score, [$F(1,82)=28.206$, $p<.001$]. There were no differences between the TYP and ASD children on the Night Wakings and Sleep Disordered Breathing subscales. Children with ASD had significantly less sleep disturbance at Time 2 than at Time 1 [$F(1,82)=32.827$, $p<.001$], but there was no difference in sleep disturbance in the TYP group between Time 1 and Time 2. For the 3 way interaction between group, time and subscale, analysis of simple main effects showed there were no differences on any of the CSHQ subscales between Time 1 and Time 2 for the control group. For the ASD group, there was significant improvement in Bedtime Resistance [$F(1,82)=19.994$, $p<.001$], Sleep Anxiety [$F(1,82)=21.930$, $p<.001$], Parasomnias [$F(1,82)=9.071$, $p=.003$], and for the Total CSHQ score, [$F(1,82)=29.896$, $p<.001$].

Table 2

Correlations between age and full-scale IQ and the Time 1 and Time 2 CSHQ subscales and total scores

	TYP		**ASD**	
	Age in months	Full Scale IQ	Age in months	Full Scale IQ
Time 1				
Bedtime resistance	.033	-.145	-.135	-.064
Sleep Onset Delay	-.034	-.141	-.031	.179
Sleep Duration	.053	-.295	-.234	.154
Sleep Anxiety	.122	-.044	-.277	.016
Night Wakings	.020	-.139	-.061	-.031
Parasomnias	-.062	-.021	-.213	-.070
Sleep Disordered Breathing	.084	-.030	.091	-.002
Daytime sleepiness	.100	-.343*	.159	.064
Total Child's Sleep Habits Questionnaire	.100	-.368*	-.105	.042
Time 2				
Bedtime resistance	.013	-.158	-.149	-.140
Sleep Onset Delay	-.158	-.093	.045	.050
Sleep Duration	-.024	.040	.050	.163
Sleep Anxiety	.007	-.201	.005	.098
Night Wakings	.062	.150	-.042	.096
Parasomnias	.133	-.073	-.168	-.038
Sleep Disordered Breathing	.242	.235	.146	-.120

	TYP		ASD	
	Age in months	Full Scale IQ	Age in months	Full Scale IQ
Daytime sleepiness	.233	-.162	.171	-.016
Total Child's Sleep Habits Questionnaire	.154	-.103	.042	.010

CSHQ, Child's Sleep Habits Questionnaire; TYP, Typically Developing; ASD, Autism Spectrum Disorder; *p<.05

Predictive associations between sleep disturbance and behavioural problems

Pearson correlations between Time 1 and Time 2 CSHQ Total sore and Time 1 behavioural factors are shown in Table 3. CSHQ Total score at Time 1 and Time 2 was correlated with anxiety, social difficulties, full-scale IQ, aggression and hyperactivity, but not gender or age. Hierarchical regression analysis were utilised to determine if any of the behavioural factors at Time 1, predicted Time 2 CSHQ Total score after accounting for Time 1 CSHQ Total score. Each behavioural variable was examined in a separate regression analysis and Bonferroni corrections for 4 comparisons were used (.05/4=.0125). No multicollinearity was present among the independent variables (Tolerance>.10 and VIF<10). In Step 1, Time 1 CSHQ Total score was entered into the model. In Step 2, full-scale IQ, and the centered behavioural variable and group term were entered. In Step 3 the interaction term between the centered behavioural variable and group was entered. These analyses showed that Time 1 SRS Total, Conners 3 Aggression and Conners 3 Hyperactivity-impulsivity scores did not predict Time 2 sleep disturbance after controlling for Time 1 CSHQ Total score. For the

Time 1 SCAS Total score, Step 3 (interaction term) approached but did not reach significance with the corrected alpha level, $R^2\Delta = .018$, $F\ \Delta\ (1,78)=4.918$, $p=.024$.

Table 3

Pearson Correlations between Time 1 and Time 2 behaviour factors and CSHQ Total Score

	Time 1 CSHQ Total	Time 1 Hyper-activity	Time 1 Aggres-sion	Time 1 SCAS	Time 1 SRS	Time 2 CSHQ Total	Time 2 Hyper-activity	Time 2 Aggression	Time 2 SCAS
Time 1 Hyperactivity	.335**	1							
Time 1 Aggression	.281**	.382**	1						
Time 1 SCAS	.653**	.349**	.204	1					
Time 1 SRS	.623**	.642**	.432**	.562**	1				
Time 2 CSHQ Total	.832**	.216*	.231*	.585**	.446**	1			
Time 2 Hyperactivity	.363**	.766**	.495**	.358**	.655**	.337**	1		
Time 2 Aggression	.155	.317**	.796**	.205	.353**	.181	.541**	1	
Time 2 SCAS	.619**	.325**	.253*	.698**	.684**	.515**	.413**	.261*	1
Time 2 SRS	.581**	.558**	.451**	.533**	.946**	.455**	.648**	.400**	.701**

5; CSHQ, Child's Sleep Habits Questionnaire; SRS, Social Responsiveness Scale; SCAS, Spence Children's Anxiety Scale.

These relationships were then examined in the opposite direction to determine whether CSHQ Total score at Time 1 predicted any of the Time 2 behavioural factors. Hierarchical regression was again used. Each Time 2 behavioural variable was examined in a separate regression analysis and Bonferroni corrections for 4 comparisons were used (.05/4=.0125). In Step 1 the Time 1value of the behaviour factor was entered. For Step 2, full-scale IQ, centered Time 1 CSHQ Total score and group were entered into the model. In step 3 the interaction term (Time 1 CSHQ total centered X group) was entered. Time 1 CSHQ Total did not predict Time 2 SRS Total, Conners 3 hyperactivity or Conners 3 Aggression after accounting for their Time 1 levels. For the prediction of Time 2 SCAS Total score, Step 1 was significant with Time 1 SCAS Total score significant (Adjusted R^2=.482, R^2 change = .488, F change=78.104, p<.001), Table 4. Step 2 was also significant, (Adjusted R^2=.566, R^2 change = .099, F change=6.289, p=.001), with both group and Time 1 CSHQ Total score significant predictors of later anxiety, Table 4. Step 3 was not significant, (Adjusted R^2=.563, R^2 change = .003, F change=0.594, p=.443), indicating no interaction between group and CSHQ Total in the prediction of later anxiety.

Table 4

Hierarchical Regression Analyses with Time 2 Anxiety (SCAS Total) as the dependent variable

Models	*B*	*t*	*p*
Step 1.			
Time 1 SCAS Total score	.698	8.838	.000***
Step 2.			
Full-scale IQ	-.101	-1.224	.225
Time 1 CSHQ Total Centered	.199	2.008	.048*
Group	.227	2.288	.025*
Step 3.			
Interaction term (Group X Time1 CSHQ Total Centered)	.144	0.770	.443

*** p<.000, *p<.05; SCAS, Spence Children's Anxiety Scale; CSHQ, Child's Sleep Habits Questionnaire.

Relationships between developmental change in sleep dysfunction and behavioural problems

Change scores were calculated by subtracting Time 2 scores from Time 1 scores for the following variables: SCAS Total score, Conners 3 hyperactivity-impulsivity, Conners 3 aggression and SRS total score, and for the outcome variable CSHQ total score. Higher scores on the change variables indicated improvement over time, negative scores indicated decline over time. Pearson

correlations were calculated for the whole sample and the ASD and TYP groups separately (Table 5). Developmental change in CSHQ was correlated with change in aggression, hyperactivity-impulsivity, and the SRS total score in the whole sample. When the TYP group was examined separately there were no significant correlations with the CSHQ change score. In the ASD group change in SRS total score was correlated with CSHQ change.

Table 5

Spearman Correlations between the change variables for the whole sample

Change Scores	1.	2	3	4
Total Sample				
1. Δ CSHQ	1.00			
2. Δ SCAS Total	-.032	1.00		
3. Δ Conners 3 Hyperactivity-Impulsivity	.191*	.144	1.00	
4. Δ Conners 3 Aggression	.186*	-.032	.268**	1.00
5. Δ Social Responsiveness Scale Total score	.321**	.160	.328**	.164
TYP Group	1	2	3	4
1. Δ CSHQ	1.00			
2. Δ SCAS Total	-.222	1.00		
3. Δ Conners 3 Hyperactivity-Impulsivity	.016	.015	1.00	
4. Δ Conners 3 Aggression	.123	.331*	.208	1.00
5. Δ Social Responsiveness Scale Total score	.120	-.108	.242	.054
ASD Group	1	2	3	4
1. Δ CSHQ	1.00			
2. Δ SCAS Total	.016	1.00		
3. Δ Conners 3 Hyperactivity-	.285	.163	1.00	

Impulsivity				
4. Δ Conners 3 Aggression	.236	-.079	.279	1.00
5. Δ Social Responsiveness Scale Total score	.310*	.204	.367*	.189

**p<.01, *p<.05; CSHQ, Child's Sleep Habits Questionnaire; SCAS, Spence Children's Anxiety Scale.

Discussion

To date, few longitudinal studies on sleep in ASD have been conducted. We examined a range of sleep difficulties using the Child's Sleep Habits Questionnaire (CSHQ; Owens, Spirito, & McGuinn, 2000) and investigated inter-relationships with behavioural difficulties in children with ASD over a year of development. Improving knowledge in this area will be important for further developing a model of sleep in ASD and for targeting interventions. Firstly, we observed a reduction in overall sleep disturbance in the ASD group after one year, whereas sleep difficulties in the TYP group remained stable. Secondly, sleep disturbance, as measured by the CSHQ Total score at Time 1 predicted later anxiety as measured by the Time 2 SCAS Total score. This suggests that sleep disturbance may be a risk factor for later anxiety difficulties in both TYP and ASD children. Finally, when developmental change over one year was examined using change scores reductions in autism symptoms, as measured by the SRS, were significantly associated with improved sleep functioning. This relationship more pronounced in children with ASD than TYP children.

As predicted, over the one year period the repeated measures MANCOVA showed a significant reduction in sleeping difficulties as measured by the total CSHQ score, in the ASD but not TYP group. This was not associated with any interventions the children received or medication use. In particular, the CSHQ subscales Bedtime Resistance, Sleep Anxiety and Parasomnias showed significant improvement over the year in ASD children. This finding is in contrast to a recent longitudinal study which included a group of children with autism spectrum 'problems' (Sivertsen et al., 2012) but is consistent with longitudinal studies of typically developing children where sleep disturbance decreases (Clarkson, Williams, & Silva, 1986; Gregory & O'Conner, 2002). The present findings are also consistent with some past cross-sectional studies of children with ASD which have found stability or a decline in sleep disturbance with age (Giannottie et al., 2008; Mayes & Calhoun, 2009). More behaviour associated sleep difficulties have been reported in younger children (aged 6 to 8 years) compared to older children (9-12 years) such as not having learnt appropriate ways to get to and stay asleep (Wiggs & Stores, 2004). A reduction in bedtime resistance in children with ASD the present sample supports this finding.

Despite the reduction in sleep disturbance, 65.2% of children with ASD still scored above the clinical cut-off on the CSHQ at Time 2 (compared to 78.1% at Time 1) suggesting that sleep disturbance continues to be a significant difficulty in children with ASD over childhood. This is consistent with past research in children with ASD indicting between 50 to 80% experience sleep disturbance (Richdale & Shreck, 2009). As expected the ASD group had more overall sleep disturbance on the CSHQ total score than TYP children. Specifically, children with ASD experienced more difficulties with bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, parasomnias and daytime sleepiness than TYP children. There were no differences between TYP and ASD children on the Night Wakings and Sleep Disordered Breathing subscales

of the CSHQ. Past research in children with ASD using the CSHQ has similarly found no differences with typically developing children on the Sleep Disordered Breathing subscale (Goldman et al., 2009).

As hypothesised, sleep disturbance (measured using the CSHQ total score at Time 1) predicted later anxiety (measured using the SCAS Total score at Time 2). This is consistent with a growing body of research in typical development indicating that sleep dysfunction is a "red flag" for the development of anxiety (Leahy & Gradisar, 2012; Gregory & O'Conner, 2002). This finding was independent of group, hence the relationship existed in both TYP and ASD children. This finding is consistent with previous cross-sectional studies showing a relationship between sleep disturbance and anxiety in ASD (Allik et al., 2006; Malow et al., 2006; Mayes & Calhoun, 2009). Given particularly high levels of anxiety are already present in ASD (van Steensel et al., 2011) knowledge that a child is experiencing sleep disturbance may be an important alert for clinicians to consider anxiety interventions. Unexpectedly, sleep disturbance did not predict later aggression, hyperactivity or autism symptoms (as measured using the SRS). However, aggression, hyperactivity and social difficulties were all correlated with sleep disturbance at both Time 1 and 2, which is consistent with ASD cross sectional studies that have found associations between sleep dysfunction and hyperactivity (DeVincent et al., 2007; Goldman et al., 2011; Mayes & Calhoun, 2009) and aggression (Mayes & Calhoun, 2009; Patzold et al., 1998). Also unexpectedly, none of the behavioural measures at Time 1 predicted later sleep difficulties. It is possible that the present sample size may have lacked the power to identify smaller effects, which may explain why the relationships between behavioural problems and later sleep disturbance found in typical development were not significant (Gregory & O'Conner, 2002). It will be important for future studies to investigate these relationships using larger samples.

Reductions in autism symptoms as measured using the SRS were correlated with improved sleep in children with ASD. This finding is consistent with past research showing social deficits are linked to sleep dysfunction in ASD (Elia et al., 2000; Hoffman et al., 2005; Malow et al., 2006; Schreck, Mulick, & Smith, 2004). Interestingly, neither variable predicted the other longitudinally, perhaps indicating that other factors may be involved. For example, sleep difficulties and autism symptoms may be caused by a common factor not measured in this study, and change in this factor may have influenced change in these two domains.

The present findings revealed similar gender trajectories for sleep in boys and girls with ASD as predicted. For all sleep subscales and for the total sleep score there were no gender differences between males and females with ASD, and similarly no gender differences in TYP children. This is in contrast to Siertsen et al (2012) who found females with autism spectrum problems had fewer sleep difficulties than males, however, they had only 6 females in their sample and ASD diagnoses were lacking. Our findings of few differences between boys and girls with ASD is consistent with past research showing very few gender differences in ASD when samples are well matched (Kozlowski & Matson, 2011; May, Cornish, & Rinehart, 2012; Pilowsky, Yirmiya, Shulman, & Dover, 1998; Rivet & Matson, 2011; Solomon, Miller, Taylor, Hinshaw, & Carter, 2011).

A limitation of the present study was that only a one year time period was assessed. Change in sleep function was not indicated in the TYP group which may be a result of this short time period, given most studies of typical development indicate that sleep improves from childhood through to adolescence (Clarkson et al., 1986; Gregory & O'Conner, 2002). An important extension of this work will be to assess sleep disturbance longitudinally over more than two time points so that the form of the change in sleep disturbance can be assessed. Given improvement in sleep was found in the ASD group but not the TYP group over this short time

period it suggests that the trajectory of sleep in ASD differs from typical development. Limitations also include the use of a clinically referred sample which may have had higher levels of psychopathology than non-referred samples. The study also relied on parent reports which may suffer from rater bias, in particular, a negative halo effect such that parents of children with behavioural disorders are likely to report more disruptive behaviours, including sleep-related behaviours, in their children (Owens, 2005). However, this effect does not appear to be present, given that there was both improvement and stability in different factors over time, whereas a negative halo effect would predict all measures would change similarly. Only high-functioning children were used in the present study, hence, our findings may not extend to children with intellectual disability. Despite these limitations, this study has extended our knowledge on the trajectory of sleep over time in high-functioning children with ASD and has highlighted factors associated with developmental change in sleep.

These findings have important clinical implications for general paediatric management and for sleep interventions which target sleep and mental health in children with ASD. Given that around 78 percent of children with ASD in this study, at ages 7 to 12 years, screened in the at risk range for common childhood sleeping disturbances these findings support current best practice assessment in ASD which includes routine assessment of sleep disturbance. Importantly sleep difficulties may be predictive of later increased difficulties with anxiety, in what is an already highly anxious population. This study is an important exploration into how problem behaviours may inter-relate with sleep over time in children with ASD, however, more longitudinal studies are needed to confirm these findings.

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Chapter 5 – A review of neuropsychological and academic functioning in the context of gender in ASD

The possibility that boys might come to clinical attention more often than girls with ASD due to differences in comorbid conditions and symptom expression was considered in the first four Chapters of this thesis. The aim of Chapter 5 and the remainder of this thesis is to explore beyond overt behavioural symptoms and examine neuropsychological and academic factors which might differ between boys and girls with ASD. Firstly, this Chapter considers neuropsychological factors, specifically the cognitive components of attention, which may account for actual differences between boys and girls with ASD. Secondly, this chapter will review academic functioning in boys and girls with ASD to determine any gender differences which might impact on different clinical ascertainment, given academic difficulties can prompt clinical referral. The cognitive components of attention are of particular interest as they have been associated with academic outcomes in typical development (Dobbs, Doctoroff, Fisher, & Arnold, 2006; Fuchs et al., 2005; Rabiner & Coie, 2000). Therefore, this chapter will also explore beyond gender, to more broadly discuss how the cognitive components of attention are associated with academic outcomes in children with ASD.

Cognitive Theories of ASD

The biopsychosocial model was introduced in Chapter 1 as a way of understanding the factors which may relate to the emergence of gender difference in ASD. This model considers (1) biological underpinnings, (2) psychological-cognitive skills (attention/executive function, psychological-emotional function) and (3) internal and external environmental factors. Chapter 1 explored possible biological underpinnings, behavioural factors such as observable clinical

symptoms, and sociocultural factors which might contribute to gender difference in ASD. The second component of the biopsychosocial model, in addition to observable behaviours, includes cognitive processing. Cognitive mechanisms are an important bridge between biological abnormalities and behavioural symptoms. There have been a number of highly influential cognitive theories of ASD which have sought to explain ASD symptoms as relating to a primary cognitive deficit. Three cognitive theories which have gained prominence over the last thirty years of research in ASD will be briefly reviewed: Theory of Mind, Executive Dysfunction and Weak Central Coherence.

Theory of Mind

Theory of Mind (ToM) is the ability to understand another's perspective or mental state such as a person's beliefs and desires. This ability is therefore important for understanding and predicting the behaviour of others. At face value these difficulties are consistent with the social deficits in ASD. This led Baron-Cohen, Leslie and Firth (1985) to empirically examine this phenomenon in ASD. They compared a simple false belief task in 4 year old children with ASD, typically developing children and children with Down's Syndrome. As expected, only children with ASD were unable to predict where a character would look for an object that had been moved in their absence, indicating children with ASD have a deficit in "mentalising" or with ToM. The ToM deficit theory of ASD can explain a number of the social and communication deficits found in this condition such as poor eye contact and a lack of social reciprocity. The finding of impaired ToM in ASD prompted a large amount of research (Baron-Cohen, 2000) which has led to further refinement of the theory. Later research suggested that many children with ASD do in fact pass simple ToM tasks, particularly when verbal abilities reach a level of around 12 years of age

(Happe, 1995). Hence this deficit may be better viewed as a delay and it is not a universal deficit in all individuals with ASD.

Executive Functioning

Some of the difficulties present in ASD, such as perseveration, difficulties with switching attention and deficits in inhibitory control are similar to those found in individuals with acquired frontal brain damage (Baddeley & Wilson, 1988). Researchers drew parallels between these areas to propose the Executive Functioning theory of ASD: deficits in goal directed, adaptive behaviours are responsible for the triad of ASD impairments (Pennington & Ozonoff, 1996). This theory attempts to link biological disruption in the frontostriatal circuits, including the prefrontal areas of the brain, to cognitive deficits which produce the behavioural symptoms of ASD. Executive Functions (EF) are an umbrella term for a range of attentional components, including working memory, planning, the ability to *switch* attention according to changes in the environment, the ability to *sustain* attention on the task at hand, and the ability to inhibit a response. However, not all of these functions are impaired in ASD.

Research to date has attempted to define the unique EF profile "signatures" of ASD and differentiate this from other neurodevelopmental conditions (for a recent review see Cornish & Wilding, 2010). The ability to switch attention is typically found to be impaired in ASD (Ames & Fletcher-Watson, 2010; Reed & McCarthy, 2012; Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008). Deficits in the basic components of disengagement and shifting attention may underpin core ASD deficits in social attention such as joint attention and be responsible for perseverative behaviours (Ames & Fletcher-Watson, 2010; Hughes & Russell, 1993). Deficits in cognitive flexibility or response set shifting (the ability to shift attention based on changing environmental demands), have also been found to correlate with repetitive and stereotyped

behaviours (Lopez, Lincoln, Ozonoff, & Lai, 2005; Sinzig et al., 2008). In contrast, sustained attention or vigilance appears intact in ASD (Goldstein, Johnson, & Minshew, 2001; Johnson et al., 2007; Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow, 2001; Sanders, Johnson, Garavan, Gill, & Gallagher, 2008). There continues to be considerable research effort in understanding which of the many executive functions are impaired in ASD, and whether these deficits are specific to this condition, given many other conditions also show EF deficits including ADHD, obsessive compulsive disorder, and schizophrenia.

Research has also found significant overlap between the components of EF and ToM development. For example, Pellicano (2007) examined children with ASD using EF and ToM tasks and found that children with EF deficits always had ToM deficits, but ToM deficits could occur without EF deficits. This was interpreted to indicate that EF had developmental primacy in that EF is required for the later development of ToM abilities, with this notion supported by later longitudinal studies (Pellicano, 2010b).

Weak Central Coherence

The Weak Central Coherence theory of ASD proposes that the symptoms of ASD derive from information processing which has a focus on the constituent parts or details rather than from extracting meaning from the overall whole (Frith & Happé, 1994; Happé, 1999). This theory can explain some aspects of social deficits in ASD such as a failure to focus on socially relevant stimuli and repetitive behaviours such as obsessions with parts of objects. This theory grew out of empirical findings using the embedded figures task which requires participants to locate a target shape in a larger everyday shape. On this task children with ASD performed better than typically developing children (Shah & Frith, 1993). This suggested that individuals with ASD were less

susceptible to the drive for central coherence from the larger figure and instead they had a focus on the details.

There have been a number of modifications to the Weak Central Coherence theory as research has further defined this cognitive process. Rather then being seen as a deficit in global processing, the theory is now understood as superior local processing. Rinehart and colleagues (2000) proposed that superior local processing may actually be due to an underlying inhibitory deficit in preventing further detailed processing and may hence arise from a core difficulty in EF. The Weak Central Coherence phenomenon is now understood as a cognitive style rather than as a deficit. The theory has also been refined to account for only some of the difficulties associated with ASD.

Summary of Cognitive Theories and Gender Implications

Each of these three cognitive theories of ASD has generated a wealth of research and has accounted for some of the deficits present in ASD. However, none have been able to fully account for the triad of deficits. Furthermore, none of the theories have been found to be universal in their impact on affected individuals. For example, while many children with ASD fail a false belief ToM task there will be a considerable number who pass. EF has been proposed to underpin both ToM and Weak Central Coherence in regard to developmental primacy. EF is an important area to further explore with respect to gender, given the importance of EF for a range of downstream functions and also given early studies which found poorer cognitive functioning in females (Lord et al., 1982; Tsai et al., 1981; Wing, 1981).

For gender, the bulk of studies on cognitive processing in ASD have used only male participants or mixed gender samples with too few females to meaningfully compare gender differences. A systematic search of Ovid MedLine identified only one study that aimed to

compare gender differences in a component of EF. Response inhibition was found to be worse in high-functioning females with ASD compared with age and IQ matched males with ASD (Lemon et al., 2010). However, the small sample size (N=12 in each group) makes this finding exploratory. Extending this area of research to determine whether there are unique gender EF 'signatures' may be important in clarifying the broader ASD EF signature. For example, if gender differences in EF are found, this may partially explain past mixed findings. Computerised EF tasks may be particularly revealing with regard to gender, as these tasks are objective, direct measures, rather than rater reports of symptoms which are subjective and may be prone to gender bias.

Another area where more objective measures can be employed is academic performance. Academic attainment in typical development is associated with the development of EF abilities, hence examining academic outcomes in ASD where there are known EF deficits may reveal important relationships with learning. The academic outcomes of girls with ASD is another area which has had limited research. The next section of this chapter will shift focus from cognitive theories of ASD to explore academic attainment.

Academic Functioning in ASD and the Impact of Gender

On average, the academic achievement of individuals with ASD in regard to basic reading and arithmetic is commensurate with IQ, but there is considerable heterogeneity in performances (Jones et al., 2009; Mayes & Calhoun, 2003; Nation, Clarke, Wright, & Williams, 2006). Profiles of both academic weaknesses and strengths relative to intellectual ability are indicated (Ashburner et al., 2010; Jones et al., 2009; Myles, Simpson, & Becker, 1994). For example, in a review of mathematical ability, Chiang and Lin (2007) found most individuals with high-

functioning autism and Asperger's Disorder had average mathematics ability but this included an area of mathematical weakness. They found only a minority of individuals would be considered mathematically gifted. High-functioning children with ASD show a profile of strengths in basic reading skills, such as decoding, and challenges with higher-order skills, such as reading comprehension (Griswold, Barnhill, Myles, Hagiwara, & Simpson, 2002; Huemer & Mann, 2010; Jones et al., 2009; Minshew, Goldstein, Taylor, & Siegel, 1994). Which factors might contribute to these profiles is largely unexplored but will be of importance in developing targeted academic interventions to assist children with ASD meet their academic potential.

The core symptoms of ASD may confer vulnerability to academic difficulties in the school environment (Ashburner et al., 2010; Macintosh & Dissanayake, 2006). For example, a lack of social support, difficulties communicating with others and difficulties with rigid behaviour may impact on the ability to learn in the school setting. In this regard, early social abilities have been found to predict later word reading achievement in children with ASD (Estes, Rivera, Bryan, Cali, & Dawson, 2011). Nation et al. (2006) also found poorer reading comprehension was associated with social and communication impairment on the Autism Diagnostic Observation Schedule (ADOS), but there were no associations between this measure and mathematics or basic reading skills.

For gender, there has been little research in the area of academic performance. Girls with high-functioning ASD appear to have similar reading comprehension at the group level to typically developing girls (Asberg, Kopp, Berg-Kelly, & Gillberg, 2010). Surprisingly no studies examining the mathematics performance of females with ASD have been reported, with most research in this area examining only males or having too few females to perform meaningful gender comparisons (Jones et al., 2009; Mayes & Calhoun, 2003; Minshew et al., 1994). Hence, there are considerable gaps in knowledge about academic performance and gender in ASD.

Given the relationship between academic outcomes with later employment and income opportunities, this area is particularly important for life outcomes. Unexplained academic difficulties during primary school may also prompt referral for clinical assessment and result in diagnosis of ASD. Hence, given more boys than girls are diagnosed with ASD, potentially ASD-affected boys may experience more academic difficulties than girls with ASD which may contribute to their higher levels of clinical ascertainment.

Inter-relationships between behavioural and cognitive attention and academic functioning in ASD

In typically developing children, associations between behavioural and cognitive attention difficulties and later academic performance have been found (Rogers, Hwang, Toplak, Weiss, & Tannock, 2011). Behavioural attention difficulties refer to observable attention symptoms such as inattention and hyperactivity-impulsivity, the core symptoms of ADHD. Cognitive attention difficulties refer to the components of EF associated with cognition such as attention switching and sustained attention. The basic relationship between these factors is illustrated in Figure 5.1. These inter-relationships will now be reviewed with respect to what is known in ASD.

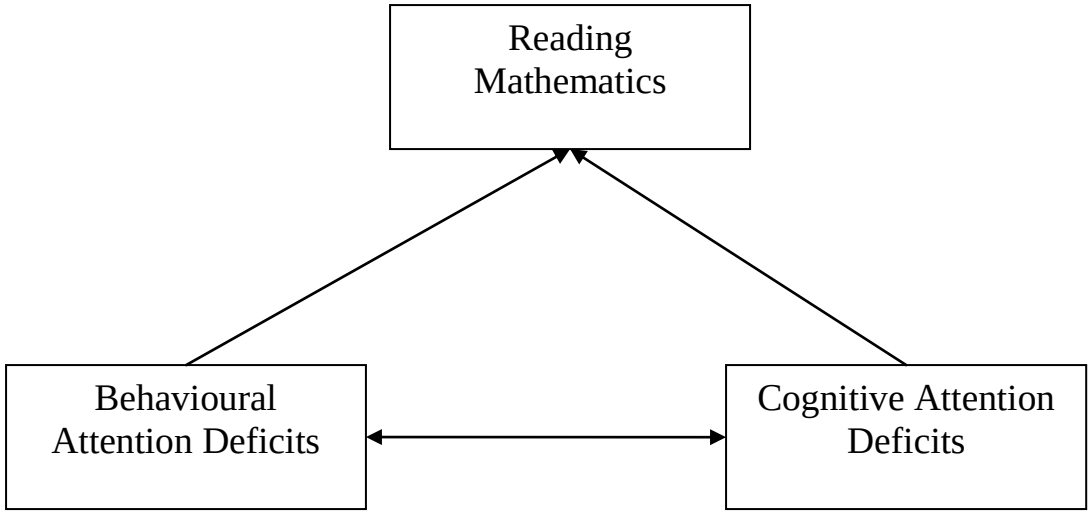

Figure 5.1. Associations between academic performance (Reading & Mathematics) and behavioural and cognitive attention difficulties.

Behavioural Attention Deficits and Academic Performance

In typical development, inattentive behaviour in kindergarten children, but not hyperactive behaviour, predicts poor reading outcomes in Grade 1 and Grade 5, independent of kindergarten reading-related skills and concurrent levels of hyperactivity (Rabiner & Coie, 2000). Inattentive behaviour in the classroom is also strongly associated with mathematics difficulties in primary school children (Dobbs et al., 2006; Fuchs et al., 2005) and predicts poorer response to evidence-based reading and mathematics instruction (Fuchs et al., 2005; Rabiner & Malone, 2004).

Although there are high rates of comorbid ADHD symptoms, such as inattention and hyperactivity-impulsivity in ASD (Leyfer et al., 2006), the relationships between these areas and academic attainment has seldom been examined. ADHD symptoms have been associated with academic underachievement in ASD (Asberg et al., 2010; Ashburner et al., 2010). Teacher ratings of attention to cognitive tasks were negatively associated with academic outcomes in children with ASD using the Conners Teacher Rating Scale and Achenbach System of Empirically Based Assessment (Ashburner et al., 2010). In a study of girls with ASD and ADHD, Asberg and colleagues (2010) found both autistic symptoms and inattention symptoms predicted reading achievement. This study did not include boys, hence whether gender differences were present in these inter-relationships is unknown.

Cognitive Attention Deficits and Academic Performance

The cognitive components of attention in typical development serve as predictors of literacy and numeracy scores in preschool through high school (Clark, Pritchard, & Woodward, 2010; Steele, Karmiloff-Smith, Cornish, & Scerif, 2012). Somewhat surprisingly, very little research has been conducted on how academic outcomes in children with ASD may be constrained by cognitive attention deficits, despite the known cognitive impairments in ASD. The inter-relationships between academic performance and cognitive attention deficits have been examined more comprehensively in other neurodevelopmental conditions with marked EF impairment, such as ADHD (Daley & Birchwood, 2010; Thorell, 2007). In ADHD, academic underachievement is the norm (Barry, Lyman, & Klinger, 2002; Biederman et al., 2004; Loe & Feldman, 2007) and EF abilities have been found to be important in predicting academic achievement in this condition (Alloway, Gathercole, & Elliott, 2010; Biederman et al., 2004; Preston, Heaton, McCann, Watson, & Selke, 2009; Thorell, 2007). These cognitive attention

difficulties may be more important in the prediction of academic attainment than the observable behaviour symptoms of ADHD. For example, a recent review of academic attainment in ADHD surmised that EF difficulties were most likely to explain academic underachievement in children with ADHD rather than comorbid difficulties or the behavioural symptoms of ADHD (Daley & Birchwood, 2010). However, EF deficits may not be present in all cases of ADHD with one study finding lower academic attainment in children with ADHD plus poor EF compared with ADHD without poor EF (Biederman et al., 2004). Thus, given the heterogeneity characteristic of ASD, examining intergroup differences in EF in this population will also be important in revealing any underlying relationships with academic performance.

With respect to inter-relationships between academic outcomes and components of EF in ASD, Mayes and Calhoun (2007) found sustained attention (using a continuous performance task) concurrently predicted reading and mathematics. However, the sample examined in this study included a range of clinical conditions, including ASD and ADHD, and no group specific findings were reported. No other studies to the author's knowledge have examined EF measures in the prediction of academic attainment in ASD.

Developmental trajectories of EF and Academic Performance in ASD

In typical development, the components of attention develop slowly over time. For example, Zhan and colleagues (2011) examined typically developing children and found that accuracy on a sustained attention task peaked by 9 years of age, compared with around 14 years of age for accuracy on an attention switching task. A lag in development of these attention components may have implications for a range of downstream dependent functions. In typical development these components have been shown to gate critical outcomes such as learning and

academic attainment (Clark et al., 2010; Steele et al., 2012). Hence children with ASD who have delays and atypical development of EF components may be at risk for later academic difficulties.

In ASD the development of EF components has not been thoroughly established. Ozonoff and McEnvoy (1994) examined a planning efficiency task (Tower of Hanoi) and a switching task in adolescents with ASD and did not find improvement in task performance at three year follow-up. Griffith, Pennington, Wehner, and Rogers (1999) found no improvement after one year on a cognitive flexibility task in preschoolers with autism. In contrast with these findings, Pellicano (2010a) showed that although children with autism, aged 4 to 8 years, performed more poorly than control children on a set-shifting and planning task (Tower of London), there was greater gain in planning ability after 3 years than in control children. This suggested a lag in the development of these functions as well as a different rate of development. The discrepant findings of these studies may relate to the different age ranges and different tasks examined, given that the components of attention show unique developmental trajectories.

Another gap in the academic literature in ASD is in understanding how academic performance may change over development. No studies were identified which examined the academic trajectories of children with ASD using longitudinal study designs. Whether gender interacts with these trajectories is another unexplored area.

Summary

The three key cognitive theories of ASD - Theory of Mind, Executive Dysfunction and Weak Central Coherence - have attempted to link biological underpinnings to the behavioural symptoms of ASD via deficits in cognitive processing. As these theories have been refined and their weaknesses identified it has become clear that the heterogeneity of ASD will likely require a complex multi-deficit account. It is also evident that these cognitive theories have not yet

attempted to explain the male predominance in ASD. Past research shows that males with ASD experience difficulties with attention switching, but largely intact sustained attention. Developmentally, males with ASD show delays relative to controls with different rates of development on some EF skills. For females the performance and trajectory of EF development is unknown.

Regarding academic attainment, idiosyncratic profiles of academic strengths and weaknesses appear to be the norm in ASD. Basic reading and mathematics skills appear to be intact, but weaknesses in higher order tasks such as reading comprehension are evident in males with ASD. For females with ASD, reading appears to be similar to typically developing females (Asberg et al., 2010) with mathematics attainment being an unexplored area.

This Chapter has revealed considerable gaps in the literature around a lack of knowledge about the EF profile and academic performance of females with ASD, a lack of longitudinal academic studies, and few studies examining the inter-relationships between academic performance and underlying EF deficits. These relationships are particularly important for high-functioning individuals given academic performance will impact on employment opportunities and income and this in tern will impact on social opportunities, living conditions and overall quality of life. These areas may be particularly revealing for gender as objective computerised and standardised psychological tests can be employed which may reduce any potential rater biases. The following two chapters of the thesis will present two empirical papers which consider these gaps in the literature and attempt to address them with a study of executive functioning and academic performance in high-functioning primary school-aged children with ASD and a matched group of typically developing children.

Monash University

Declaration for Thesis Chapter 6

In the case of Chapter 6, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Project design, review of relevant literature, attainment of ethics approval, recruitment and all testing of research participants, analysis of data and writing of manuscript.	70%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	**Nature of contribution**
Prof. Nicole Rinehart	Contributed to project design and provided input during final draft stage of manuscript.
Prof. Kim Cornish	Contributed to project design and provided input during final draft stage of manuscript.
Dr. John Wilding	Contributed to project design and provided input During data analysis and final draft stage of manuscript.

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work*.

Candidate's Signature		**Date**
Main Supervisor's Signature		**Date**

*Note: Where the responsible author is not the candidate's main supervisor, the main supervisor should consult with the responsible author to agree on the respective contributions of the authors.

Chapter 6 Gender differences in Academic and Executive Functioning

Preamble to Paper 4

The previous three papers in this thesis have examined symptoms of ASD, internalizing and externalizing behaviours and sleep disturbance in high-functioning children with ASD to understand any gender differences and determine developmental trajectories. The thesis now shifts focus to explore gender differences and developmental trajectories in neuropsychological and academic functioning. The focus of Paper 4 is to determining any gender differences in basic reading and mathematics attainment and in two cognitive components of attention – sustained and switching attention using a computerized task. The paper then examines inter-relationships between behavioural symptoms of attention, sustained and switching attention and academic performance. This paper examines these factors at one time point. This paper has been published online in the Journal of Autism and Developmental Disorders.

May, T., Rinehart, N.J., Wilding, J, & Cornish, K. (2013). The role of attention in the academic attainment of children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*.

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ORIGINAL PAPER

The Role of Attention in the Academic Attainment of Children with Autism Spectrum Disorder

Tamara May · Nicole Rinehart · John Wilding · Kim Cornish

Abstract Academic attainment in children with Autism Spectrum Disorder (ASD) is under-studied, with associated factors largely undetermined. Parent-reported attention symptoms, attentional-switching and sustained-attention tasks were examined to determine relationships with mathematics and reading attainment in 124 children aged 7–12 years; sixty-four with high-functioning ASD, half girls, and sixty age- and gender-matched typical children (TYP). With full-scale IQ controlled there were no differences in mathematics, reading, attentional switching or sustained attention. In regression analysis, attentional switching was related to mathematics achievement in ASD but not TYP children. Findings highlight attentional switching difficulties are linked with poorer mathematics outcomes in ASD.

Keywords Academic · Autism spectrum disorder · Reading · Mathematics · Attention switching · Sustained attention

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Introduction

The ability to concentrate and stay focused on a task, to switch attention between tasks, to inhibit impulsive responding, and to mentally hold and use information are critical skills for learning and academic outcomes. The development of these skills, collectively known as Executive Functions (EF), begins early in life and become progressively more robust from the preschool years onwards (Hanania and Smith 2010; Steele et al. in press). Recent studies highlight that EFs are more strongly associated with school readiness than IQ quotient (Blair and Razza 2007), serve as predictors of literacy and numeracy scores in preschool through high school (Clark et al. 2010), and facilitate social inclusion and peer relationships (Frederick and Olmi 1994; Gomes and Livesey 2008). Fundamental to EF skills is the construct of "attention", a set of cognitive processes that gate learning more generally. Disruption to these essential processes can lead to increased levels of distractibility, impulsivity, forgetfulness and poor focus. In the case of children who are especially vulnerable to learning impairments because of an underlying developmental disorder, for example children with Autism Spectrum Disorder (ASD), attention difficulties will likely exacerbate an already compromised cognitive system making them at increased risk for poor academic outcomes and long term emotional and behavioral problems. Accordingly, the presence of even a few persistent inattentive behaviors should be seen as a developmental risk factor. However, attention is a complex, multi-dimensional construct that encompasses both overt behavioral characteristics such as distractibility, impulsivity and disorganization as well as underlying cognitive components such as sustained attention or vigilance, attention switching and executive attention, subserved by distinct neural systems (Mirskey 1989; Posner and Petersen

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Paper 4: The role of attention in the academic attainment of children with autism spectrum disorder

Academic attainment in children with Autism Spectrum Disorder (ASD) is under-studied, with associated factors largely undetermined. Parent-reported attention symptoms, attentional-switching and sustained-attention tasks were examined to determine relationships with mathematics and reading attainment in 124 children aged 7-12 years; sixty-four with high-functioning ASD, half girls, and sixty age- and gender-matched typical children (TYP). With full-scale IQ controlled there were no differences in mathematics, reading, attentional switching or sustained attention. In regression analysis, attentional switching was related to mathematics achievement in ASD but not TYP children. Findings highlight attentional switching difficulties are linked with poorer mathematics outcomes in ASD.

Keywords: academic; autism spectrum disorder; reading; mathematics; attention switching; sustained attention

The ability to concentrate and stay focused on a task, to switch attention between tasks, to inhibit impulsive responding, and to mentally hold and use information are critical skills for learning and academic outcomes. The development of these skills, collectively known as Executive Functions (EF), begins early in life and become progressively more robust from the preschool years onwards (Hanania & Smith, 2010; Steele, Scerif, Karmiloff-Smith, & Cornish, in press; Zhan et al 2011). Recent studies highlight that EFs are more strongly associated with school readiness than IQ quotient (Blair & Razza, 2007), serve as predictors of literacy and numeracy scores in preschool through high school (Clark, Pritchard, & Woodward, 2010), and facilitate social inclusion and peer relationships (Frederick & Olmi, 1994; Gomes & Livesey, 2008). Fundamental to EF skills is the construct of "attention", a set of cognitive processes that gate learning more generally. Disruption to these essential processes can lead to increased levels of distractibility, impulsivity, forgetfulness and poor focus. In the case of children who are especially vulnerable to learning impairments because of an underlying developmental disorder, for example children with Autism Spectrum Disorder (ASD), attention difficulties will likely exacerbate an already compromised cognitive system making them at increased risk for poor academic outcomes and long term emotional and behavioral problems. Accordingly, the presence of even a few persistent inattentive behaviors should be seen as a developmental risk factor. However, attention is a complex, multi-dimensional construct that encompasses both overt behavioral characteristics such as distractibility, impulsivity and disorganization as well as underlying cognitive components such as sustained attention or vigilance, attention switching and executive attention, subserved by distinct neural systems (Mirsky, 1989; Posner & Petersen, 1990). A plethora of developmental research now attests to the dynamic nature of these attention components across childhood into adolescence (Brocki, Tillman, & Bohlin, 2010; Zahn et al., 2011) and their critical and independent role in predicting later academic skills such as reading

and math (Steele et al., in press). Of considerable interest in recent years and in light of the premise that attention is an essential building block that shapes the broader cognitive landscape across development, there has been a significant research push to investigate the range and impact of early attention deficits prevalent in a number of neurodevelopmental disorders including children with ASD (see Cornish & Wilding, 2010 for a comprehensive review).

ASD is an early onset neurodevelopmental condition that affects around 1 in 150 children worldwide (Fombonne, 2009). The core symptoms of autism are defined by social and communicative deficits, as well rigid, repetitive patterns of behavior and interests (American Psychiatric Association, 2000). Attentional difficulties represent a core concern for parents (Hartley et al., 2008) and appear early in development. There is a strong association between Attention Deficit Hyperactivity Disorder (ADHD) symptoms and ASD in approximately 50% of children (Leyfer et al., 2006) with inattentive behaviours being more pervasive than hyperactivity levels. Impairments in *visual orienting*, probably related to abnormal gaze processing, have been widely cited (Elsabbagh et al., 2012; Landry & Bryson, 2004) alongside relative strengths in *sustained attention* or *vigilance* (Johnson et al., 2007). In contrast, there still remains confusion as to the stability and nature of deficits in more domain-general EFs, especially on tasks that require control and regulation of competing demands, for example the ability to *switch attention* efficiently between task demands according to changes in the environment (see Ames & Fletcher-Watson, 2010; Hughes & Russell, 1993; Lopez, Lincoln, Ozonoff, & Lai, 2005; Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008 but see Kaland, Smith, & Mortensen, 2008; Russell, Jarrold, & Hood, 1999). Although factors such as small sample sizes, wide IQ discrepancies and broad age ranges may account for some of the EF inconsistencies, it remains unknown how ADHD behavioural symptoms map onto underlying cognitive components of attention to

constrain specific EF skills such as attentional switching and sustained attention in children with ASD. The extent to which this relationship then impacts on academic outcomes will be critically important, as although IQ is usually strongly related to academic attainment (Mayes & Calhoun, 2007; Neisser et al., 1996), converging empirical findings demonstrate a relationship between ADHD symptoms and reduced academic outcomes in ASD especially in the domains of reading and math (Asberg, Kopp, Berg-Kelly, & Gillberg, 2010; Ashburner, Ziviani, & Rodger, 2010; Mayes & Calhoun, 2007; Yoshida & Uchiyama, 2004).

Another finding which may influence attention is gender, given both ASD and ADHD are conditions with much higher incidence of males than females (APA, 2000; Fombonne, 2003). There are mixed findings regarding whether gender differences in the components of attention exist in the typical population, and any differences may be subtle (for a recent review see Trent & Davies, 2012). In ASD there are mixed findings with regard to gender differences in attention symptoms; some studies suggest similar levels of ADHD symptoms (Brereton, Tonge, & Einfeld, 2006; Gadow, et al., 2005; Hofvander, et al., 2009; Simonoff, et al., 2008), others indicate that girls show fewer hyperactive symptoms (May, Cornish, & Rinehart, 2012), and yet others suggest that girls with ASD show more attention problems than boys with ASD using parent report on the Child Behaviour Checklist (Holtmann, Bolte, & Poustka, 2007). Holtman and colleagues suggested that the cognitive functions which underlie attention symptoms may be more impaired in females than males. In this regard, very few studies have examined gender differences in the underlying cognitive components of attention in ASD, yet one such study found females with ASD had poorer response inhibition than males, although the sample size was small (Lemon et al., 2010). For academic attainment, girls with ASD appear to perform similarly to typically developing girls in regard to reading (Asberg, Koop, Berg-Kelly, & Gillberg, 2010).

Mathematics attainment in females is a particularly neglected area, with most studies in this area recruiting too few females to examine gender effects (Jones et al., 2009; Mayes & Calhoun, 2003; Minshew et al., 1994). The extent to which gender may modulate the associations between attention and academic attainment in ASD is unknown.

Understanding the interplay between ADHD symptoms, the underlying cognitive components of attention, and academic achievement in children with ASD will facilitate a new generation of more targeted resource programs that maximize academic potential. The current study focused on primary school aged children with high functioning Autistic Disorder and Asperger's Disorder and aimed to test the associations between inattentive and hyperactive-impulsive symptoms, attentional switching, sustained attention, and gender in academic achievement. Firstly, it was predicted that children with ASD would show poorer attentional switching, but similar sustained attention, to typical children based on previous findings of intact sustained attention in ASD. Secondly, based on past research (Clark, Pritchard, & Woodward, 2010; Mayes & Culhoun, 2007), the degree of ADHD symptoms as well as attentional switching and sustained attention capacity was predicted to be associated with both reading and mathematics attainment in ASD and typical children. However, on the basis of past research (Asberg, Kopp, Berg-Kelly, & Gillberg, 2010; Ashburner, Ziviani, & Rodger, 2010; Mayes & Calhoun, 2007; Yoshida & Uchiyama, 2004) we hypothesised that in a regression analysis this relationship would remain significant in children with ASD given the compromised cognitive system in ASD, beyond age, cognitive functioning (Mayes & Calhoun, 2007). Finally, we expected that girls with ASD would show similar academic attainment but poorer attentional switching and sustained attention than boys with ASD based on past studies indicating more

impairment in underlying cognitive components of attention in girls with ASD (Holtmann, Bolte, & Poustka, 2007; Lemon et al., 2010).

Method

Participants

Participants were 64 children, 32 male and 32 female, with Autistic Disorder or Asperger's Disorder aged between 7 and 12 years. Participants were recruited as part of a larger developmental study to assess a range of cognitive abilities in children with ASD. The DSM-IV-TR criteria for Autistic Disorder (16 male, 7 female) or Asperger's Disorder (16 male, 25 female) was confirmed met for all clinical participants via reviewing diagnostic reports from registered psychologists and pediatricians. All participants were recruited through the Monash University Centre for Developmental Psychology and Psychiatry, the Autism Victoria 'Get Involved' volunteer register, and from private clinics in the Melbourne metropolitan area. Only children with a full-scale IQ of 70 and above were included in the study. Seven of the 64 children with ASD (2 female, 5 male) were taking psychostimulant medication (5 methylphenidate and 2 atomoxetine). Sixty typically developing children, 30 male and 30 female, were recruited from a Melbourne metropolitan Primary School. None of these children had any prior history of parent reported developmental disability or psychopathology. Children were excluded if they had a history of brain injury or any genetic disorders (such as Fragile X syndrome).

Measures

Intellectual functioning. For children with ASD intellectual ability was assessed using the Wechsler Preschool and Primary School Intelligence III (WPPSI; Pearson Clinical Assessment, 2003), or the Wechsler Intelligence Scales for Children IV (WISC-IV; Wechsler, 2005)

Australian versions. These yield a full-scale IQ, Verbal Comprehension Index, and a Perceptual Reasoning Index. The Wechsler Abbreviated Scales of Intelligence (WASI; Wechsler, 1999) which yields a full-scale IQ, a Verbal IQ, and a Performance IQ, was completed for all typically developing children. The WASI full-scale IQ is comparable to the WISC-IV and WPPSI-III full-scale IQ, the Verbal IQ comparable to the Verbal Comprehension Index of the WISC-IV and WPPSI, and the Performance IQ is comparable to the Perceptual Reasoning Index from the WISC-IV and WPPSI-III (Wechsler, 1999).

Short-term memory was assessed using the digit length forward task and the sentence length task from the Auditory Processing Test (APT; Rowe, Pollard, & Rowe, 2006). The digit span task involves the recorded presentation of digit lists of increasing length which children are instructed to copy. Three trials of each digit length are presented and a child must accomplish 2 out of 3 trials correctly to achieve that digit length. For the sentence length task, children are instructed to copy sentences of increasing length. Children only need to correctly repeat 1 out of 2 trials of the same sentence length to achieve that sentence length.

Visual Attention. The Visearch task (Wilding, Munir, & Cornish, 2001) is a computerized visual search task which shows on a computer screen a picture with trees, a river, and a variety of other objects. Each child is required to search for a certain type of target (e.g., a vertical black ellipse) according to the instructions and to click on it to reveal a monster hidden behind this shape. If the child clicks on the distracter items, the monster does not appear on the screen. There are 20 monsters to be found in each trial. Once all the monsters are found or the frequency of clicking reaches 50, the trial terminates automatically. The single target search condition was used as a practice to familiarize participants with the task. Past research has found that the number of false

alarms to non-targets in the dual target search, in which alternation between two targets is required, are characteristic of poor attention, reflecting not only impulsivity but the additional demands of switching (Wilding, Munir & Cornish, 2001; Wilding, 2003). As false alarms in the single target search have not been found to differentiate groups with differing attentional ability, results from the single search condition were discarded.

Attentional Switching Task. In the Visearch dual-target task the child has to search alternately for the black vertical ellipse then a brown horizontal ellipse to reveal a hidden monster by clicking on the appropriate target. Fifteen targets of each of the two types are present, plus 70 distracters. There is one trial only, with a maximum of 20 targets to be found (10 for the first shape and 10 for the second). The game terminates when all the monsters have been found or a maximum of 50 clicks has been reached. The computer program records the number of false alarms, the type of target the false alarm occurs on, and time taken per hit, with and without errors included. This task is now regarded as a test of the executive control function involved in switching attention between different stimuli (Wilding, Munir, & Cornish, 2001).

Sustained Attention Task. The Vigilan task (WATT) is a computerized vigilance task. Using the same screen display as for the Visearch task (see above), each child has to watch for a yellow border that appears randomly surrounding a target shape on the screen and click on it within seven seconds, after which the yellow border vanishes and a miss is recorded . Sixteen targets appear one by one at irregular intervals. The dependent variables are number of correct targets detected (maximum 16), mean response time to a target, number of false positives, and distance wandered.

Both the Visearch and Vigilan accuracy factors (number of false alarms) have been found to relate to the behavioural ratings of attentional ability, whereas the speed factor (time per hit) is more closely related to IQ (Cornish, Wilding, & Hollis, 2008; Wilding & Cornish, 2007). The

number of hits (the converse of misses) has not been found to differentiate between good and poor attenders in prior studies (Wilding & Cornish, 2007). As such, in this study the accuracy factor in Visearch was used as the measure of attentional switching, and the accuracy factor in Vigilan as the measure of sustained attention in the analyses. The tasks have been found to be sensitive in distinguishing good and poor attenders based on behavioural ratings (Cornish & Wilding, 2010; Cornish et al., 2008). These tasks have been used to study inattention in a range of developmental conditions including Fragile X syndrome, Down Syndrome and William's syndrome and have been able to differentiate these groups across development (Cornish, Scerif, & Karmiloff-Smith, 2007; Scerif, Cornish, Wilding, Driver, & Karmiloff-Smith, 2007).

Academic Achievement. Literacy and numeracy were assessed using two subtests from the Wechsler Individual Achievement Test II Australian version (Wechsler, 2007). Reading achievement was determined using the Word Reading subtest, where children are required to read words from a word card and the total number of words read aloud correctly is recorded. Mathematics achievement was assessed via the Numerical Operations subtest where children are required to solve paper and pencil computations with the total number of correct responses recorded.

ADHD Symptomatology. The Conners 3rd Edition (Conners, 2003) is a commonly used standardized screening instrument that targets ADHD symptomatology. The parent short form consists of 43 items, measuring indices of oppositional behavior problems, hyperactive behavior and inattention problems across the school setting in 3-17 year olds. The inattention and hyperactivity-impulsivity subscales from the parent reported short form were utilised in this

study. Test-retest reliability ranges from .71 to .98 and internal consistency ranges from .77 to .97 (Conners, 2003).

Procedure

The study was approved by Human Research Ethics Committees of Monash University and the Victorian Government Department of Education and Early Childhood. Parents received an explanatory statement and provided written informed consent. Participation was voluntary and participants did not receive any monetary reward for participation other than reimbursement for travel costs.

Parents of participants were invited to participate via email or letter and follow-up telephone call. Participants were tested at a home visit, at the Monash University campus, or at their primary school. The WASI, WISC-IV and subtests from the WIAT-II were administered according to standardized instructions. Participants completed the Visearch and Vigilan task using the same laptop and mouse. Each participant completed a practice trial of the dual search and vigilance tasks prior to the trial to ensure they understood the task instructions. All participants were tested individually in a quiet room, with task presentation counterbalanced across children.

Parents filled out the questionnaires as per their standard instructions. Age-based standardized scores were utilized for the WISC-IV and WASI. Raw scores were used in analyses unless otherwise stated. All data were entered into Statistical Package for the Social Sciences (SPSS) version 17.0 for statistical analyses.

Analyses

The data set was assessed for outliers and deviations from normality. An extreme outlier from the ASD group was detected (>3 standard deviations on the Visearch false alarm task) was

removed from the analysis. All statistical tests were two-tailed. Significance level was set at $p<.01$ to control for multiple comparisons. For bivariate correlations, Pearson correlation coefficients were calculated to determine the degree of relationship between variables. Independent t-tests were used to determine group differences. Where full-scale IQ was associated with a dependent variable in group comparisons, Analysis of Covariance (ANCOVA) covarying for full-scale IQ was also employed.

Results

Demographic and ADHD symptoms

Independent t-tests showed there was no significant difference in the age of the ASD and TYP groups, but the TYP group had higher full-scale IQ, and verbal IQ scores than the ASD group (Table 1). The groups were matched on perceptual IQ's using the adjusted alpha level. Independent t-tests showed the ASD group had significantly higher scores on the parent reported Conners 3 Inattention and Hyperactivity subscales, Table 1.

Table 1

Age and IQ summary for ASD and TYP groups

Variable	ASD Group (N=64) M (SD)	TYP Group (N=60) M (SD)	*t*	*p*
Age in months, M (SD)	118.77 (22.02)	111.87 (20.54)	1.801	.074
Boys:Girls	32:32	30:30		
Full-scale IQ M (SD)	All 96.78 (13.16)	All 107.47 (11.57)	-4.788	.00**
	Boys 97.38 (13.86)	Boys 108.43 (12.00)		
	Girls 96.19 (12.62)	Girls 106.50 (11.25)		
Verbal IQ M (SD)	98.89 (13.78)	107.03 (9.64)	-3.790	.00**
Performance IQ M (SD)	101.08 (14.98)	106.35 (13.51)	-2.054	.042
Conners 3 Inattention Raw Score	8.59 (3.49)	2.77 (2.43)	10.721	.000**
Conners 3 Hyperactivity-impulsivity Raw Score	8.59 (5.01)	2.73 (3.14)	7.660	.000**
Numerical Operations Standard Score	All 87.61 (18.66)	All 97.97 (13.66)	-3.487	.001**
	Boys 89.00 (20.54)	Boys 99.27 (15.98)		
	Girls 86.31 (16.95)	Girls 96.67 (10.99)		
Word Reading Standard Score	All 98.52 (15.66)	All 101.93 (12.90)	-1.322	.189
	Boys 96.53 (17.59)	Boys 102.40 (14.22)		
	Girls 100.50 (13.45)	Girls 101.47 (11.66)		

ASD, Autism Spectrum Disorder; TYP, Typical ** $p<.01$;

Group differences in short-term memory

Independent measures t-tests showed there was no difference in digit length between the TYP (*M*=4.58, *SD*=0.98) and ASD group (*M*=4.44, *SD*=0.97),*t*(120)=-.838, p>.01. As full-scale IQ was correlated with digit-length in the ASD group, Table 3, an ANCOVA was conducted with full-scale IQ as the covariate. This similarly found no difference in digit length between the groups, *F*(1,119)=1.118, *p*>.01. On the sentence length measure, an independent measures t-test found no difference with the TYP group (*M*=12.60, *SD*=1.98) and ASD group (*M*=12.59, *SD*=2.02) performing similarly, *t*(121)=-.035, *p*>.01. As sentence length was correlated with full-scale IQ in both groups, Table 3, an ANCOVA was conducted with full-scale IQ as the covariate. This similarly found no difference in sentence length between the groups, *F*(1,120)=2.615, *p*>.01.

Group differences in Academic Achievement.

Means and standard deviations of the scaled Numerical Operations and Word Reading standard scores are shown in Table 1. Independent measures t-tests showed the ASD group performed significantly lower on the Numerical Operations task than the TYP group, Table 1. There was no difference in Word Reading standard scores between the groups based on t-tests, Table 1. To determine any gender differences, and given academic measures were correlated with full-scale IQ in the ASD group (Table 3), a 2X2 ANCOVA (group X gender) was conducted with full-scale IQ as a covariate. There was no significant difference in the Numerical Operations standard score between the groups, *F*(1,117)=0.500, *p*=.481, or between genders, *F*(1,117)=.397, *p*=.530, nor was there any interaction between these factors, *F*(1,117)=.032,*p*=.858, when full-scale IQ was controlled. For Word Reading, when full-scale IQ was controlled, there remained no significant difference in word reading standard scores between the groups, *F(*1,119)=3.124,

p=.080. There were no gender differences, *F*(1,119)=1.558, *p*=.214, nor interaction between gender and group on Word Reading performance, *F*(1,119)=1.110, *p*=.294.

Group differences in Attentional Switching and Sustained Attention.

VIGILAN. Four of the children with ASD were unable to complete the task and were excluded from the analyses leaving 60 in each group. Independent t-tests to compare group differences found no difference in the number of hits and mean time per hit, Table 2. There was a trend towards more false alarms in the ASD group but this did not reach significance with the corrected alpha level, Table 2. Given false alarms were correlated with full-scale IQ in the ASD group and to compare gender differences, a 2X2 ANCOVA (group X gender) controlling for full-scale IQ was performed. When full-scale IQ was taken into account, there were no significant differences by group or gender for Vigilan hits [group *F*(1,116)=.204 *p*>.01; gender *F*(1,116)=.002, *p*>.01; group X gender *F*(1,116)=3.839, *p*>.01], Vigilan mean time per hit [group *F*(1,116)=.289 *p*>.01; gender *F*(1,116)=.679, *p*>.01; group X gender *F*(1,116)=.000, *p*>.01], and Vigilan false alarms [group *F*(1,116)=1.147 *p*>.01; gender *F*(1,116)=.153, *p*>.01; group X gender *F*(1,116)=.763, *p*>.01].

Visearch Dual Search. Independent measures t-tests were used to compare group differences on the number of false alarms, error types, and mean time per hit with errors removed. There were no significant differences between groups on these variables, Table 2. To compare gender differences, a 2X2 ANOVA (group X gender) was performed or ANCOVA controlling for full-scale IQ when it was correlated with an dependent variable (mean time per hit was correlated with full-scale IQ in the ASD group, *r*=-.356, *p*=.004, and perseverations were correlated with full-scale IQ in the ASD group, *r*=-.329, *p*=.000). Controlling for full-scale IQ, ANCOVA

showed there was no difference in the mean time per hit by group, $F(1,117)=.407$, $p>.01$, or gender, $F(1,117)=.360$, $p>.01$, or group X gender interaction, $F(1,117)=4.594$, $p>.01$. ANOVA also revealed no difference in the total number of false alarms by group, $F(1,118)=1.710$, $p>.01$, or gender, $F(1,118)=2.606$, $p>.01$, nor interaction between gender and group, $F(1,118)=0.655$, $p>.01$. Similarly, ANOVA showed there was no difference in number of repetitions (clicks on previously found targets) by group, $F(1,118)=1.602$, $p>.01$, gender $F(1,118)=0.439$, $p>.01$, and no interaction, $F(1,118)=0.439$, $p>.01$. ANOVA indicated no difference in the number of clicks on distracters by group, $F(1,118)=2.400$, $p>.01$, gender $F(1,118)=0.669$, $p>.01$, and no interaction, $F(1,117)=0.288$, $p>.01$. ANCOVA controlling for full-scale IQ showed there was no difference between the TYP and ASD group on the number of perseverations (failure to switch target type by clicking on another target identical to the previously found target), $F(1,117)=.034$, $p>.01$, or gender, $F(1,117)=4.078$, $p>.01$, and no interaction between group and gender, $F(1,117)=0.418$, $p>.01$.

Table 2

Group differences in Attentional Switching tasks for ASD and TYP groups

Variable	ASD Group M (SD)	TYP Group M (SD)	*t*	*p*
Vigilan (sustained attention)				
Number of hits	All 8.55 (3.06) Boys 9.03 (2.58) Girls 8.03 (3.47)	All 9.42 (3.02) Boys 8.97 (3.40) Girls 9.87 (2.57)	-1.672	.097
Mean time per hit	All 3.54 (0.77) Boys 3.49 (0.68) Girls 3.60 (0.86)	All 3.44 (0.68) Boys 3.38 (0.64) Girls 3.50 (0.72)	0.742	.640
Total False Alarms	All 4.75 (6.06) Boys 4.74 (5.75) Girls 4.76 (5.75)	All 2.62 (3.62) Boys 3.07 (4.14) Girls 2.17 (3.02)	2.535	.013*
Visearch (Attentional Switching)				
Mean time per hit with errors removed	All 2.83 (0.89) Boys 2.62 (0.92) Girls 3.04 (0.84)	All 2.56 (0.81) Boys 2.67 (0.91) Girls 2.46 (0.70)	1.762	.081
Total Errors (False Alarms)	All 4.89 (5.05) Boys 3.80 (4.19) Girls 5.91 (5.61)	All 3.72 (4.58) Boys 3.37 (3.52) Girls 4.07 (5.48)	1.340	.183
Repetitions (clicks on previously found targets)	All .064 (.40) Boys 0.10 (0.55) Girls 0.03 (0.18)	All .000 (.00) Boys 0.00 (0.00) Girls 0.00 (0.00)	1.250	.241
Distracter errors (clicks on Distracters)	All 3.08 (3.53) Boys 2.67 (3.12) Girls 3.47 (3.89)	All 2.15 (2.94) Boys 2.07 (2.50) Girls 2.23 (3.37)	1.578	.117
Perseverations	All .85 (1.99) Boys 0.30 (0.70) Girls 1.38 (2.61)	All .53 (2.37) Boys 0.23 (0.57) Girls 0.83 (3.31)	0.810	.420

P<.05; ASD, Autism Spectrum Disorder; TYP, Typical;

Associations with academic achievement

For the regression analyses, the Numerical Operations task was negatively skewed and normalized with a square root transformation. The Word Reading task was positively skewed and normalized with a reflect and square root transformation, which means lower scores on the transformed variable indicated better performance. A number of other variables could not be transformed to normality: Conners 3 Inattention and Hyperactivity-impulsivity raw scores, and Visearch false alarms, mean time per hit corrected, digit length, sentence length, Vigilan hits, and false alarms. These were entered into analyses without transformation as per Tabachnick and Fidell (2007).

Mathematics. Pearson correlations between the variables (full-scale IQ, age, gender, digit and sentence length, parent reported inattention and hyperactivity subscales, Vigilan and Visearch false alarms) and mathematics achievement for each group are shown in Table 3. Mathematics achievement in the ASD group was significantly correlated with age, full-scale IQ, digit length, sentence length, Vigilan and Visearch false alarms (Table 3). In the TYP group, mathematics achievement was significantly correlated with age, digit length, sentence length, and Visearch false alarms (Table 3).

Table 3

Pearson's correlations between word reading, numerical operations and the variables for the ASD (above the diagonal) and TYP (below the diagonal) groups

	1	2	3	4	5	6	7	8	9	10	11
1. Word Reading Raw (tsfm)	1	**.774****	**.584****	**-.050**	**.536****	**.605****	**.544****	**.245**	**.261**	**.342****	**.206**
2. Numerical Operations Raw (tsfm)	.813**	1	**.717****	**.075**	**.407****	**.539****	**.410****	**-.284**	**-.273**	**.458****	**.434****
3. Age	.717**	.809**	1	**.039**	**-.077**	**.231**	**.307**	**-.004**	**.325****	**-.262**	**-.160**
4. Sex	.060	-.087	-.193	1	**.045**	**-.002**	**-.146**	**.226**	**.291****	**-.039**	**-.210**
5. Full-scale IQ	-.272	.242	-.075	.084	1	**.544****	**.354****	**-.274**	**-.008**	**.348****	**-.286**
6. Digit Length	.470**	.553**	.397**	-.051	.222	1	**.559****	**-.220**	**-.165**	**-.107**	**-.141**
7. Sentence Length	.524**	.465**	.462**	.357**	.306	.368**	1	**.056**	**-.147**	**-.148**	**-.071**
8. Inattention Symptoms	.261	-.139	-.073	.041	-.327	.136	-.231	1	**.426****	**.171**	**.284**
9. Hyperactivity Symptoms	.238	-.072	-.087	.182	-.101	.079	-.222	.473**	1	**.154**	**-.027**
10. Vigilan False Alarms	.108	-.105	-.187	.125	-.208	-.051	-.327	.224	.158	1	**.395****
11. Visearch False Alarms	.332**	-.403**	-.344**	-.077	-.129	-.246	-.194	.136	-.038	.101	1

** p<.01; ASD, Autism Spectrum Disorder; TYP, Typically Developing

Stepwise linear regression analyses were used to predict academic achievement test raw transformed scores from those variables which were significantly correlated, Table 3. Separate stepwise linear regression analyses were conducted for the TYP and ASD groups, Table 4. In the ASD group age, full-scale IQ, Visearch false alarms and digit length were significant predictors of mathematics attainment in the regression. In the TYP group, age and digit length were the significant predictors of mathematics. In the ASD group this analysis was repeated with the children on psychostimulant medication removed. The same predictors remained significant.

Table 4

Results of stepwise regression analysis on Numerical Operations in the ASD and TYP groups

	B	*t*	*p*
ASD Group			
Age	.630	9.218	.000***
Full-scale IQ	.276	3.373	.001**
VISEARCH False Alarms	-.237	-3.530	.001**
Digit Length	.229	2.832	.007**
VIGILAN False Alarms	-.093	-1.155	.254
Sentence Length	.011	0.140	.889
Adjusted R^2	.772		
TYP Group			
Age	.700	9.132	.000***
Digit Length	.275	3.594	.001**
VISEARCH False Alarms	-.109	-1.457	.151
Sentence Length	.055	.669	.506
Adjusted R^2	.708		

**p<.001; ** *p*<.01; ASD, Autism Spectrum Disorder; TYP, Typically Developing

Reading. Pearson correlations between the variables (full-scale IQ, gender, age, digit length, sentence length, behavioural inattention and hyperactivity, Vigilan and Visearch false alarms) and reading achievement for each group are shown in Table 3. Reading achievement in the ASD group was correlated with age, full-scale IQ, Vigilan false alarms, digit length, and

sentence length, Table 3. Reading in the TYP group was correlated with the following: age, digit length, sentence length, and Visearch false alarms, Table 3.

Separate stepwise linear regression analyses were conducted for the TYP and ASD groups with reading achievement as the outcome measure and those variables which correlated for each group as the independent variables, Table 5. In the ASD group age and full-scale IQ were significant predictors of reading attainment in the regression. In the TYP group, age accounted for a significant amount of the variance in reading. In the ASD group the regression was repeated with children on psychostimulant medication removed. The same findings emerged.

Table 5

Results of stepwise regression analysis on Word Reading in the ASD and TYP groups

	B	*t*	*p*
ASD Group			
Age	-.501	-6.317	.000***
Full-scale IQ	-.478	-5.131	.000***
Digit Length	-.230	-2.412	.019
Sentence Length	-.134	-1.424	.160
VIGILAN False Alarms	.033	.354	.725
Adjusted R^2	.669		
TYP Group			
Age	-.604	-6.103	.000***
Sentence Length	-.245	-2.474	.016
Digit Length	-.175	-1.821	.074
Visearch False Alarms	-.095	-1.025	.310
Adjusted R^2	.546		

***p<.001; ** *p*<.01; ASD, Autism Spectrum Disorder; TYP, Typically Developing

Discussion

This study aimed to understand the associations between measures of attention and academic achievement in children with ASD and typically developing children. The main finding was that although academic attainment and performance on sustained attention and

attention switching tasks were relatively similar in TYP and ASD children, attentional switching was associated with mathematics attainment in children with ASD, with this relationship not a significant factor in typical children in regression analyses. Children with ASD who made more errors on a visual search dual task were likely to have lower mathematics attainment than those who made fewer errors. This finding highlights that although not impaired in all children with ASD, the ability to switch attention, a critical aspect of executive control, when deficient, is associated with detrimental functional outcomes in mathematics. Mathematics knowledge is important for various daily living skills such as estimation, cooking, and budgeting, hence, impairment in this domain can have significant impacts on adaptive behaviour.

Our hypothesis that parent-reported inattention and hyperactivity symptoms as well as measures of attentional switching and sustained attention would be associated with mathematics attainment was partially supported. The accuracy factors from a sustained attention and attentional switching task were negatively correlated with mathematics achievement in children with ASD. For typically developing children, only attentional switching was correlated with mathematics performance. When all the factors including age, and IQ were taken into consideration, a regression analysis showed that for children with ASD, attentional switching, as measured by the accuracy factor on a visual search dual task, explained a significant amount of variance in mathematics attainment in children with ASD. The relationship showed that higher levels of attentional switching errors were associated with poorer mathematics outcomes in children with ASD. Mayes and Culhoun (2007) found a sustained visual attention task contributed to mathematics (and reading) attainment in a group of children including a subgroup with ASD. In the present study errors on the sustained attention task were correlated with mathematics attainment. In the overall regression model however, sustained attention was not a significant factor in the prediction of mathematics.

This may have been due to the overlap in variance between the sustained attention and attentional switching tasks, with the latter being significant in the model as discussed, whereas, the Mayes and Culhoun study did not include a measure of attentional switching. Hence, the present results appear largely consistent with the findings of Mayes and Culhoun with both studies showing cognitive components of attention are associated with mathematics attainment in children with ASD.

The present findings mirror that which has been found in ADHD (Biederman et al., 2004), where children with ADHD plus EF deficits had poorer academic outcomes than ADHD minus EF deficits as well as controls with or without EF deficits. Biederman and colleagues did not find differences in behaviourally reported ADHD symptoms between those with or without EF deficits, indicating EF may not simply be an expression of ADHD clinical symptoms. These authors suggested that typically developing children were not significantly impacted by EF deficits because they may not have reached a dysfunction threshold whereas children with ADHD already had numerous impairments (such as psychiatric comorbidity and social impairments) and thus an additional EF deficit might trigger academic difficulties. This may be similar for children with ASD where attention switching difficulties in combination with a compromised cognitive system are associated with poorer mathematics attainment. What factors were related to poor attentional switching in the ASD group other than lower mathematics attainment were not identified in this study but would be an important area for future investigation.

Regarding word reading, our hypothesis that reading would also be associated with parent reported attention symptoms, attentional switching and sustained attention was partially supported. In the TYP group only attentional switching was associated with reading, whereas, in the ASD group, sustained attention was correlated with reading. However, none of these factors were significant in the regression analyses in the TYP or ASD groups. Age,

and full-scale IQ were the factors which explained a significant amount of the variance in word reading attainment in the ASD group and age in the TYP group. Further examination of what other factors might contribute to the reading attainment of children with ASD is an area which requires investigation. For example, the exclusive use of a parental report measure to determine the severity of inattentive and hyperactive symptoms was a limitation of the present study. Although parents may be well informed about their child's behavior in the home environment they are less aware of their child's behavior in a broader context, such as in the school environment. Past studies of children with ASD have linked teacher reports of behavioural inattention to lower academic achievement (Ashburner, Ziviani, & Rodger, 2008) or combined teacher and parent reports (Asberg et al., 2010). Hence, including teacher reports of ADHD symptoms when investigating academic attainment would be an important extension of the current work.

Our hypothesis that children with ASD would perform more poorly on the attentional switching task but not the sustained attention task was only partially supported. There were no group differences on the sustained attention task. Some past studies have indicated that sustained attention may be largely intact in children with ASD (Johnson et al., 2007) and our findings appear consistent with this. Contrary to the hypothesis, no group differences in the attentional switching task were found, with or without full-scale IQ taken into account. Given the inconsistent findings for whether attention switching is impaired in ASD, our findings in this regard are not entirely unexpected (Kaland, Smith, & Mortensen, 2008; Russell, Jarrold, & Hood, 1999).

For academic attainment we found that children with ASD showed poorer mathematics attainment than typically developing children, however when full-scale IQ was considered both groups performed similarly. There was no group difference in word reading, with or without full-scale IQ covaried. This finding is consistent with past studies which have

found that reading accuracy (rather than reading comprehension) in ASD is usually intact (Heumer & Mann, 2010; Nation et al., 2006), which may relate to good rote learning and even hyperlexia in some individuals with ASD (Mayes & Calhoun, 2003; 1999; Rumsey, 1992). Our findings are consistent with past research which shows at the group level, individuals with ASD show similar academic achievement to TYP children (Nation et al., 2006; Chiang & Lin, 2007).

A strength of the present study was the inclusion of half female participants, given that females have been under-represented in ASD research to date (Thompson, Caruso, & Ellerbeck, 2003). Our findings in this regard were that there were no gender differences on the sustained attention or attention switching tasks. These findings are somewhat different to a past study of a response inhibition stop task, where females with ASD performed more poorly than boys with ASD (Lemon et al., 2011). However, the tasks were of different executive control mechanisms, and importantly, there were only a small number of participants in the Lemon et al. study which may explain the difference. There were no differences in reading and mathematics performance between boys and girls with ASD. To our knowledge this is the largest study of mathematics achievement in girls with ASD containing a matched group of boys with ASD and controls, and findings indicate gender parity in this domain.

Although this was the first known attempt to investigate the interplay between attention symptoms and underlying components of cognitive attention with academic outcomes in children with ASD, including both males and females, future research needs to incorporate a broader range of literacy and numeracy measures that vary in complexity and are sufficiently sensitive to capture subtle changes in performance. For example, the present study may have been constrained by including relatively basic academic measures such as single word reading. Additional measures of reading fluency and reading comprehension may have be more closely associated and sensitive to changes in attentional constructs in the

groups. It is also clear that these results cannot be generalized to all children with ASD, particularly given that our cohort was high functioning and included no child with an IQ in the atypical range. A further extension of this work would be to include a more representative sample of children with ASD such as those with intellectual disability, and to compare across disorders, such as in children with ADHD without ASD features.

Despite these limitations, this study has highlighted the importance of attentional switching particularly regarding the mathematics attainment of children with ASD. This work provides directions for early interventions that specifically target mathematics development in children with ASD. The findings underscore the importance of identification or screening of not only parent reported ADHD symptoms but also the underlying cognitive constructs of attention in primary school age children with ASD, and provides an example of functional outcomes of attentional switching difficulties. For teachers, although the symptoms of inattention and hyperactivity-impulsivity are related to poor mathematics outcomes, interventions aimed at improving the visual switching of attention may be most useful. Importantly, academic achievement is strongly related to future life outcomes including earning capacity and employment. Essential daily living skills such as budgeting, and understanding the value of money require basic mathematics skills. The present findings may relate to why seemingly high-functioning individuals with ASD can have difficulties in these areas given the ability to switch attention was an important factor beyond full-scale IQ in determining mathematics achievement.

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Monash University

Declaration for Thesis Chapter 7

In the case of Chapter 7, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Project design, review of relevant literature, attainment of ethics approval, recruitment and all testing of research participants, analysis of data and writing of manuscript.	70%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	**Nature of contribution**
Prof. Nicole Rinehart	Contributed to project design and provided input during final draft stage of manuscript.
Prof. Kim Cornish	Contributed to project design and provided input during final draft stage of manuscript.
Dr. John Wilding	Contributed to project design and provided input during data analysis and final draft stage of manuscript.

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work*.

Candidate's Signature		**Date**
Main Supervisor's Signature		**Date**

*Note: Where the responsible author is not the candidate's main supervisor, the main supervisor should consult with the responsible author to agree on the respective contributions of the authors.

Chapter 7 Gender differences in academic and executive functioning over time and inter-relationships

Preamble to Paper 5

The previous paper examined academic performance and executive functioning in high-functioning children with ASD using a cross-sectional design. The final paper extends this to examine developmental trajectories by incorporating two measurement points, one year apart. This paper again explores whether there are gender differences in reading, mathematics, sustained and switching attention over two time points. It then examines the developmental trajectories of these factors over time. Finally it examines inter-relationships to determine which factors at the first time point might predict academic performance at the second time point. This is the final paper in a series of five empirical papers which seek to define the gender profile of ASD in relation to neuropsychological and academic functioning. This paper has been submitted for publication to the Journal of Experimental Child Psychology.

May, T., Rinehart, NJ., Wilding, J., & Cornish, K. (Submitted). Understanding the role of attentional switching in academic outcomes for boys and girls with Autism Spectrum Disorder: A one-year follow-up study.

Paper 5: Understanding the role of attentional switching in academic outcomes for boys and girls with Autism Spectrum Disorder: A one-year follow-up study

Children with Autism Spectrum Disorder (ASD) show impairment in attentional switching, yet how this might affect academic performance is poorly understood. This study examined the impact of attention on the development of reading and mathematics abilities in children with ASD over time. Gender was also considered in this study design to provide further insights into possible academic differences which may be exacerbated in the autism population. Normally intelligent 7 to 12 year olds (ASD N=64; typical developing [TYP] N=60) with equal numbers of boys and girls, were assessed at Time 1 and one year later (ASD N=56; comparison N=52). Measures were collected for Word Reading and Numerical Operations performance and computerised tasks tapping attention switching and sustained attention. There were no *gender* differences in reading, mathematics, attention switching or sustained attention. Children with ASD had lower mathematics, but similar reading attainment to TYP children. Children with ASD made more attention switching errors than TYP children but performed similarly on the sustained attention task. There were no group differences in the rate of development of academic and attention skills over the year. In children with ASD attentional switching errors predicted poorer mathematics ability one year later with this relationship not present in TYP children. These findings reveal gender parity in ASD in objective academic and attentional measures. The clinical and educational implications of these findings are discussed.

Keywords: Autism Spectrum Disorder, Reading, Mathematics, Gender, Attention Switching

Highlights

- We examined the academic attainment of children with Autism Spectrum Disorder (ASD) and investigated whether attentional components constrained later academic outcomes
- Children with ASD performed similarly in regard to reading, but had poorer mathematics attainment to typical children.
- Children with ASD made more errors than typical children on an attention switching task but performed similarly on a sustained attention task
- Attention switching ability constrained mathematics attainment in children with ASD but not typically developing children
- There were no *gender* differences in reading, mathematics, sustained attention and switching attention tasks in children with ASD, a robust finding over two time points

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition typified by social deficits, communication disturbance and restricted interests (American Psychiatric Association, 2000). One theory of ASD proposes these core symptoms are underpinned by dysfunction in the ability to plan and organize goal-directed behaviour, often referred to as Executive Functioning (EF; Pennington & Ozonoff, 1996). EF is a broad term for a range of attentional components, including working memory, the ability to *switch* attention according to changes in the environment and the ability to *sustain* attention on the task at hand. While the ability to switch attention is typically found to be impaired in ASD (see Ames & Fletcher-Watson, 2010; Hughes & Russell, 1993; but see also Kaland, Smith, & Mortensen, 2008; Lopez, Lincoln, Ozonoff, & Lai, 2005; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001; Russell, Jarrold, & Hood, 1999; Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008), sustained attention appears generally intact (Johnson et al., 2007).These components of attention develop gradually over-time in typically development children (Zhan et al., 2011). In children with ASD the developmental path of these attentional components has not been thoroughly established yet mapping this path is important given that EF underpins the development of core life skills such as the ability to learn, organize and plan.

Ozonoff and McEnvoy (1994) examined a planning efficiency task (Tower of Hanoi) and a switching task in adolescents with ASD and did not find improvement in task performance at three year follow-up. Griffith, Pennington, Wehner, and Rogers (1999) found no improvement after one year on a cognitive flexibility task in preschoolers with autism. In contrast to these findings, Pellicano (2010) showed that although children with autism, aged 4 to 8 years, performed more poorly than control children on a set-shifting and planning task (Tower of London), there was greater gain in planning ability after 3 years than in control children. This suggested a lag in the development of these functions as well as a different rate of development. The discrepant findings of these studies may relate to the different age ranges

and tasks examined, given that the components of attention show unique developmental trajectories in typically developing children. For example, Zhan and colleagues (2011) examined typically developing children and found that accuracy on a sustained attention task peaked by 9 years of age, compared with around 14 years of age for accuracy on an attention switching task (Zhan et al., 2011). A lag in development of these attention components may have implications for a range of downstream dependent functions. In typical development these components have been shown to gate critical outcomes such as learning and academic attainment (Clark, Pritchard, & Woodward, 2010; Steele, Karmiloff-Smith, Cornish, & Scerif, 2012). Hence children with ASD who have delays and atypical development of attentional components may be at risk for later academic difficulties.

An uneven pattern of idiosyncratic academic strengths and weaknesses is generally present in individuals with ASD with achievement at the group level similar to typically developing children (Chiang & Lin, 2007; Nation, Clarke, Wright, & Williams, 2006; Whitby & Mancil, 2009). The relationship between EF deficits and poor academic functioning has been established in other neurodevelopmental conditions with marked EF impairment, for example Attention Deficit Hyperactivity Disorder (ADHD; Daley & Birchwood, 2010; Thorell, 2007). For example, inattentive behaviour in kindergarten children, but not hyperactive behaviour, predicts poor reading outcomes in Grade 1 and also in Grade 5, independent of kindergarten reading-related skills and concurrent levels of hyperactivity (Rabiner & Coie, 2000). Inattentive behaviour in the classroom is also strongly associated with mathematics difficulties in elementary-school children (Dobbs, Doctoroff, Fisher, & Arnold, 2006; Fuchs et al., 2005) and predicts poorer response to evidence-based reading and math instruction (Fuchs et al., 2005; Rabiner & Malone, 2004). Surprisingly few studies have examined the relationships between attentional components in ASD and academic performance despite established attention switching difficulties and high rates of comorbid

ADHD (Leyfer et al., 2006). ADHD symptoms have been associated with academic underachievement in ASD (Asberg, Kopp, Berg-Kelly, & Gillberg, 2010; Ashburner, Ziviani, & Rodger, 2010; Mayes & Calhoun, 2007; Yoshida & Uchiyama, 2004). Mayes and Calhoun (2007) found sustained attention (using a continuous performance task) concurrently predicted reading and mathematics performances. A limitation of this study was that the sample included a range of clinical conditions including ADHD. Switching attention but not sustained attention was found to concurrently predict mathematics but not reading attainment in children aged 7 to 12 with ASD (May, Rinehart, Wilding, & Cornish, 2013).

To date there have been very few *gender* comparisons of EF and academic performance in ASD. Many more males than females are diagnosed with ASD with an average gender ratio of 4.3 males to each female (Fombonne, 2003). One study found females performed more poorly than males on a response inhibition task, however, the small sample size makes this finding exploratory (Lemon, Gargaro, Enticott, & Rinehart, 2010). A larger study found no gender differences in a measure of sustained and switching attention in children with ASD (May et al., 2013). Academically, girls with ASD appear to have similar reading ability to typically developing girls (Asberg et al., 2010), however, there are surprisingly no studies of the mathematics performance of females with ASD, with most studies in this area examining only males or too few females to perform gender comparisons (Jones et al., 2009; Mayes & Calhoun, 2003; Minshew, Goldstein, Taylor, & Siegel, 1994).

The purpose of the present study was to extend our cross-sectional study (May et al., 2013) to understand any group or gender differences in the development of academic achievement and sustained and switching attention in children with ASD compared to typically developing children. Based on prior studies in regard to gender and academic performance (Asberg et al., 2010), given a well-matched group of normally intelligent boys and girls with ASD, it was expected there would be no *gender* differences in reading,

mathematics, sustained and switching attention over time. Secondly, it was predicted that children with ASD would show more difficulties on the attention switching task, but comparable performance to controls in regard to sustained attention, reading and mathematics attainment. Thirdly, it was hypothesized that for children with ASD there will be a stronger association between attention switching difficulties and poor academic attainment. Finally, it was predicted that for children with ASD there would be an association between academic progress over the year and attention switching.

Method

Participants

At Time 1, 124 children aged between 7 and 12 years were recruited. This included 64 children, 32 male and 32 female, with Autistic Disorder or Asperger's Disorder. Only children who had a current diagnosis of ASD from their paediatrician or psychologist were invited into the study. The DSM-IV-TR criteria for Autistic Disorder (16 male, 7 female) or Asperger's Disorder (16 male, 25 female) was confirmed for all clinical participants using our standard process involving reviewing diagnostic reports from registered psychologists and paediatricians with a symptom checklist to ensure the DSM-IV-TR criteria were fulfilled. In addition, all participants scored within the clinical range on the Social Responsiveness Scale parent report (Constantino, 2002). Participants were recruited through the Monash University Centre for Developmental Psychology and Psychiatry, the Autism Victoria 'Get Involved' volunteer register, and from private clinics in the Melbourne metropolitan area. Only children with a full-scale IQ of 70 and above were included. Seven of the 64 children with ASD (2 female, 5 male) were taking psychostimulant medication (5 methylphenidate and 2 atomoxetine) at Time 1. At Time 2, four females and six males with ASD were taking psychostimulant medication (7 methylphenidate and 2 atomoxetine with one participant taking both). Sixty typically developing children, 30 male and 30 female, were recruited from

a Melbourne metropolitan Primary School. These children were screened to ensure they had no history of developmental disability or psychopathology according to both parent and teacher report. Children were excluded if they had a history of brain injury or any genetic disorders (such as Fragile X syndrome).

Of the 64 children in the ASD group, 56 were reassessed at Time 2 (28 males and 28 females), which was a drop-out rate of 12.5%. Of the 60 typically developing children, 52 were reassessed at Time 2 (26 males and 26 females), with a drop out rate of 8.6% percent. Drop out was due to not being able to contact families, or due to parent report of being too busy to participate in Time 2.

Measures

Intellectual functioning. Intellectual functioning was assessed at Time 1 using the Wechsler Intelligence Scale for Children IV (WISC-IV; Wechsler, 2005) Australian version in children with ASD, and the Wechsler Abbreviated Scales of Intelligence (Wechsler, 1999; WASI) for TYP children. The WASI Verbal IQ is comparable to the WISC-IV Verbal Comprehension Index, and the WASI Performance IQ is comparable to the WISC-IV Perceptual Reasoning Index (Wechsler, 1999).

*Short-term memory. A*t Time 1 and 2 the digit length forward task and the sentence length task from the Auditory Processing Test were administered (APT; Rowe, Pollard, & Rowe, 2006).

Attention Switching Task. The Visearch dual-target task from the Wilding Attention Tasks (WATT; John Wilding, Munir, & Cornish, 2001) is a computerized visual search task. The participant has to search alternately for a black vertical ellipse then a brown horizontal ellipse to reveal a hidden monster by clicking on the appropriate target. Fifteen targets of each of the two types are present, plus 70 distracters. There is one trial only, with a maximum of 20 targets to be found (10 for the first shape and 10 for the second). The game terminates when

all the monsters have been found or a maximum of 50 clicks has been reached. The computer program records the number of false alarms, the type of target the false alarm occurs on, and time taken per hit, with and without errors included. This task is regarded as a test of the executive control function involved in switching attention between different stimuli (Wilding et al., 2001). Past research has found that the number of false alarms to non-targets in the dual target search, in which alternation between two targets is required, is characteristic of poor attention, reflecting not only impulsivity but the additional demands of switching (Wilding et al., 2001; Wilding, 2003). This task was administered at Times 1 and 2 using the same scene.

Sustained Attention Task. The Vigilan task (WATT) is a computerized vigilance task using the same screen display as for the Visearch task (see above). Each child has to watch for a yellow border that appears randomly surrounding a target shape on the screen and click on it within seven seconds, after which the yellow border vanishes and a miss is recorded. Sixteen targets appear one by one at irregular intervals. The number of correct targets detected (maximum 16), mean response time to a target, number of false positives, and distance wandered were recorded. Both the Visearch and Vigilan accuracy factors (number of false alarms) have been found to relate to the behavioural ratings of attentional ability, whereas the speed factor (time per hit) is more closely related to IQ (Cornish, Wilding, & Hollis, 2008; Wilding & Cornish, 2007). In this study the accuracy factor (false alarms) in Visearch was used as the measure of attention switching, and the accuracy factor (false alarms) in Vigilan as the measure of sustained attention. This task was administered at Times 1 and 2 using the same scene.

Academic Achievement. Literacy and numeracy were assessed at Times 1 and 2 using two subtests from the Wechsler Individual Achievement Test II Australian version (Wechsler, 2007). Reading achievement was determined using the Word Reading subtest, where children were required to read words from a word card and the total number of words read aloud

correctly is recorded. Mathematics achievement was assessed via the Numerical Operations subtest where children were required to solve paper and pencil computations with the total number of correct responses recorded.

Procedure

The study was approved by the Human Research Ethics Committees of Monash University and the Victorian Government Department of Education and Early Childhood. Parents received an explanatory statement and provided written informed consent and children provided assent. Participation was voluntary and participants did not receive any monetary reward for participation other than reimbursement for travel costs.

At Time 1 and 2 parents of participants were invited to participate via email or letter and follow-up telephone call. Participants were tested at a home visit, at Monash University, or at their primary school. Participants completed the Visearch and Vigilan tasks using a laptop and mouse. All participants were tested individually in a quiet room, with task presentation counterbalanced across children. All data were entered into Statistical Package for the Social Sciences (SPSS) version 21.0 for statistical analyses.

Analyses

Distributions and outliers were assessed for each variable by group. An outlier in the Time 1 Visearch false alarms variable which was greater than 3 standard deviations from the mean was removed from the ASD group. The Time 1 variables Visearch and Vigilan false alarms, digit and sentence length were non-normally distributed and were not improved with transformation. These were entered into analyses without transformation as per Tabachnick and Fidell (2007). Time 1 Numerical Operations raw score was negatively skewed and normalized with a square root transformation. The Time 1 Word Reading raw score was positively skewed and normalized with a reflect and square root transformation, which means

lower scores on the transformed variable indicated better performance. The Time 2 Word Reading raw score was normally distributed in both groups. The Time 2 Numerical Operations raw score was non-normally distributed and normalised with a log 10 transformation. For the Time 2 Visearch false alarms variable, an outlier in the ASD group which was greater than 3 standard deviations from the mean was removed and normality was improved via a log 10 transformation.

Independent t-tests and Analysis of Variance (ANOVA) were used to compare the groups on demographic variables. To compare group and gender differences over time Repeated Measures ANCOVA were employed controlling for any demographic group differences. Given non-normal distribution of some variables, Spearman correlations were used to examine the relationships between the outcome variables (reading and mathematics) and the predictors. The second stage comprised the multivariate analysis examining the impact of attention switching on reading and mathematics performance as moderated by group (ASD or TYP). In linear regression analysis, the control variables (age, verbal IQ, digit and sentence length), attention switching, group and the interaction term will be entered using stepwise entry (computed by the product term of attention switching and group), after centering attention switching in the interaction term. This interaction term allows the assessment of whether group (moderator variable) affects the direction and/or strength of the relationship between attention switching and the dependent variable (Baron & Kenny, 1986). If the interaction term is significant in the predictive model, further post-hoc probing using simple slopes analysis will be conducted. Finally, to determine if attention switching was associated with *change* in academic performance over the year, hierarchical regression analyses were calculated with Time 1 academic performance entered as the first step and control variables and attention switching as the second step. Bonferonni corrections were employed for post hoc tests.

Results

Demographic information

An independent t-test showed there was no difference in the time interval between Time 1 and Time 2 testing for the ASD (*M*=12.9 months, *SD*=1.1 months) and TYP group (*M*=12.7 months, *SD*=1.0 months), *t*(106)=1.241, *p*=.271, *Cohen's d*=.24. There was no gender difference in the number of males and females at Time 1 or Time 2 with half in each of the ASD and TYP groups being female. Two by two ANOVAs (group X gender) showed no *gender* differences in age, verbal IQ, and perceptual IQ and no interactions between gender and group. At Time 2 the ASD group were significantly older than the TYP group, $F(1,107)=5.639$, $p=.019$, $\eta_P^2=.057$. IQ was assessed only at Time 1, where there were significant group differences with the TYP group having higher verbal IQ $F(1,120)=14.146$, $p<.001$, $\eta_P^2=.105$,and perceptual IQ, $F(1,120)=4.306$, $p=.040$, $\eta_P^2=.035$. Hence, age and verbal IQ were used as covariates in group comparisons.

Switching and sustained attention over time

Spearman correlations revealed significant relationships between Time 1 and Time 2 measures of Vigilan false alarms [ASD group $r=.365$, $p=.007$; TYP group $r=.304$, $p<.029$] and Visearch false alarms in the ASD group $r=.308$, $p=.025$, but not TYP group $r=.096$, $p>.05$. To determine any group or gender differences in switching and sustained attention, two repeated measures ANCOVA's controlling for age and verbal IQ were conducted with time as the repeated measure and group and gender as the between subjects factors. Bonferonni corrections were employed (.05/2=.025). There were no significant main effects of group, time, and gender and no interactions for Vigilan false alarms, indicating no differences in sustained attention over time, for the ASD and TYP groups and for boys and girls. As predicted, there was a significant main effect of group for Visearch false alarms,

indicating the ASD group made more errors on this attention switching task than the TYP group, $F(1,99)=8.243$, $p=.005$, $\eta_P^2= .077$. There were no changes in switching attention over time, and no differences between boys and girls.

Reading and mathematics over time

Two males with ASD did not complete the Numerical Operations task leaving 54 in the ASD group. Spearman correlations revealed significant relationships between Time 1 and Time 2 measures of Word Reading raw scores [ASD group $r=.962$, $p<.001$; TYP group $r=.924$, $p<.001$] and Numerical Operations raw scores [ASD group $r=.955$, $p<.001$; TYP group $r=.804$, $p<.001$]. To examine if there were any differences in academic performance over time and whether performance differed by group or gender, four repeated measures ANCOVA's controlling for age and verbal IQ were conducted with time (Time 1 and Time 2) as the repeated measure and group and gender as the between groups factors, with scaled and raw scores from Word Reading and Numerical Operations tests as dependent variables. Bonferonni corrections were employed (.05/4=.0125). As predicted, there was no difference in the Word Reading scaled score over time, and no difference between the ASD and TYP children or boys and girls, with or without age and verbal IQ covaried. Unexpectedly, for the Numerical Operations scaled score over time, the TYP group performed significantly better than the ASD group with [$F(1,102)=16.209$, $p<.000$, $\eta_P^2=.138$] and without [$F(1,102)=6.788$, $p<.011$, $\eta_P^2=.064$] verbal IQ, controlled. As expected there were no gender differences in mathematics performance. For mathematics, the main effect of time approached but did not reach significance with corrected p values, $F(1,102)=4.582$, $p<.035$, $\eta_P^2=.043$. In regards to raw scores, there was a significant improvement in Word Reading raw score over time, $F(1,102)=49.880$, $p<.001$, $\eta_P^2=.328$, and no group or gender differences. For the Numerical Operations raw score there was no main effect of time, group or gender, and no interactions.

Table 1

Time 1 and 2 Demographic, academic and attention variables for the TYP and ASD groups

Variable	*Time 1*		*Time 2*	
Time 1	ASD N=64 M (SD)	TYP N=60 M (SD)	ASD M (SD)	TYP M (SD)
Age (months)	118.77 (22.02)	111.87 (20.54)	131.4 (22.4)	121.4 (18.9)
Verbal IQ	98.89 (13.78)	107.03 (9.64)		
Perceptual IQ	101.08 (14.98)	106.35 (13.51)		
Numerical Operations Standard Score	All 87.61 (18.66) Boys 89.00 (20.54) Girls 86.31 (16.95)	All 97.97 (13.66) Boys 99.27 (15.98) Girls 96.67 (10.99)	All 88.7 (17.0) Boys 91.6 (17.9) Girls 86.3 (15.9) (N=54)	All 100.1 (13.5) Boys 101.1 (15.9) Girls 97.8 (10.3) (N=52)
Numerical Operations Raw Score	18.7 (7.9)	19.5 (7.3)	21.9 (8.6) (N=54)	22.3 (7.9) (N=52)
Word Reading Standard Score	All 98.52 (15.66) Boys 96.53 (17.59) Girls 100.50 (13.45)	All 101.93 (12.90) Boys 102.40 (14.22) Girls 101.47 (11.66)	All 98.7 (14.9) Boys 97.9 (16.2) Girls 99.5 (13.8) (N=54)	All 102.9 (11.4) Boys 103.2 (12.3) Girls 102.6 (10.9) (N=52)
Word Reading Raw Score	98.7 (18.9)	97.1 (18.0)	104.9 (14.8) (N=56)	104.0 (12.9) (N=52)
Digit Span	4.4 (1.0)	4.6 (2.0)	4.6 (1.1) (N=53)	4.7 (0.9) (N=52)
Sentence Length	12.5 (2.0)	12.6 (2.0)	13.3 (2.4) (N=53)	13.3 (2.2) (N=52)
Vigilan false alarms	5.0 (6.3) (N=61)	2.6 (3.6)	5.0 (6.8) (N=53)	3.1 (3.5) (N=52)
Visearch false alarms	4.9 (5.1) (N=62)	3.7 (4.6)	3.7 (4.2) (N=53)	1.5 (1.7) (N=52)

Correlations with Time 1 Control and Attention Variables and Time 2 Academic Measures

Spearman's correlations were used to assess the relationships between the Time 1 attention measures and the Time 2 academic measures (Table 2). Visearch false alarms were negatively associated with mathematics and reading in both groups, however, with the Bonferroni corrected p value (05/9=.005), the relationship only remained significant for mathematics in the ASD group, r^2=.198. Vigilan false alarms were negatively correlated with both mathematics and reading in the ASD group but this correlation only remained significant with mathematics after p-value correction, r^2=.182.

Table 2

Spearman's correlations between Time 2 Word Reading and Numerical Operations and Time 1 predictors for the ASD and TYP groups

Time 1 Predictors	*Time 2 Numerical Operations Raw (log 10)*			*Time 2 Word Reading Raw Score*		
	Whole sample	ASD	TYP	Whole Sample	ASD	TYP
Age	**.752*** **	**.756*** **	**.786*** **	**.589*** **	**.481*** **	**.676*** **
Gender	.099	.161	-.015	-.009	.023	-.064
Verbal IQ	**.274** **	**.381** **	.199	**.393** **	**.579*** **	.339*
Digit Length	**.467*** **	**.542*** **	**.385** **	**.555*** **	**.643*** **	**.452** **
Sentence Length	**.417*** **	**.376** **	**.511** **	**.514*** **	**.534*** **	**.501** **
Vigilan False Alarms	-.306**	**-.427** **	-.163	-.203*	-.315*	-.116
Visearch False Alarms	**-.378*** **	**-.445** **	-.298*	-.255**	-.291*	-.244

Note: Correlations were corrected for multiple comparisons, .05/9=.005. Those correlations with significance levels at or below this p value have been bolded.

***p<.001, ** *p*<.01; * *p*<.05;

The role of Time 1 attention switching in predicting Time 2 Academic Performance

The following research question was tested using multiple regression analysis: Does group moderate the extent to which greater attention switching difficulties are associated with poorer academic performance? To do so, the interaction term of group and switching attention was computed. The attention switching variable was first centered by subtracting the sample mean from all individual scores, in an effort to reduce multicollinearity and allow for simple slopes analysis (Aiken & West, 1991). No multicollinearity was present among the independent variables (Tolerance>.10 and VIF<10). The predictors entered into the regression analysis were age, verbal IQ, digit span, sentence length, Visearch false alarms, group (ASD or TYP) and the interaction term (Visearch false alarms X group). Table 3 presents the unstandardized coefficients, standard error and standardized beta coefficients for regression analysis on the entire sample. For Word Reading, digit length and age were the significant predictors. For Numerical Operations, age, verbal IQ, digit length, group X switching, and group were significant predictors. As the interaction term was significant, post-hoc probing was conducted (Aiken & West, 1991). Further regression analysis for both groups was conducted and indicated attention switching was significant in predicting mathematics for the ASD group, (β=-.225, p<.01), but not for the TYP group (β=-.116, p>.05). From the regression equations mean Numerical Operations scores were calculated one standard deviation above and one standard deviation below the whole sample centered mean of Visearch False Alarms (Figure 1).

Table 3

Results of regression analysis on Time 2 Word Reading and Numerical Operations in the whole sample using Time 1 measures as predictors.

	Model Summary			
	B	*SE*	*β*	*T*
Time 2 Numerical Operations raw log 10				
Age	.003***	.001	.245	4.284
Verbal IQ	.036***	.009	.225	4.028
Digit Length	-.008***	.002	-.180	-3.565
Group X Visearch false alarms	-.044**	.017	-.138	-2.530
Group	.005**	.000	.705	12.901
R^2	.747			
F for change in R^2	61.835			
Time 2 Word Reading raw				
Digit length	4.277	.926	.322	4.621
Age	.317	.041	.510	7.749
Verbal IQ	.370	.069	.364	5.359
R^2	.605			
F for change in R^2	28.723			

***p<.001; ** *p*<.01;

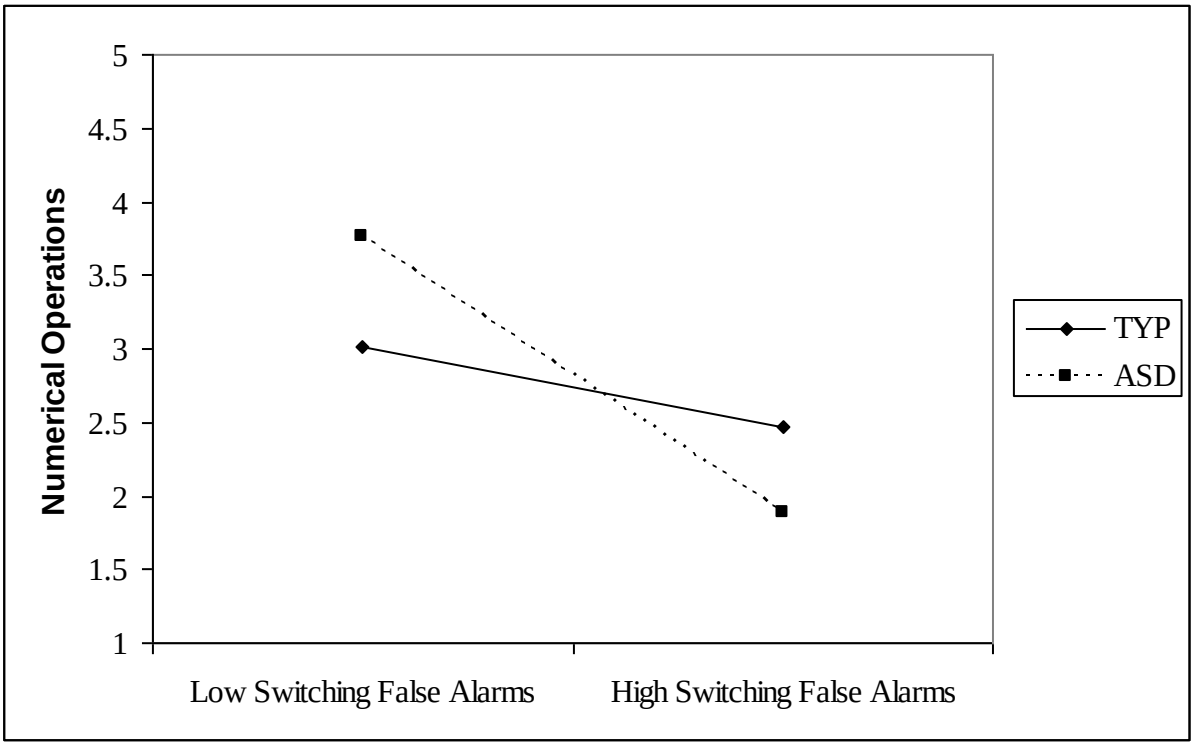

Figure 1. Interaction of Switching False Alarms and Group on Numerical Operations (raw transformed score).

Predictors of the change in academic progress over 1 year

The final research question was to determine if the change in academic performance over the year was associated with attention switching. Two hierarchical regression analyses were conducted with either Time 1 Numerical Operations or Time 1 Word Reading performance as the first step, and age, verbal IQ, digit and sentence length, switching attention, group, and switching attention by group in the second step with either Time 2 Numerical Operations or Time 2 Word Reading as the predictor. Contrary to our prediction, for Time 2 Numerical Operations, after accounting for Time 1 Numerical Operations performance, only age and verbal IQ were significant predictors. Similarly, for Time 2 Word

Reading, there were no significant predictors after accounting for Time 1 Word Reading performance.

Discussion

The aim of this study was to investigate whether children with ASD and typically developing children differed over time in regard to reading, mathematics and switching and sustained attention and to determine whether there were inter-relationships between these factors. The study found no difference between TYP and ASD children in regard to performance on a sustained attention task, and reading achievement over one year. Children with ASD made more errors on an attention switching task and also had lower mathematical attainment. The study found no gender differences in any of these areas. Finally, attention switching at baseline predicted later mathematics (but not reading) outcomes in children with ASD but not TYP children.

As predicted, there were no differences in word reading attainment in children with ASD and TYP children. This is consistent with past findings at the group level (Nation et al., 2006). This relationship held whether verbal IQ was controlled or not, indicating that basic word reading is generally an intact area in high-functioning children with ASD. Although, this does not necessarily infer that the same underlying processes were utilized to achieve this outcome. In contrast, children with ASD performed more poorly than TYP children in regard to mathematics, with or without verbal IQ controlled. This finding is consistent with the limited past research into mathematics in ASD, for example, in a review Chiang and Lin (2007) found that although most individuals with high-functioning autism and Asperger's Disorder have average mathematics ability this is likely to include an area of mathematics weakness. There was no difference in the *rate of change* over the period in reading or mathematics achievement between the ASD or TYP groups. This indicates that academic development over the year in children with ASD was similar to typically developing children.

In regard to sustained and switching attention tasks, as predicted, children with ASD performed more poorly than TYP children on the attention switching task, making more errors. There have been some past mixed findings in regards to attention switching (Kaland et al., 2008; Russell et al., 1999), however, our finding of poorer attention switching is consistent with the theory of some underlying executive dysfunction in ASD (Pennington & Ozonoff, 1996; Rinehart et al., 2001). On the other hand, consistent with past research, there was no group difference in the sustained attention task indicating that sustained attention is intact in ASD (Johnson et al., 2007). There was no effect of time on either the sustained and switching attention tasks, with performance similar at Time 1 and 2 in both groups.

As expected Time 1 attention switching false alarms (errors) predicted Time 2 mathematics attainment in children with ASD. This relationship was not present in typically developing children as evidenced by the significant group by switching interaction in multivariate analysis. Unexpectedly, attention switching did not predict the *amount of change* over the year that occurred in mathematics when Time 1 mathematics was taken into account. However, given no significant change in mathematics raw scores over the period and a resulting large correlation between Time 1 and Time 2 performance, little variance was left to be explained. A longer time duration may be needed to detect any relationship. Attention switching did not predict reading outcomes. This contrasts with longitudinal studies of typical development (Steele et al., 2012) and could be due the large age range which may have masked subtle developmental effects. Other factors, not examined in this study, such as environmental and social factors, will also be important in the prediction of academic performance. For example, early social abilities and autistic symptoms have been associated with reading in ASD (Asberg et al., 2010; Esters et al., 2011). Attentional factors are one component involved in a complex development process, and any intervention in this area should consider a holistic approach including environmental and psychosocial factors.

Finally, as expected, in this group of males and females with ASD who were well matched on age and IQ, there were no gender differences in academic attainment over both time periods. This was also reflected in the TYP group with no gender differences in academic attainment at either time point. Mathematics attainment in females with ASD is a particularly neglected area, with most studies in this area recruiting too few females to examine gender effects (Jones et al., 2009; Minshew et al., 1994). Similarly, there were no gender differences in the sustained and switching attention tasks over time with boys and girls with ASD performing similarly. There has been past research suggesting that females are cognitively more impaired than males with ASD (Lemon et al., 2010; Lord, Schopler, & Revicki, 1982; Pilowsky, Yirmiya, Shulman, & Dover, 1998), and other theories that females may be under-identified due to clinician bias or better compensation for their difficulties, particularly when they have normal intellectual functioning (Kopp & Gillberg, 1992). Our findings do not support a theory of either greater or lesser impairment in females diagnosed with ASD given no gender differences were found across the domains of intellectual, academic, and cognitive attention.

One limitation of the present study was the wide age range of participants from 7 to 12 years at Time 1. Although this is a relatively narrow age range in the ASD literature, given the developmental sequences of attention functions over time (Klenberg, Korkman, & Lahti-Nuuttila, 2001; Zhan et al., 2011), examining children with ASD within more highly delimited age ranges will be important. In typical development children show very gradual improvement on switching and sustained attention tasks (Zhan et al., 2011), hence, a longer time gap may be needed to detect any improvement and discover whether different group developmental trajectories will emerge. Another limitation of the present study is that the present findings cannot be generalized to children with ASD with IQ's in the intellectual disability range. Extending this work to including children with ASD with intellectual

disability will be important, although differentiating between attention deficits associated with intellectual disability versus ASD will be complex.

Conclusions

To summarize, this study has examined interplay between attention switching and academic attainment in children with ASD over time and also examined the influence of gender. Children with ASD had equivalent reading but poorer mathematics performance compared to typically developing children, with rates of change over the year similar. Findings highlight that difficulties with switching attention may be one factor linked with poor mathematics outcomes in children with ASD. Finally, the finding of no gender differences across these objective measures suggests that clinically ascertained 7 to 12 year old high-functioning boys and girls with ASD will present with similar academic and cognitive attention profiles in the primary school years; a robust finding occurring over two time points.

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Chapter 8 General Discussion

Autism Spectrum Disorder (ASD) is a lifelong neurodevelopmental disorder which impacts on the ability to communicate and form social relationships and is associated with rigidity and narrow interests. This condition is renowned for more frequently affecting males. Yet the cause for this gender inequity remains unclear. This thesis offers a systematic investigation into the gender profiles of cognitively high-functioning primary school-aged children with ASD in respect to clinical symptoms, neuropsychological functioning and academic outcomes, in order to better understand the influence of gender in the presentation of ASD. This research examined both subjective parental reports as well as objective measures of neuropsychological and academic functioning. This investigation of gender in ASD further defines and validates the female presentation of ASD in childhood, and importantly, identifies parallels and deviations from typically developing girls and boys. This information may aid in the identification and treatment of girls with ASD. Furthermore, this thesis examined the inter-relationship between executive functioning and academic outcomes, an area that is yet to be thoroughly explored in ASD. This informs factors which influence academic achievement in high-functioning children with ASD and will aid in establishing appropriate academic expectations and in tailoring academic interventions in this group.

This final chapter integrates findings across the five studies presented in this thesis. It discusses how the present findings might be integrated to inform a model of gender difference in ASD using a broader biopsychosocial framework. The clinical implications of the current work are also discussed as are the study limitations. The discussion concludes with suggested directions for further research.

Overview of Findings

The present thesis aimed to examine the clinical, neuropsychological and academic profiles of primary school-aged girls and boys with ASD. Secondly, the thesis examined how neuropsychological functioning, specifically sustained and switching attention, may impact on academic performance, specifically basic reading and mathematics attainment. A summary of the findings from this thesis are found in Table 8.1.

The findings from Chapter 2 extend previous gender studies of clinical and associated symptoms in ASD by examining children within a narrow age range who were cognitively high-functioning. There were no gender differences in *total* levels of social responsiveness, repetitive behaviours or communication ability. There were some minor gender differences in measurement subscales including more repetitive motor movements in boys, more inappropriate initiations in boys, and poorer pragmatic versus language structure in boys compared with girls with ASD. Overall, these findings indicate very few gender differences in parent-reported autistic symptoms. Boys with ASD were reported to experience higher levels of hyperactivity-impulsivity. Hyperactivity-impulsivity in boys with ASD was particularly pronounced in younger boys, similar to that found in populations of boys with ADHD where hyperactive-impulsive symptoms decrease with age (Biederman et al., 2000). Higher levels of hyperactive behaviours, which are overt behaviours such as difficulties sitting still and being 'on the go', may result in boys' difficulties being more apparent than girls. This could prompt higher levels of clinical referrals in boys than girls and contribute to the male predominance in ASD.

Chapter 3 extended the findings from Chapter 2 and also extended previous gender studies in ASD by examining autistic, anxiety and attention symptoms over two time points. There were no gender differences in *total* scores on the parent-reported autistic symptoms over the two time points, consistent with Chapter 2 findings. There were no difference in

parent-reported aggression between boys and girls with ASD which is in contrary to differences usually seen in typical development (although not reflected in the typically developing group in this study where similarly low levels of aggressive behaviour were reported). This could indicate that for high-functioning girls to be diagnosed with ASD they require similarly high levels of overt aggressive behaviours to that of boys with ASD. Potentially clinically referred girls may need to exhibit these high-levels of problem behaviours to be ascertained. Girls were reported to experience higher levels of social anxiety than boys, regardless of whether they had ASD or were typically developing. This indicates that girls with ASD experience a 'double hit' of the high levels of social anxiety associated with both having ASD and being female. Boys had higher levels of hyperactivity-impulsivity than girls when the two time points were considered, however, this elevation was also present in typical boys relative to typical girls, indicating that this gender difference was not specific to ASD. Another important finding in this paper was that boys received more integration aide support in mainstream schools than did girls with ASD despite similar levels of academic functioning and autistic symptoms. Overt hyperactive symptoms may have contributed to this finding; however, it cannot be excluded that other factors, such as a gender bias may have contributed to this inequity.

Chapter 4 explored another area of significant difficulty in ASD, that of sleep disturbance. Gender differences in this area have not been comprehensively examined in groups with well defined age and IQ ranges. Very few longitudinal studies in this area exist; hence developmental sleep change is poorly understood in ASD. This study revealed that sleep disturbance decreased over time in ASD but not in typically developing children; however, clinically significant sleep difficulties were still present in 65% of children with ASD at follow-up. There were no gender differences in sleep disturbance found in this study. This is one of the few longitudinal studies of sleep disturbance in ASD, and it revealed some

important associations including sleep disturbance being an indicator for later high anxiety. It also indicated a different trajectory of sleep disturbance in children with ASD: stability was indicated in TYP children versus improvement in ASD children over one year. Improvement in sleep disturbance was associated with improvement in social reciprocity. This inter-relationship is consistent with past cross-sectional studies showing that social difficulties and sleep disturbance in ASD are related. Whether this may indicate a causal relationship or that both variables were impacted by a third variable, is an important area of future research given the possibilities to target interventions.

The final two chapters of the thesis examined academic performance and executive functioning in relation to gender and inter-relationships between these areas over time. Chapter 6 found no gender differences in reading and mathematical attainment in children with ASD. There were also no gender differences in the measures of executive functioning: sustained attention and attention switching tasks. Children with ASD had similar sustained attention, attention switching, mathematics and reading achievement compared with typically developing children. In children with ASD who had attention switching difficulties, mathematics attainment was impaired compared with those without attention switching difficulties. This was not the case for typical children where mathematics performance was similar regardless of attention switching performance. This paper highlighted how attention switching and mathematics performance were inter-related in ASD.

Chapter 7 then explored these relationships over time. There continued to be no gender difference in academic performance and executive functioning in children with ASD. When the two time points were considered, children with ASD performed more poorly on the attention switching task compared with typically developing children, but had similar performance on a sustained attention task. Mathematics performance was poorer in children with ASD compared with typical children when the two time points were considered, but

basic reading skills were similar. Again, attention switching difficulties in children with ASD predicted later difficulties with mathematics. In contrast, typical children performed similarly in mathematics regardless of their attention switching ability. This finding highlighted the involvement of early attention switching difficulties on later poorer mathematics attainment and revealed no gender differences in academic and EF functioning.

Table 8.1

Summary of findings

Domain	Measure	Males versus Females (ASD)	Males versus Females (Typical)	ASD versus TYP	Developmental Impact over 1 year
Social Deficits	Parent Report – SRS Total	=	=	ASD > TYP	No change
Repetitive Behaviours	Parent Report RBQ Total	=	=	ASD > TYP	No change
Communication Deficits	Parent Report- CCC-GCC, SIDC	=	=	ASD > TYP	No change
Hyperactive-Impulsive	Parent Report – Conners 3	Males > Females	Males > Females	ASD > TYP	No change
Inattention	Parent Report – Conners 3	=	=	ASD > TYP	No change
Executive Functioning	Parent Report – Conners 3	=	=	ASD > TYP	No change
Learning Problems	Parent Report – Conners 3	=	=	ASD > TYP	No change
Aggression	Parent Report – Conners 3	=	=	ASD > TYP	No change

Domain	Measure	Males versus Females (ASD)	Males versus Females (Typical)	ASD versus TYP	Developmental Impact over 1 year
Anxiety	Parent Report – SCAS Total score	=	=	ASD > TYP	No change
Family Psychopathology	Parent Report – FAD	=	=	ASD > TYP	Increase over time
Sleep Dysfunction	Parent Report – CSHQ Total	=	=	ASD > TYP	Reduction over time in ASD but not TYP
Reading	WIAT-II word reading	=	=	ASD = TYP	Improved raw scores
Mathematics	WIAT-II Numerical Operations	=	=	ASD < TYP	No change
EF – Switching False Alarms	Computerised WATT Visearch	=	=	ASD > TYP	No change
EF – Sustained Attention False Alarms	Computerised WATT Vigilan	=	=	ASD = TYP	No change

ASD, Autism Spectrum Disorder; TYP, Typically Developing; EF, Executive Functioning; SRS, Social Responsiveness Scale; CCC, Children's Communication Checklist; GCC, General Communication Composite; SIDC, Social-Interaction Deviance Composite; RBQ, Repetitive Behaviours Questionnaire; SCAS, Spence Children's Anxiety Scale; FAD, Family Assessment Device; CSHQ, Child's Sleep Habits Questionnaire; WIAT, Wechsler Individual Achievement Test; WATT, Wilding Attention Tasks.

Theoretical Implications

Cognitive Attention Difficulties and Academic Outcomes in ASD

This thesis has revealed attention switching difficulties were more prominent in children with ASD compared with typically developing children. These attention switching difficulties were associated with poorer mathematics performance in children with ASD. However, not all children with ASD experienced attention switching deficits, consistent with ASD being a highly heterogeneous condition. This finding also parallels past research on ADHD where only a subset of individuals experience EF deficits (Lambek et al., 2011). This finding in ASD supports the notion of a multiple cause model of ASD. It may be beneficial to employ neuropsychological subtypes, based on the presence of EF deficits, to better understand the heterogeneity in ASD.

A Biopsychosocial Model of Gender Difference in ASD

An emerging interest in gender is evident from the recent research focus in this area (Goldman, 2013; Rinehart et al., 2011; Rivet & Matson, 2011b; Zwaigenbaum et al., 2012) and from the studies presented in this paper. There have been very few models beyond the biological perspectives seeking to determine how gender differences in the prevalence of ASD emerge. Integrating knowledge of the biopsychosocial factors associated with gender difference in ASD may lay the groundwork for more holistic etiological theories of ASD. The biopsychosocial approach includes aspects of biological, psychological and social factors and views these areas as being in constant interaction with one another. This model can provide a framework to aid in the identification of ASD in females. It examines components

using a systems approach and focuses on the interactions between the component parts.

The following preliminary model has been proposed to explain factors which may contribute to gender difference in ASD, including more males with ASD being diagnosed than females and differences in behaviour, Figure 8.1. It sets the scene for future research, highlighting areas which require consideration when examining the role of gender in ASD and also identifies areas which are yet to receive research attention.

Biological Level

Genetic Factors

The sex chromosomes differ for males and females and hence are an obvious area which might contribute to the gender disparity in prevalence and symptom severity of ASD. For example, Fragile X syndrome is commonly associated with ASD, and more male than female cases exist with this condition due to females having two X chromosomes which dampen the effects of this X-linked genetic mutation. Genetic imprinting of social cognition is another possible mechanism of sex difference (Skuse et al., 1997). Skuse and colleagues work on Turner's Syndrome has revealed better social functioning from the paternal X chromosome (which girls may receive through X inactivation) compared with the maternal X chromosome (which boys always receive). This may result in boys being more vulnerable to social deficits than girls and subsequently result in more male cases of ASD.

Sex Hormones

Endocrine influences on the developing brain differ by sex. Differences in social and communicative behaviours have been associated with specific hormones,

such as androgen (Hollier et al., 2013b; Whitehouse, Mattes, Maybery, Dissanayake, et al., 2012; Whitehouse et al., 2010). Higher levels of testosterone during perinatal development have been associated with communicative and social impairment (Hollier et al., 2013b; Whitehouse, Mattes, Maybery, Dissanayake, et al., 2012). Other supporting evidence comes from studies which indicate an earlier age of menarche in females which may relate to elevated levels of testosterone (Knickmeyer et al., 2006; Whitehouse, Maybery, Hickey, & Sloboda, 2011a). Naturally higher levels of oxytocin in females have also been associated with nurturance behaviour and social cohesion which might act as a protective factor by improving the social ability of females (Carter, 2007; Insel et al., 1999). Oxytocin may protect the brain at critical times during fetal development (Carter, 2007; Yamasue, Kuwabara, Kawakubo, & Kasai, 2009). Oxytocin levels also increase around puberty in females which could result in an increased drive for social affiliation in females and offer protection against stress given this hormone increases relaxation, reduces fearfulness and decreases sympathetic nervous activity (Crick & Zahn-Waxler, 2003). Key developmental periods where sex hormones undergo significant changes for females and require particular consideration when examining gender differences in ASD include puberty, pregnancy, the postnatal period, and menopause.

Different Rates of Brain Development and Morphology

Boys have less rapid brain maturation making them more vulnerable to brain damage during early development (Lenroot et al., 2007). Brain damage may be caused by interaction with environmental factors. At the biological level, brain development requires interaction with the environment and this interaction may differ

for males and females, thus modifying the behavioural expressions of language, social ability and patterns of behaviour.

Psychological Level

Overt Behaviour Problems

As discussed throughout this thesis, boys experience higher levels of externalising behaviour problems such as ADHD, Oppositional Defiant Disorder and Conduct Disorder whereas girls are more likely to experience internalising symptoms associated with anxiety and mood disorders (American Psychiatric Association, 2000). These behavioural differences can result in boys' difficulties being more obvious and problematic for parents and teachers, further resulting in their being more frequently referred for clinical assessment. Girls with ASD may only be identified when they exhibit overt behaviour problems like aggression. This is supported by the findings in this thesis where boys and girls with ASD had similarly high levels of aggressive behaviour which is contrary to that usually observed in the general population.

Autistic Symptoms

The findings from this thesis suggest that for boys and girls with ASD there are similarly high levels of autistic symptoms. Some past studies have found more repetitive behaviours in boys compared with girls which may relate to the broader finding that boys are more hyperactive than girls (Levy, Hay, Bennett, & McStephen, 2005). The present study found more repetitive motor movements in boys than girls, consistent with this notion. It was also found that boys with ASD tended to have higher levels of inappropriate initiations during communication compared with girls with ASD; again, another overt behavioural symptom which may contribute to boys' difficulties being more obvious than girls. It is also possible that circumscribed

interests could be more socially related or less unusual in girls, such as an obsession with a particular friend, compared to boys, resulting in girls' difficulties being less obvious to carers and clinicians (Kopp et al., 2010; Rinehart et al., 2011; Wolff & McGuire, 1995). This could contribute to girls' difficulties being overlooked. This was supported by our findings that boys were reported by parents to have more unusual autistic interests than girls.

Social Level

Gender role socialisation

Gender role socialisation is a variable which impacts on an individual's interactions with family and society and acts to modify the expression of behaviour in boys and girls. For example, physical aggression is more accepted in boys whereas girls are expected to resolve inter-personal difficulties in positive ways (Crick & Zahn-Waxler, 2003). Hence, socialisation practices act to reduce physical aggression in girls and increase prosocial behaviour. More overt behaviour problems like aggression in boys than in girls are likely to act to increase the number of boys referred for clinical assessment and contribute to gender disparity in ASD prevalence rates.

Gender stereotypes and expectations associated with core ASD symptoms, such as viewing girls as being more social and having better language abilities than boys, could differentially influence the development of these areas in boys and girls. Mothers have been found to converse and interact more with baby girls than baby boys (Clearfield & Nelson, 2006), hence, girls may learn higher levels of language and greater social ability is expected of them compared with boys and they may gain more skills due to more exposure to these social and language interactions. This could

result in subclinical social and communication deficits in girls precluding them from a diagnosis of ASD, or from ever being referred for assessment. This was partially supported by the Time 1 data in the present study where girls with ASD were reported to have better basic language skills relative to pragmatic language skills compared to boys with ASD.

Sex-based discrimination

Sex-based discrimination, such as not considering girls for an ASD diagnosis or referral for assessment based only on their gender, is another important variable in ASD which has been under-studied. This may be based on societal views that girls are unlikely to manifest neurodevelopmental conditions such as ASD. Parents and teachers may be less aware of ASD occurring in girls and overlook or misinterpret symptoms. Clinicians similarly may not consider high-functioning girls for a diagnosis of ASD given less experience with female cases of ASD. The present study found girls were less likely to receive integration aide support; potentially this may indicate that they are overlooked for this type of intervention due to their gender. However, it could also relate to girls exhibiting lower levels of problem behaviours such as hyperactivity. All those involved in the referral and diagnostic process need to be aware their own potential gender biases in this area. This is also particularly important given parents and teachers are the main informants of behaviour in the ASD assessment process.

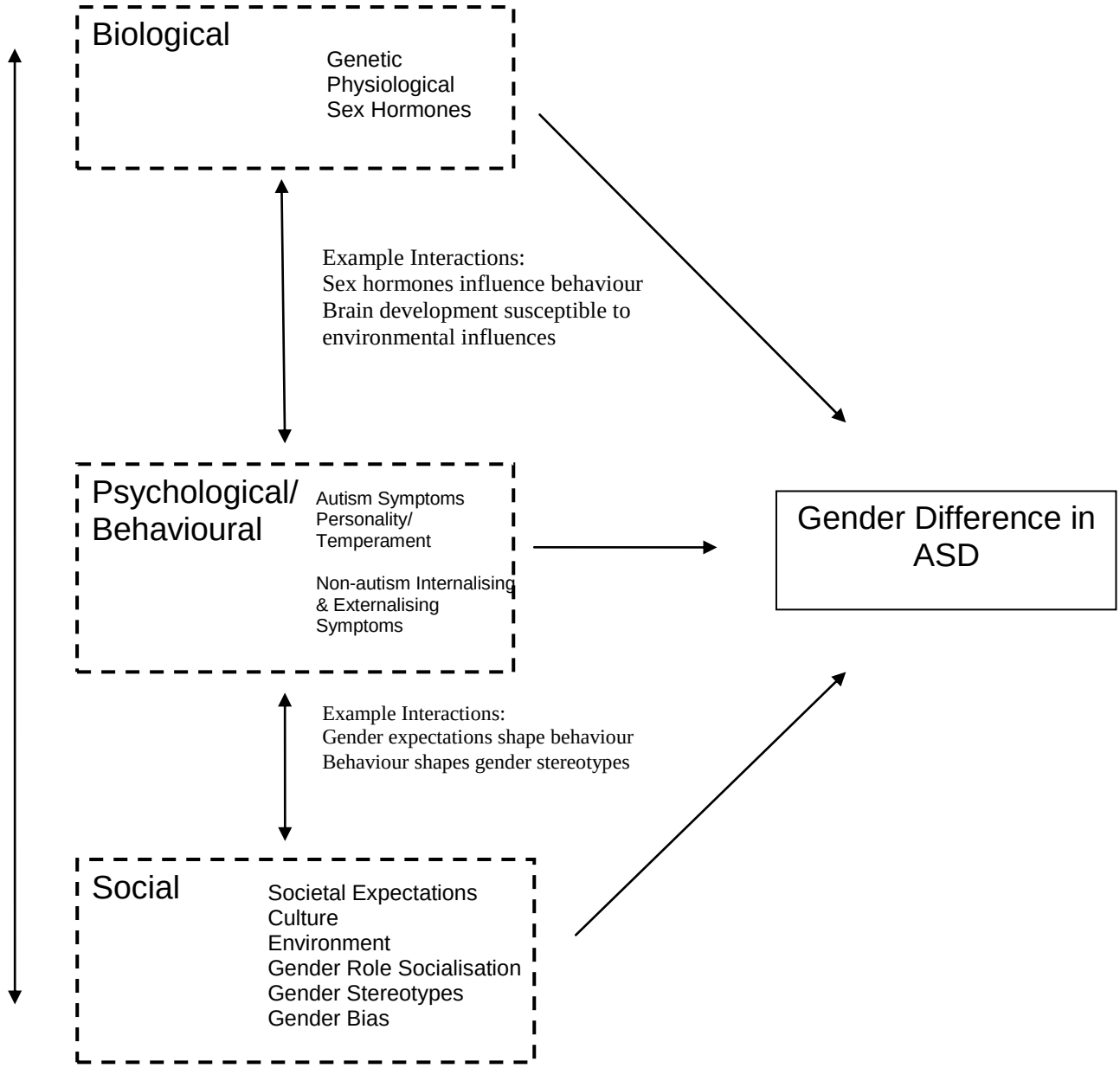

Figure 8.1. A Preliminary Biopsychosocial Model of Gender Difference in ASD.

Implications for DSM-5

In May 2013 the new version of the Diagnostic and Statistical Manual for Mental Disorders was released which involves significant change in the ASD criteria, conceptualising ASD as a duo rather than triad of deficits (refer Table 1.3 Chapter 1). There was early concern that the new DSM-5 criteria for ASD would have

implications for the detection of females. For example, Mattila and colleagues (2011) found that some individuals with Asperger's Disorder and high-functioning autism who met DSM-IV-TR criteria did not meet DSM-5 criteria. A larger study of 4,453 children meeting DSM-IV-TR criteria for PDD found that the DSM-5 criteria were sensitive to detecting girls. However, the girls assessed in this study were those already diagnosed with ASD according to DSM-IV-TR. It remains unknown how the new criteria will affect higher-functioning girls who are undiagnosed. Importantly, the DSM-5 has acknowledged that high-functioning girls with ASD may go unrecognised by including a statement about females as follows:

> "In clinic samples females tend to be more likely to show accompanying intellectual disability, which suggests that girls without accompanying intellectual disability or language delays may go unrecognized, perhaps because of subtler manifestation of social and communication difficulties." (American Psychiatric Association, 2013, p.57)

This statement acknowledges that there may be gender differences in the manifestation of social and communication difficulties in ASD and that high-functioning girls with ASD may go unrecognised. It is an important step in increasing the awareness of potential under-diagnosis of females with ASD. However, the findings from the present thesis indicate that in an already diagnosed group of boys and girls there are minimal gender differences in social and communication deficits (and repetitive behaviours). Instead, another difficulty not diagnostic of ASD, specifically hyperactivity, was one of the key factors which differed significantly by

gender. This finding is consistent with Dworzynski, Ronald, Bolton and Happe (2012) who found that girls who had high levels of ASD symptoms but were not diagnosed with ASD had fewer associated behaviour problems than girls diagnosed with ASD. Collectively, these findings indicate that externalising behaviour difficulties not diagnostic of ASD may be a particularly important factor which results in girls with clinically significant ASD symptoms going unrecognized. It will be important for clinicians to be cognisant of this possibility to aid in the recognition of girls with ASD.

Limitations

While this research has led to a broader understanding of gender, academic and neuropsychological functioning in ASD there are limitations which relate to the design of this study. While the inclusion of a restricted age range in this study may be viewed as a relative strength, this may also limit the generalisability of the findings. Similarly, the restriction to cognitively high-functioning children means findings cannot be generalised to individuals with low-functioning ASD. Symptoms were assessed using parent report rather than objective clinician or direct measures. Hence, as highlighted, parents may be influenced by a range of factors which may produce gender bias in their interpretation of symptoms. Studies using more objective measures of these types of symptoms will be important.

The children with ASD were a clinical sample. Hence, these children may be more impaired than population samples. It may also be possible that the girls with ASD were more impaired compared with population samples of girls with ASD than the clinical boys were compared with population samples of boys with ASD. For example, the typical gender difference in aggressive/oppositional behaviours was not

present in the children with ASD. This may indicate that girls with ASD need to display heightened levels of aggression to be clinically assessed. Thus it is possible that the girls in this study may not have been representative of most girls with the disorder. Furthermore, the Autism Diagnostic Interview – Revised and Autism Diagnostic Observation Schedule, the gold standard assessment tools for ASD, were not employed in this study. This is a significant limitation as some children in the ASD group potentially may not have met ASD cut-offs on these instruments. However, this possibility was minimised by ensuring all children had been assessed by qualified psychologists and paediatricians and met clinical cut-offs on other screening instruments such as the Social Responsiveness Scale. A DSM-IV-TR checklist of symptoms was also utilised.

Studies examining gender require large sample sizes to reduce the likelihood of Type II errors (failing to find a real differencce; Crick & Zahn-Waxler, 2003). This is particularly troublesome in ASD research where the recruitment of girls is difficult due to their much lower prevalence than boy, particularly within the high-functioning range. The present study initially included 32 girls with ASD which is larger than most prior studies in this area. However, the authors readily acknowledge that it may be possible that Type II errors may have occurred in the present study.

This study also has not controlled for the timing of pubertal development which may influence the types of behaviours examined in this study (e.g. externalising and internalising behaviours) and is likely to differ between boys and girls. For example, the high levels of aggression and social anxiety in the girls with ASD may have been associated with pubertal development rather than autistic symptoms *per se*. This factor was not controlled for in this study and will be important to account for in future studies.

Only two time points one year apart were able to be measured in this study. Some areas considered in this study may not have shown measurable developmental change over this time period. Tracking these children over a longer duration will be necessary to further understand any gender trajectories of the areas considered in this thesis.

Clinical Implications

Understanding the predominance of boys with ASD using a biopsychosocial model is an important step forward in the conceptualisation of gender in ASD. Epidemiological researchers can utilise this model when designing prevalence studies to be cognisant of factors which may influence an ascertainment bias towards identification of boys. Research on gender differences could utilise this model in order to consider the factors which might contribute to differences in the presentation of clinical symptoms. The model facilitates clinicians to be cognisant of their own potential gender biases and that of informants during the assessment process. For teachers similarly, the model facilitates awareness of potential gender biases in their own referral decisions. For parents the model can similarly help to identify factors associated with the environment and behaviours which may contribute to girl's symptoms being missed or masked. Clinically, the model also highlights when girls may be of higher risk of developing emotional difficulties during critical developmental periods such as puberty.

The empirical studies presented in this thesis have revealed that girls and boys with high-functioning ASD are likely to present with very similar symptoms of ASD in respect to quality and quantity. Academic attainment and executive functioning are also likely to be similar for boys and girls with ASD. Hyperactivity may be a particular problem in young boys with ASD. This may in part contribute to more

males than females being ascertained given that overt problem behaviours such as hyperactivity are more likely to prompt clinical referral. Girls with ASD could potentially be overlooked for integration aide support in schools because of their fewer overt symptoms of hyperactivity, despite similarly impaired levels of social, communicative and academic functioning as boys with ASD. This finding is particularly important for parents, teachers and clinicians to be aware of to ensure girls are not being overlooked for these services due to fewer comorbid overt problem behaviours.

Findings from this thesis also suggest that attention switching difficulties are associated with mathematical difficulties. Screening for these cognitive deficits and providing increased mathematical support may be beneficial. The finding that sleep difficulties may be an indicator of later intensified anxiety symptoms in ASD, similar to the pattern seen in typical development, is an important finding for clinicians and parents. Conceivably, sleep interventions in children with ASD may act to prevent or lessen later anxiety symptoms. This may be particularly important to address in girls with ASD prior to adolescence, given higher levels of anxiety are generally experienced in girls from this time.

From a translational clinical perspective, all children with ASD involved in this study received detailed reports regarding their cognitive and academic performances over the two time points. These reports were made available via the families involved to the children's paediatricians, psychologists and schools to assist in tailoring individual learning and management plans and ensuring that these children received adequate support.

Future Directions

As there continues to be a lack of clear etiological cause for the male predominance in ASD, empirical investigation into the sociocultural influence on the diagnosis of females with ASD is an important area to explore. Examining behavioural symptoms in an objective manner and comparing this with parent, teacher and clinician reports of these same behaviours will help to determine if there is any gender bias in clinician, parent and teacher reports of autism symptoms. Examining the influence of clinician and parent gender may also provide important insights. Further elucidation on how social factors may impact on the behaviour of boys and girls with ASD and influence ascertainment will be important. For example, examining girls with subclinical ASD symptoms to determine what behavioural or other factors influence this sub-clinical status will be important, with some seminal work in this area already commenced (Dworzynski et al., 2012).

The finding from this thesis that more males than females received integration aide support also needs further examination as it may indicate that females with ASD who have similar levels of difficulties as boys with ASD do not gain proportional access to support. This could have significant implications for later academic outcomes and subsequent life outcomes in females such as education level obtained, employment opportunities and earning capacity.

Longitudinal studies, tracking girls from childhood through adolescence and adulthood are crucial. In the general population females are likely to experience depression at twice the rate of males from adolescence onwards. One theory proposed to account for this gender disparity is a ruminative thinking style being more prominent in females than males at this time of development (Crick & Zahn-Waxler, 2003). Given the rumination associated with repetitive thinking patterns and

behaviours already present in ASD, are females with ASD therefore at a higher risk of developing depression than typical females and males with ASD during adolescence? There is already some evidence that deterioration occurs around puberty for females with ASD (Burd et al., 2002; Gillberg & Steffenburg, 1987; Howlin et al., 2004). Low-functioning females with ASD have shown more deterioration around puberty than males including more aggressive, hyperactive and destructive behaviour and the onset of seizure disorders (Gillberg & Steffenburg, 1987). Whether this is reflected in high-functioning females with ASD is unclear, however, in light of the typical female vulnerabilities around puberty for depression this is an important area for future research on females with ASD.

Concurrent improvement in sleep and reduced social difficulties was found in Chapter 4. This is an area which is worthy of future exploration to understand whether there was a causal relationship or other factors which resulted in improvement in both areas. For example, it could have eventuated that improvement in social understanding may have increased understanding around bed-time routines resulting in improved sleep. Which factors influenced improvement in these areas will be particularly important to identify given the potential to target these areas in interventions.

Up until the release of DSM-5 in May 2013, a comorbid diagnosis of ADHD and ASD was not permitted under this classification system. The DSM-5 has now recognised the significant overlap of inattentive and hyperactive-impulsive behaviours in children with ASD and allowed for the dual diagnosis of ADHD and ASD (American Psychiatric Association, 2013). The current thesis has revealed high levels of ADHD symptoms of hyperactivity-impulsivity and inattention in both boys and girls with ASD. Longitudinal studies have shown that individuals with ADHD are at

risk of academic underachievement and poorer occupational outcomes (Ek, Westerlund, Holmberg, & Fernell, 2011; Kuriyan et al., 2013). Whether high levels of ADHD in ASD will result in similar underachievement will be an important area to understand.

The present study found associations between attention switching deficits and poorer mathematics performance. Factors which contributed to basic reading performance were more elusive and require further investigation. It may be that longer time periods are required to understand the influence of attentional factors in the reading performance in children with ASD. Examining factors which contribute to more complex reading skills such as reading comprehension, where children with ASD show more difficulties, will be important.

Concluding Remarks

This thesis has revealed very similar clinical profiles in boys and girls with ASD, particularly in ASD symptoms, cognitive attention tasks and academic functioning. It has also provided useful direction for future research in this area. Additionally, this thesis has initiated the exploration of the relationship between executive functions and mathematics attainment in ASD. Careful examination of factors associated with why fewer girls are diagnosed with ASD will have profound implications for the identification and treatment of girls as well as significant broader implications in conceptualising the etiology of ASD more broadly. Taking a biopsychosocial perspective in understanding the male predominance in ASD will have implications for research, clinical, educational, parental and societal conceptualisations of how females with ASD may be overlooked or protected from an ASD diagnosis Ultimately, there is a pressing need to enhance cognitive and social-emotional development and resilience in this ‘at-risk’ population through innovative,

evidence-based early intervention programs which are community-based and targeted at the most developmentally sensitive stages.

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Appendix

Monash University

Declaration for Thesis Appendix

In the case of the Appendix, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Project design, review of relevant literature, attainment of ethics approval, recruitment and all testing of research participants, analysis of data and writing of manuscript.	70%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	**Nature of contribution**
Prof. Nicole Rinehart	Contributed to project design and provided input during final draft stage of manuscript.
Prof. Kim Cornish	Contributed to project design and provided input during final draft stage of manuscript.
Dr. John Wilding	Contributed to project design and provided input during data analysis and final draft stage of manuscript.

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work*.

Candidate's Signature		**Date**
Main Supervisor's Signature		**Date**

*Note: Where the responsible author is not the candidate's main supervisor, the main supervisor should consult with the responsible author to agree on the respective contributions of the authors.

Preamble to Paper 6

This paper is a rework of Paper 5 to focus on examining developmental change in reading and mathematics attainment and sustained and switching attention. This paper again explores whether there are gender differences in reading, mathematics, sustained and switching attention over two time points. It then examines the developmental trajectories of these factors over time and their inter-relationships. This paper has been submitted for publication to the Journal of Autism and Developmental Disorders.

May, T., Rinehart, NJ., Wilding, J., & Cornish, K. (Submitted). Academic and Executive Functioning Performances for Boys and Girls with Autism Spectrum Disorder: A One-Year Follow-Up Study.

Academic and Executive Functioning Performances for Boys and Girls with Autism Spectrum Disorder: A One-Year Follow-Up Study

Little is known about the link between executive functioning (EF) and academic performance in children with Autism Spectrum Disorder (ASD), how these profiles change over time, and whether gender matters in these associations. This study examined reading and mathematics achievement, attention switching, sustained attention and their relations over time. Normally intelligent 7-12 year olds (ASD N=64; typical developing [TYP] N=60) with equal numbers of boys and girls, were assessed at Time 1 and one year later (ASD N=56; TYP N=52), completing Word Reading and Numerical Operations tests and computerised tasks tapping attention switching and sustained attention. There were no *gender* differences in any measures. Children with ASD had poorer mathematics and attention switching performance and similar reading and sustained attention as TYP children. No group differences in the rate of development of academic and attention skills over the year emerged. Unexpectedly, there were no associations between academic change and attention change over the 1-year period. These findings indicate similar academic and EF development in high-functioning ASD and TYP children over one year.

Keywords: Autism Spectrum Disorder; Reading; Mathematics; Gender; Attention Switching

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition typified by social deficits, communication disturbance and restricted interests (American Psychiatric Association, 2000). In childhood, these deficits present as significant difficulties in communicating with, and socially relating to, others. Repetitive behaviours may manifest as difficulties changing between activities, obsessions with particularly focused interests, and rigid adherence to routines. These behavioural deficits have been theorized to be underpinned by disturbances in underlying cognitive processing, in particular impairment in a group of attentional components known collectively as Executive Functions (Pennington & Ozonoff, 1996). Executive Functioning (EF) is a broad term for a range of attentional components, including working memory, the ability to *switch* attention according to changes in the environment, the ability to *sustain* attention on the task at hand, and the ability to inhibit responses to irrelevant stimuli. These components of attention are important for planning and organizing goal-directed behaviour and may impact on important functional outcomes such as academic performance. Surprisingly little is known about the link between executive functioning and academic performance in children with ASD. Furthermore, very few studies have investigated how learning and executive profiles change over time in children with ASD, and how the development of EF may impact on the development of academic skills. Understanding these trajectories and inter-relationships will be important for supporting individuals with ASD in the school environment.

A specific profile of EF deficit is indicated in ASD. While not all studies show clear evidence that the ability to switch attention is universally impaired in ASD, most studies find deficits (see Ames & Fletcher-Watson, 2010; Hughes & Russell, 1993; but see also Kaland, Smith, & Mortensen, 2008; Lopez, Lincoln, Ozonoff, & Lai,

2005; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001; Russell, Jarrold, & Hood, 1999; Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008). In contrast sustained attention appears generally intact in ASD (Johnson et al., 2007). In line with ASD being a disorder of neurodevelopment there is evidence that the *development* of EF skills is also atypical in ASD. The notion of a second wave of impairment in EF which occurs in the second decade of life in ASD has been indicated (Luna, Doll, Hegedus, Minshew, & Sweeney, 2007; Minshew & Williams, 2007). Consistent with this, a recent cross-sectional study suggested that real world EF skills (particularly switching attention) were poorer in *adolescents* with ASD relative to controls, than that found for *children* with ASD, indicating a slowed development in these skills over time (Rosenthal et al., 2013). However, only longitudinal studies can confirm these findings. In this regard, Ozonoff and McEnvoy (1994) examined a planning efficiency task (Tower of Hanoi) and a switching task in adolescents with ASD and did not find improvement in task performance at three year follow-up which was in contrast to controls. Griffith, Pennington, Wehner, and Rogers (1999) found no improvement after one year on a cognitive flexibility task in preschoolers with autism but this also the case for controls. In contrast to these findings, Pellicano (2010) showed that although children with autism, aged 4 to 8 years, performed more poorly than controls on a set-shifting and planning task (Tower of London), there was greater gain in planning ability after 3 years than in the control children. This suggested a lag in the development of these functions as well as a different rate of development compared with typical children. Any lag in development of EF components may have implications for a range of downstream dependent functions such as learning (Cartwright, 2012; Clark, Pritchard, & Woodward, 2010; Steele, Karmiloff-Smith, Cornish, & Scerif, 2012).

EF components are vital for the development of academic skills in typically developing children (Bull & Scerif, 2001; Cartwright, 2012; Christopher et al., 2012; Espy et al., 2004; Foy & Mann, 2013). They serve as predictors of literacy and numeracy scores in preschool through high school in typical development (Clark, Pritchard, & Woodward, 2010; Steele, Karmiloff-Smith, Cornish, & Scerif, 2012). Reading is a complex mental process which requires the integration of many elements. For example, early pre-reading skills have been associated with cognitive flexibility and inhibitory control (Cartwright, 2012). Similarly, mathematics requires a range of cognitive skills such as the ability to shift attention, inhibit responses and working memory (Bull & Scerif, 2001). Considering how underlying EF difficulties in ASD may impact on academic performance will therefore be important for addressing barriers to learning in this population.

Generally, academic achievement in ASD at the group level is similar to typically developing children, however, there are uneven patterns of idiosyncratic strengths and weaknesses (Chiang & Lin, 2007; Nation, Clarke, Wright, & Williams, 2006; Whitby & Mancil, 2009). Children with ASD generally show intact basic reading skills (Nation et al., 2006) but impaired reading comprehension (Griswold, Barnhill, Myles, Hagiwara, & Simpson, 2002; Huemer & Mann, 2010; Jones et al., 2009; Minshew, Goldstein, Taylor, & Siegel, 1994). Mathematics achievement is generally similar to typically developing children but with areas of weakness (Chiang & Lin, 2007). How academic achievement develops over time in children with ASD is largely unknown with a paucity of longitudinal studies.

There have also been very few studies that have examined the relationships between EF and academic performance in ASD. Mayes and Calhoun (2007) found sustained attention (using a continuous performance task) concurrently predicted

reading and mathematics performance. A limitation of this study was that the sample included a range of clinical conditions including Attention Deficit Hyperactivity Disorder which is a condition with know EF and academic difficulties and group effects were not reported. Our cross-sectional study found switching attention but not sustained attention concurrently predict mathematics but not reading attainment in children aged 7 to 12 with ASD (May, Rinehart, Wilding, & Cornish, 2013). No other studies examining EF and academic performance in ASD were identified in the literature.

Another important factor which might contribute to atypical development of EF and academic skills in ASD is gender. Many more males than females are diagnosed with ASD with an average gender ratio of 4.3 males to each female, without known cause (Fombonne, 2003). For EF, only one study examining gender was identified which found females performed more poorly than males on a response inhibition task, however, the small sample size in this study makes this finding exploratory (Lemon, Gargaro, Enticott, & Rinehart, 2010). Our cross-sectional study in 7-12 year old children with ASD found no gender differences in sustained and switching attention (May et al., 2013). We also found no gender differences in reading and mathematics performance in this group of children. These academic findings were consistent with past studies of reading where girls with ASD appear to have similar basic reading ability to typically developing girls (Asberg, Kopp, Berg-Kelly, & Gillberg, 2010). There are surprisingly no other studies of the mathematics performance of females with ASD, with most studies in this area examining only males or too few females to perform gender comparisons (Jones et al., 2009; Mayes & Calhoun, 2003; Minshew, Goldstein, Taylor, & Siegel, 1994). Examining the academic and EF performance of females over time will be important to understand

whether unique gender developmental trajectories exist and if interventions may need to be gender specific.

The purpose of the present study was to extend our cross-sectional study (May et al., 2013) to explore the *development* of academic and EF skills in children with ASD and determine whether this differed (1) in children with ASD compared to typically developing children and (2) by gender. The present study also aimed to examine whether changes in executive functioning were associated with changes in academic performance over a 1 year period in children with ASD. To do this we aimed to complete a one year follow-up the children in our original study (May et al., 2013). The following hypotheses were made: (1) consistent with prior studies (Ames & Fletcher-Watson, 2010; Hughes & Russell, 1994), it was predicted that children with ASD would show more difficulties on an attention switching task, but comparable performance to controls in regard to sustained attention, word reading and written mathematics attainment; (2) it was predicted that the *rate* of development of switching and sustained attention would be different in the ASD group compared to the typically developing group given past findings showing differing rates of EF development in children with ASD (Ozonoff & McEnoy, 1994; Pellicano, 2010). No predictions were made about the *rate* of development of reading and mathematics in children with ASD compared with typically developing children given a lack of prior research; (3) it was hypothesized that the *rate of change* of EF would be correlated with *the rate of change* of academic performance based on past studies in typically developing children which closely links the development of these areas (Cartwright, 2012); (4) based on prior studies (Asberg et al., 2010), given a well-matched group of normally intelligent boys and girls with ASD, it was expected there would be no

gender differences in reading, mathematics, sustained and switching attention over time.

Method

Participants

At Time 1, 124 children aged between 7 and 12 years were recruited (May et al., 2013). This included 64 children, 32 male and 32 female, with Autistic Disorder or Asperger's Disorder. Only children who had a current diagnosis of ASD from their paediatrician or psychologist were invited into the study. The DSM-IV-TR criteria for Autistic Disorder (16 male, 7 female) or Asperger's Disorder (16 male, 25 female) was confirmed for all clinical participants using our standard process involving reviewing diagnostic reports from registered psychologists and paediatricians with a symptom checklist to ensure the DSM-IV-TR criteria were fulfilled. In addition, all clinical participants scored within the clinical range on the Social Responsiveness Scale parent report (Constantino, 2002). Participants were recruited through the Monash University Centre for Developmental Psychology and Psychiatry, the Autism Victoria 'Get Involved' volunteer register, and from private clinics in the Melbourne metropolitan area. Only children with a full-scale IQ of 70 and above were included. Seven of the 64 children with ASD (2 female, 5 male) were taking psychostimulant medication (5 methylphenidate and 2 atomoxetine) at Time 1. At Time 2, four females and six males with ASD were taking psychostimulant medication (7 methylphenidate and 2 atomoxetine with one participant taking both). Sixty typically developing children, 30 male and 30 female, were recruited from a Melbourne metropolitan Primary School. These children were screened to ensure they had no history of developmental disability or psychopathology according to both parent and

teacher report. Children were excluded if they had a history of brain injury or any genetic disorders (such as Fragile X syndrome).

Of the 64 children in the ASD group, 56 were reassessed at follow-up for this study (28 males and 28 females), which was a drop-out rate of 12.5%. Of the 60 typically developing children, 52 were reassessed at Time 2 (26 males and 26 females), with a drop out rate of 8.6% percent. Drop out was due to not being able to contact families, or due to parents reporting being too busy to participate in Time 2.

Measures

Intellectual functioning. Intellectual functioning was assessed at Time 1 using the Wechsler Intelligence Scale for Children IV (WISC-IV)(Wechsler, 2005) Australian version in children with ASD, and the Wechsler Abbreviated Scales of Intelligence (Wechsler, 1999)(WASI) for TYP children. The WASI Verbal IQ is comparable to the WISC-IV Verbal Comprehension Index, and the WASI Performance IQ is comparable to the WISC-IV Perceptual Reasoning Index (Wechsler, 1999).

*Short-term memory. A*t Time 1 and 2 the digit length forward task and the sentence length task from the Auditory Processing Test were administered (APT)(Rowe, Pollard, & Rowe, 2006).

Attention Switching Task. The Visearch dual-target task from the Wilding Attention Tasks (WATT)(John Wilding, Munir, & Cornish, 2001) is a computerized visual search task. The participant has to search alternately for a black vertical ellipse then a brown horizontal ellipse to reveal a hidden monster by clicking on the appropriate target. Fifteen targets of each of the two types are present, plus 70 distracters. There is one trial only, with a maximum of 20 targets to be found (10 for the first shape and 10 for the second). The game terminates when all the monsters have been found or a maximum of 50 clicks has been reached. The computer program records the number

of false alarms, the type of target the false alarm occurs on, and time taken per hit, with and without errors included. This task is regarded as a test of the executive control function involved in switching attention between different stimuli (John Wilding et al., 2001). Past research has found that the number of false alarms to non-targets in the dual target search, in which alternation between two targets is required, is characteristic of poor attention, reflecting not only impulsivity but the additional demands of switching (John Wilding, 2003; John Wilding et al., 2001). This task was administered at Times 1 and 2 using the same scene.

Sustained Attention Task. The Vigilan task (WATT) is a computerized vigilance task using the same screen display as for the Visearch task (see above). Each child has to watch for a yellow border that appears randomly surrounding a target shape on the screen and click on it within seven seconds, after which the yellow border vanishes and a miss is recorded. Sixteen targets appear one by one at irregular intervals. The number of correct targets detected (maximum 16), mean response time to a target, number of false positives, and distance wandered were recorded. Both the Visearch and Vigilan accuracy factors (number of false alarms) have been found to relate to the behavioural ratings of attentional ability, whereas the speed factor (time per hit) is more closely related to IQ (Cornish, Wilding, & Hollis, 2008; John. Wilding & Cornish, 2007). In this study the accuracy factor (false alarms) in Visearch was used as the measure of attention switching, and the accuracy factor (false alarms) in Vigilan as the measure of sustained attention. This task was administered at Times 1 and 2 using the same scene.

Academic Achievement. Literacy and numeracy were assessed at Times 1 and 2 using two subtests from the Wechsler Individual Achievement Test II Australian version (Wechsler, 2007). Reading achievement was determined using the Word Reading

subtest, where children were required to read words from a word card and the total number of words read aloud correctly is recorded. Mathematics achievement was assessed via the Numerical Operations subtest where children were required to solve paper and pencil computations with the total number of correct responses recorded.

Procedure

The study was approved by the Human Research Ethics Committees of Monash University and the Victorian Government Department of Education and Early Childhood. Parents received an explanatory statement and provided written informed consent and children provided assent. Participation was voluntary and participants did not receive any monetary reward for participation other than reimbursement for travel costs.

At Time 1 and 2 parents of participants were invited to participate via email or letter and follow-up telephone call. Participants were tested at a home visit, at Monash University, or at their primary school. Participants completed the Visearch and Vigilan tasks using a laptop and mouse. All participants were tested individually in a quiet room, with task presentation counterbalanced across children. All data were entered into Statistical Package for the Social Sciences (SPSS) version 21.0 for statistical analyses.

Analyses

Distributions and outliers were assessed for each variable by group. An outlier in the Time 1 Visearch false alarms variable which was greater than 3 standard deviations from the mean was removed from the ASD group. The Time 1 variables Visearch and Vigilan false alarms, digit and sentence length were non-normally distributed and were not improved with transformation. These were entered into analyses without transformation as per Tabachnick and Fidell (2007). Time 1

Numerical Operations raw score was negatively skewed and normalized with a square root transformation. The Time 1 Word Reading raw score was positively skewed and normalized with a reflect and square root transformation, which means lower scores on the transformed variable indicated better performance. The Time 2 Word Reading raw score was normally distributed in both groups. The Time 2 Numerical Operations raw score was non-normally distributed and normalised with a log 10 transformation. For the Time 2 Visearch false alarms variable, an outlier in the ASD group which was greater than 3 standard deviations from the mean was removed and normality was improved via a log 10 transformation.

Independent t-tests and Analysis of Variance (ANOVA) were used to compare the groups on demographic variables. To compare group and gender differences over time Repeated Measures ANCOVA were employed controlling for any demographic group differences. Given non-normal distribution of some variables, Spearman correlations were used to examine the relationships between variables. Bonferonni corrections were employed for post hoc tests.

Results

Demographic information

An independent t-test showed there was no difference in the time interval between Time 1 and Time 2 testing for the ASD (*M*=12.9 months, *SD*=1.1 months) and TYP group (*M*=12.7 months, *SD*=1.0 months), *t*(106)=1.241, *p*=.271, *Cohen's d*=.24. There was no gender difference in the number of males and females at Time 1 or Time 2 with half in each of the ASD and TYP groups being female. Two by two ANOVAs (group X gender) showed no *gender* differences in age, verbal IQ, and perceptual IQ and no interactions between gender and group. At Time 2, due to the drop out of 16 participants, the ASD group were significantly older than the TYP

group, $F(1,107)=5.639$, $p=.019$, $\eta_P^2=.057$. IQ was assessed only at Time 1, where there were significant group differences with the TYP group having higher verbal IQ $F(1,120)=14.146$, $p<.001$, $\eta_P^2=.105$,and perceptual IQ, $F(1,120)=4.306$, $p=.040$, $\eta_P^2=.035$. Hence, age and verbal IQ were used as covariates in group comparisons.

Switching and sustained attention over time

Spearman correlations revealed significant relationships between Time 1 and Time 2 measures of Vigilan false alarms [ASD group $r=.365$, $p=.007$; TYP group $r=.304$, $p=.029$] and Visearch false alarms in the ASD group $r=.308$, $p=.025$, but not TYP group $r=.096$, $p>.05$. To determine any group or gender differences in switching and sustained attention, two repeated measures ANCOVA's controlling for age and verbal IQ were conducted with time as the repeated measure and group and gender as the between subjects factors. Bonferonni corrections were employed (.05/2=.025). There were no significant main effects of group, time, and gender and no interactions for Vigilan false alarms, indicating no differences in sustained attention performance over time, for the ASD and TYP groups and for boys and girls. As predicted, there was a significant main effect of group for Visearch false alarms, indicating the ASD group made more errors on the attention switching task than the TYP group, $F(1,99)=8.243$, $p=.005$, $\eta_P^2= .077$. There were no changes in Visearch false alarms over time, and no gender differences.

Reading and mathematics over time

Two males with ASD did not complete the Numerical Operations task leaving 54 in the ASD group. Spearman correlations revealed significant relationships

between Time 1 and Time 2 measures of Word Reading raw scores [ASD group r=.962, p<.001; TYP group r=.924, p<.001] and Numerical Operations raw scores [ASD group r=.955, p<.001; TYP group r=.804, p<.001].

To examine if there were any differences in academic performance over time and whether performance differed by group or gender, four repeated measures ANCOVA's were conducted with time (Time 1 and Time 2) as the repeated measure and group and gender as the between groups factors, with scaled and raw scores from Word Reading and Numerical Operations tests as dependent variables. Raw scores were examined so that change over time could be assessed. When scaled scores were used in the analysis only verbal IQ was covaried given standard scores account for age. When raw scores were used in the analysis both age and Verbal IQ were covaried. Bonferonni corrections were employed (.05/4=.0125).

As predicted, there was no difference in the Word Reading scaled score, and no difference between the ASD and TYP groups, or boys and girls, with or without verbal IQ covaried. Unexpectedly, for the Numerical Operations scaled score, the TYP group performed significantly better than the ASD group without verbal IQ controlled [F(1,101)=12.967, p<.000, η_P^2=.113]. When verbal IQ was controlled the group difference was still significant [F(1,101)=4.067, p<.046, η_P^2=.039] but not with the Bonferonni correction. As expected there were no gender differences in mathematics performance. There was no main effect of time.

In regards to raw scores, there was a significant improvement in Word Reading raw score over time, F(1,102)=49.880, p<.001, η_P^2=.328, and no group or gender differences. For the Numerical Operations raw score there was no main effect of time, group or gender, and no interactions.

Table 1.
Time 1 and 2 Demographic, academic and attention variables for the TYP and ASD groups

Variable	*Time 1*		*Time 2*	
Time 1	ASD N=64 M (SD)	TYP N=60 M (SD)	ASD M (SD)	TYP M (SD)
Age (months)	118.77 (22.02)	111.87 (20.54)	131.4 (22.4)	121.4 (18.9)
Verbal IQ	98.89 (13.78)	107.03 (9.64)		
Perceptual IQ	101.08 (14.98)	106.35 (13.51)		
Numerical Operations Standard Score	All 87.61 (18.66) Boys 89.00 (20.54) Girls 86.31 (16.95)	All 97.97 (13.66) Boys 99.27 (15.98) Girls 96.67 (10.99)	All 88.6 (17.2) Boys 91.1 (18.5) Girls 86.3 (15.9) (N=54)	All 99.4 (13.4) Boys 101.1 (15.9) Girls 97.8 (10.3) (N=52)
Numerical Operations Raw Score	18.7 (7.9)	19.5 (7.3)	21.9 (8.6) (N=54)	22.3 (7.9) (N=52)
Word Reading Standard Score	All 98.52 (15.66) Boys 96.53 (17.59) Girls 100.50 (13.45)	All 101.93 (12.90) Boys 102.40 (14.22) Girls 101.47 (11.66)	All 98.7 (14.9) Boys 97.9 (16.2) Girls 99.5 (13.8) (N=54)	All 102.9 (11.4) Boys 103.2 (12.3) Girls 102.6 (10.9) (N=52)
Word Reading Raw Score	98.7 (18.9)	97.1 (18.0)	104.9 (14.8) (N=56)	104.0 (12.9) (N=52)
Digit Span	4.4 (1.0)	4.6 (2.0)	4.6 (1.1) (N=53)	4.7 (0.9) (N=52)
Sentence Length	12.5 (2.0)	12.6 (2.0)	13.3 (2.4) (N=53)	13.3 (2.2) (N=52)
Vigilan false alarms	5.0 (6.3) (N=61)	2.6 (3.6)	5.0 (6.8) (N=53)	3.1 (3.5) (N=52)
Visearch false alarms	4.9 (5.1) (N=62)	3.7 (4.6)	3.7 (4.2) (N=53)	1.5 (1.7) (N=52)

Associations between developmental change over time for Academic Performance, EF, and Working Memory

Gain scores were calculated by subtracting Time 2 scores from Time 1 scores for word reading raw score, numerical operations raw score, switching attention errors, sustained attention errors, digit length and sentence length, Table 2. Spearman correlations were used to examine the associations between these gain scores, age and verbal-IQ. Word reading raw score changes were negatively associated with age (Whole group r=-.484, p<.001; ASD r=-.454, p<.001; TYP, r=-.470, p<.001), indicating there was greater improvement in younger children in word reading performance. Unexpectedly, there were no significant correlations between any of the other gain scores in the whole sample or in each group separately.

Table 2.

Gain scores (Time 2 minus Time 1) for academic and attention components in ASD and TYP Children.

	TYP Mean (SD)	ASD Mean (SD)
Δ Word Reading (Raw)	7.77 (5.93)	7.84 (6.87)
Δ Numerical Operations (Raw)	3.96 (3.50)	3.50 (3.40)
Δ Attention Switching False Alarms	2.67 (4.83)	1.16 (0.67)
Δ Sustained Attention False Alarms	-0.56 (3.64)	0.17 (7.47)
Δ Digit length	0.19 (0.95)	0.13 (0.92)
Δ Sentence Length	0.78 (1.56)	0.52 (1.54)

ASD, Autism Spectrum Disorder; TYP, Typical children

Discussion

The aim of this study was to investigate whether children with ASD and typically developing children differed over time with regard to reading, mathematics and switching and sustained attention and to determine whether there were any gender differences and inter-relationships between these factors. The study found no difference between TYP and ASD children in regard to performance on a sustained attention task, and reading achievement. Children with ASD made more errors on an attention switching task and also tended to have lower mathematical attainment than TYP children. The study found no gender differences in any of these areas. The development rates of academic and EF skills were similar in children with ASD and TYP children over the one year period, with reading ability improving and stable mathematics and EF performance. Unexpectedly, there were no associations between change in EF and change in academic performances over the year. These findings indicate similar EF and academic development over one year in primary school-aged children with and without ASD.

There was no difference in word reading attainment in children with ASD and TYP children as predicted. This is consistent with past findings at the group level (Minshew et al., 1994; Nation et al., 2006). This relationship held whether verbal IQ was controlled or not, indicating that basic word reading is generally an intact area in high-functioning children with ASD, despite significantly lower verbal IQ. However this finding of similar performance does not necessarily infer that the same underlying processes were utilized to achieve this outcome in children with ASD. In contrast, children with ASD tended to perform more poorly than TYP children in regard to mathematics. This finding is largely consistent with the limited past research into mathematics in ASD, for example, in a review Chiang and Lin (2007) found that although most individuals with high-functioning autism and Asperger's Disorder had average mathematics ability this was likely to include an area of mathematics weakness. It is noteworthy that the Numerical Operations task used in the present study to assess

mathematics attainment required children to independently work through written mathematics problems and handwrite their responses. This is in contrast to the Mathematics Reasoning task, also from the WIAT-II, where children are provided with verbal instructions from the examiner and visual cues for each problem with verbal responding. The format of the Mathematics Reasoning task may be less overwhelming for children with ASD and utilize their characteristic visual strengths. Potentially, these factors (motivation, handwriting and independently working) may have contributed to poorer performance on the Numerical Operations task in children with ASD rather than a deficit *per se* in calculation ability. It will be important for future studies to examine other mathematics tasks to rule out these factors.

In the whole sample there was improvement in word reading, but not in mathematics, where performances were stable, over the one year period. Importantly, there was no difference in the *rate of change* over the period in reading or mathematics achievement between the ASD or TYP groups. In regard to word reading, improvement was associated with being younger, with this association similar in TYP and ASD children. This is consistent with the rapid improvement in basic reading skills during the early primary school years which reduces as children age into later primary and high school years (Skibbe et al., 2008). Importantly, this developmental profile appears to be present in children with ASD. However, examining this trajectory over a longer time period will be important. It will be also be necessary for mathematics ability in children with ASD to be tracked longitudinally to determine if the present gap remains stable or decreases or increases relative to typically developing children.

In regard to sustained and switching attention tasks, as predicted, children with ASD performed more poorly than TYP children on the attention switching task, making more errors. There have been some past mixed findings in regards to attention switching (Kaland et al., 2008; Russell et al., 1999), however, our finding of poorer attention switching is

consistent with the theory of underlying executive dysfunction in ASD (Pennington & Ozonoff, 1996; Rinehart et al., 2001). Consistent with past research, there was no group difference in the sustained attention task indicating that sustained attention is generally intact in ASD (Johnson et al., 2007).

Unexpectedly, there was no difference in the *rate of development* of sustained and switching attention between the TYP and ASD groups. Past studies have suggested that there is a lack of development or more rapid development of some EF skills in children with ASD compared to their peers (Ozonoff & McEnoy, 1994; Pellicano, 2010). Differences between these past findings and the present study may be due to the different tasks used, different age ranges and different developmental periods examined. The present findings indicate stable EF performances over one year in TYP and ASD groups. It is also noteworthy that the correlation between Time 1 and Time 2 performances on the switching attention task in the TYP group was unexpectedly low which is a limitation of the study and may relate to the lack of developmental differences.

Unexpectedly, there were no significant *associations* between change in attentional switching or sustained atttention and change in reading and mathematics. Past studies of typical development have shown that change in EF skill is associated with change in academic performance (Cartwright, 2012). Potentially, one year may not have been a long enough period to show these associations, particularly within the primary school-age range. These relationships may be stronger in pre-school children when the components of EF develop more rapidly in conjunction with pre-reading skills (Cartwright, 2012). It will be important for future studies to examine these relationships across longer periods of time and in younger children with ASD.

Finally, as expected, in this group of males and females with ASD who were well matched on age and IQ, there were no *gender* differences in academic attainment over both

time periods. This was also reflected in the TYP group with no gender differences in academic attainment. Mathematics attainment in females with ASD is a particularly neglected area, with most studies in this area recruiting too few females to examine gender effects (Jones et al., 2009; Minshew et al., 1994). The present findings suggest children with ASD are likely to experience poorer mathematics performance, regardless of gender. Similarly, there were no gender differences in the sustained and switching attention tasks over time with boys and girls with ASD performing similarly. There has been past research suggesting that females are cognitively more impaired than males with ASD (Lemon et al., 2010; Lord, Schopler, & Revicki, 1982; Pilowsky, Yirmiya, Shulman, & Dover, 1998), and other theories suggesting that females may be under-identified due to clinician bias or better compensation for their difficulties, particularly when they have normal intellectual functioning (Kopp & Gillberg, 1992). Our findings do not support a theory of either greater or lesser impairment in high-functioning females already *diagnosed* with ASD given no gender differences were found across the domains of intellectual, academic, and cognitive attention.

A limitation of the present study was the wide age range of participants from 7 to 12 years at Time 1. Although this is a relatively narrow age range in the ASD literature, given the developmental sequences of attention functions over time (Klenberg, Korkman, & Lahti-Nuuttila, 2001; Zhan et al., 2011), examining children with ASD within more highly delimited age ranges will be important to detect change. Another limitation of the present study is that the present findings cannot be generalized to children with ASD with IQ's in the atypical range. Extending this work to including children with ASD with intellectual disability will be important, although differentiating between attention deficits associated with intellectual disability versus ASD will be complex. Future research in this area which focuses on adolescence may be informative given the findings of a second wave of executive functioning deficit that occurs in the second decade of life in children with ASD (Luna et al.,

2007; Minshew & Williams, 2007). Examining whether this may inter-relate with poorer academic attainment during this period will be beneficial for understanding what additional educational supports may be required for children with ASD in the early secondary school years.

To summarize, this study has examined the development of attention switching, sustained attention and academic attainment in children with ASD over one year, their inter-relationships and the influence of gender. Children with ASD had equivalent reading and sustained attention and poorer mathematics and attention switching performance compared to typically developing children, with rates of change over the year similar regardless of whether a child had ASD. Although ASD is primarily a condition of atypical neurodevelopment, the high-functioning children with ASD in this study appeared to show similar developmental profiles in regard to EF and academic performance to typically developing children. There were no gender differences across these objective measures which suggest that clinically ascertained high-functioning boys and girls with ASD will present with similar academic and EF profiles in the primary school years. Future studies longitudinally examining the development of academic and EF skills in this population will be important to identify possible risk periods for academic underperformance, and their correlates, in children with ASD.

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