# PERCEPTION, COGNITION AND HETROGENEITY IN AUTISM SPECTRUM DISORDER

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# ABSTRACT

Theoretical models of cognition in Autism Spectrum Disorder (ASD) propose that hierarchical processing is atypical and that perception is characterised by a local information processing bias. Whilst these models have gained considerable support from experimental studies, changes in ASD diagnostic criteria and increases in prevalence figures are reflected in increased heterogeneity at both cognitive and clinical levels in this condition. The aim of this study was to investigate perception and cognition in adolescents with ASD and typical development (TD) in the context of cognitive heterogeneity. Chapter two provided a detailed account of the standardised memory and intelligence tests administered in the study and the results from these tests were described in chapter three. Group differences, with poorer performance in the ASD group was observed on tests measuring verbal working memory, attention/concentration, whilst this group score higher on the Matrices subtest from the WASI-II (Wechsler, 2011). Inspection of individual data on standardised memory and intelligence tests revealed considerably variable subtest scores within the ASD group, and this was most marked on subtests measuring auditory and visual attention, visual perception, and memory for complex language. Experimental studies using flanker tasks to assess visual and auditory attention were presented in chapter four. The results from these studies showed some reduction in accuracy and an increase in RTs although responses to congruent and incongruent manipulations did not differ across groups. Experiment three, described in chapter five directly tested local and global processing using a Navon paradigm that included congruent and incongruent distractor trials. The group difference was marked on this study and showed a significantly increased susceptibility to both local and global incongruent distractors in the ASD group. The ASD scores on the selective attention and local/global processing tasks showed considerable within group variability and correlations carried out on the experimental and background data revealed links between task performance, cognitive and memory skills. In chapter six, a test of visual averaging was administered and failed to reveal a significant difference between the ASD and TD groups. These results were consistent with previous findings showing preserved visual averaging in adults with ASD. The results from the standardised and experimental tasks were discussed in chapter seven and it was concluded that the cognitive profile in ASD cannot be explained within a single theoretical model. Limitations in the studies and potential routes to better understanding heterogeneity in ASD were discussed.

# CONTENTS

# LIST OF FIGURES

## CHAPTER 2: INTELLIGENCE AND MEMORY IN AUTISM SPECTRUM DISORDER AND TYPICAL DEVELPEMENT



## CHAPTER 3: MEMORY AND INTELLIGENCE PROFILES IN AUTISM SPECTRUM DISORDER AND TYPICAL DEVELOPMENT

**CHAPTER 4: VISUAL AND AUDITORY SELECTIVE ATTENTION IN AUTISM SPECTRUM DISORDER AND TYPICAL DEVELOPMENT**



**CHAPTER 5: LOCAL-GLOBAL PROCESSING IN AUTISM SPECTRUM DISORDER**

**CHAPTER 6: PERCEPTUAL AVERAGING IN AUTISM SPECTRUM DISORDER**

# LIST OF TABLES

## CHAPTER 3: MEMORY AND INTELLIGENCE PROFILES IN AUTISM SPECTRUM DISORDER AND TYPICAL DEVELOPMENT



## CHAPTER 4: VISUAL AND AUDITORY SELECTIVE ATTENTION IN AUTISM SPECTRUM DISORDER AND TYPICAL DEVELOPMENT

**CHAPTER 5: LOCAL-GLOBAL PROCESSING IN AUTISM SPECTRUM DISORDER**



**CHAPTER 6: PERCEPTUAL AVERAGING IN AUTISM SPECTRUM DISORDER**

# DEDICATION

This thesis is dedicated to my family, especially my late father (Makhmood Ahmed), my beautiful mother (Tahira Tabassum) and to the most amazing brothers (Imran Makhmood & Zeeshan Makhmood). I would like to thank you all wholeheartedly for your unconditional love, endless support, eternal patience, and beautiful prayers. Thank you for always believing in me and for making me truly believe in myself. You have taught me that the sky is indeed the limit, and to always follow what is in my heart and in my dreams.

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# THESIS OUTLINE

Chapter one will provide a brief overview of changes in the diagnostic criteria, prevalence rates and the problem of heterogeneity as well as comorbidity in ASD.  Theoretical accounts of cognition in ASD were also outlined.  Memory and intelligence are important sources of heterogeneity within the ASD population and were assessed using the Children's Memory Scale (CMS; Cohen, 1997) and the Weschler Abbreviated Scale of Intelligence (WASI-II: Wechsler, 2011). In chapter two, a detailed description of these tests was provided together with information about participants, recruitment, testing, and ethics. The analysis of the data from the background memory and intelligence tests will be presented for groups and individual participants in chapter three.  Chapter four begins with a review of the literature on attention in ASD before presenting the methods and results from two studies of selective attention in ASD and TD. The focus of the analysis will be on comparing groups and examining heterogeneity within the groups. Theoretical models of ASD, outlined in chapter one proposes that perception is locally biased, and this will be directly investigated in chapter five. The literature on local/global processing in ASD will be briefly reviewed and the results from experiment three which uses a Navon paradigm will be described and analysed for group differences and within group variance.  The experiment described in chapter 6 will investigate perceptual averaging in participants with ASD and TD. Intact visual averaging has been demonstrated in adults with ASD and this will be the first study to extend these findings to a younger age group. The results from the standardised and experimental tests will be discussed in the context of what is known about heterogeneity in ASD.

# CHAPTER 1: INTRODUCTION

## ABSTRACT

This chapter provides a brief overview of changes in the diagnostic criteria for Autism Spectrum Disorders (ASD) detailed in the different editions of the Diagnostic Statistical Manual (American Psychiatric Association, 1980 (3rd ed), 1987 (3rd ed revised), 1994 (4th ed), 1997 (4th ed revised), 2013 (5th edition). This will be followed by discussion of heterogeneity within ASD. Theoretical models describing atypical perceptual and cognitive processing in ASD will also be described.

### CHANGES IN THE DESCRIPTION AND THE DIAGNOSTIC CRITERIA OF ASD

Since Autism was first included in the DSM-III in 1980, there have been several revisions to the diagnostic criteria, all of which have been informed and driven by ongoing research. The Fourth edition of the Diagnostic and Statistical Manual (1994) (DSM-IV) included a range of pervasive development disorders including Autistic disorder, Asperger's disorder, Rett's syndrome as well as Childhood Disintegrative disorder and Pervasive development disorder not otherwise specified (PDD-NOS). The International Classification of Diseases 10th edition (ICD-10) (WHO) diagnostic criteria also includes autism subgroups. Childhood autism, atypical autism and Asperger syndrome are listed as Pervasive Developmental Disorders which are defined as "A group of disorders characterized by qualitative abnormalities in reciprocal social interactions and in patterns of communication, and by a restricted, stereotyped, repetitive repertoire of interests and activities. These qualitative abnormalities are a pervasive feature of the individual's functioning in all situations" (ICD-10). The first section of the ICD-10 diagnostic criteria for autism states that abnormal or impaired development must be present before the age of three in at least one of the following three areas: receptive or expressive language as used in social communication, the development of selective social attachments or of reciprocal social interaction, functional or symbolic play. The second section states that at least 6 symptoms from a total of 12 listed should be in evidence. The six should include two symptoms from those listed under qualitative impairment in social interaction, at least one symptom from those listed under qualitive abnormalities in communication behaviours, and at least one symptom from those listed under repetitive and stereotyped patterns of behaviour, interests, and activities.

Like the ICD-10 diagnostic criteria, the DSM-IV-TR (2000) diagnostic criteria included autism under the title of Pervasive Developmental Disorders alongside Asperger Syndrome, Retts Disorder, Childhood Disintegrative Disorder as well as those not otherwise specified (PDD-NOS). In the DSM-IV-TR (2000), autism was characterised by a triad of impairments involving impairments in the development of social interaction combined with either impairment in verbal or non-verbal communication and the presence of stereotypical behaviours. However, in the most current revised DSM-5 2013 edition, all subgroups of PDD in DSM-IV-TR were removed and presented under one category with the umbrella term Autism Spectrum Disorders (ASD). Another change in the DSM-5 diagnostic criteria is that the triad of impairments described in earlier versions of DSM and in ICD-10 were collapsed into a dyad of impairments. The impairments in social and communication domains were integrated. This was because it was difficult to define and measure these impairments separately. The scientific rationale for utilising the umbrella term ASD was that research had largely failed to validate the DSM-IV subgroupings (Howlin, 2000). Howlin (2000) suggested that it was difficult to distinguish intellectually high functioning individuals with Autistic Disorder (HFA) from individuals with Asperger Syndrome at later points in development. DSM-5 therefore reflects the wide heterogeneity characterising ASD, and this sets a new agenda for researchers interested in understanding this complex disorder.

## PREVALENCE RATES IN ASD

One question which has received much attention in recent years concerns an apparent rise in the prevalence rates of ASD. In an early study carried out in the county of Middlesex, Lotter (1966) utilised Kanner's criteria (1943) and collected behavioural questionnaire data, completed by teachers and caregivers, and conducted interviews with parents and children. They reported a prevalence rate of 4.5 per 10,000. Two subsequent studies, utilising Rutter's criteria (1978), which was very similar to that of Kanner (1943), reported markedly different prevalence rates.

Steinhausen et al. (1986) conducted a study in West Berlin in Germany and reported an ASD prevalence rate of 1.9 per 10,000 in individuals under 15 years of age, whereas Bohman et al. (1983) conducted a study in North Sweden and reported a prevalence rate of 5.9 per 10,000. Furthermore, later studies which employed the formal DSM-III criteria (Rutter, 1978) for diagnosing ASD yielded a significant increase in prevalence rates. Matsuishi, et al. (1987) surveyed ASD prevalence rates in Japanese children aged 4 to 12 years in the city of Kurume and reported prevalence rates of 15.5 per 10,000. In support of this study by using the same diagnostic criteria, Sugiyama & Abe (1989) conducted an epidemiological study in Majoya Japan. This study was a statistical survey of diagnoses made over a 5-year period and reported a prevalence rate of 13 per 10,000. However, Fombonne & Du (1992) conducted a study in four French regions, using the ICD-10 diagnostic criteria and reported prevalence rates of 4.9 per 10,000. In line with this, Magnússon & Saemundson (2001) conducted a clinical based study from which they estimated prevalence rates of ASD in Iceland using two consecutive birth cohort records: participants born between 1974-83 and 1984-93. The older cohort record had employed the ICD-9 diagnostic criteria for 72% of the cases whereas the ICD-10 criteria was used for diagnosing the individuals in the more recent cohort. They reported a prevalence rate of 3.8 per 10,000 in the older cohort and a prevalence rate of 8.6 per 10,000 in the more recent cohort. Sponheim & Skjeldal (1998) conducted a study in Norway in which they employed the ICD-10 diagnostic criteria to assess children aged between 3-14 years. They reported a prevalence rate of 4-5 per 10,000 which is considerably lower compared to studies which have used the DSM-III diagnostic criteria. For example, Webb et al. (1997), Gillberg et al. (1991), and Bryson et al. (1988), used the revised edition of the DSM-III diagnostic criteria and reported prevalence rates that ranged between 7.2 and 10.1 per 10,000.

Scott et al. (2002) used both ICD-10 and DSM-IV criteria, in a study of 5-11-year-old children living in Cambridgeshire during the period spanning July to December 1999. Their aim was to determine whether prevalence rates for this group and location was comparable with other recent national and international findings. They reported a prevalence rate of 57 per 10,000. Though this was 11 times higher than the estimated rate for classic ASD, the findings were consistent with other national studies assessing the broader spectrum. For example, Baird et al. (2000) reported that 57.9 per 10,000 of a group of 7-year-old children living in the Southeast of England met the diagnostic criteria for ASD. However, studies conducted outside of the UK have yielded different prevalence rates for ASD. For example, Kielinen et al. (2000) reported a prevalence rate of 20.7 in 10,000 in a sample of

5 -7-year-olds living in Northern Finland, and Eapen et al. (2007) reported a prevalence of 29 in 10,000 in 3-year-old children living in the United Arab Emirates.

A recent report by the Centre for Disease Control and Prevention (CDC, 2018), described prevalence data from eleven sites in the US. The data was obtained via the Autism and Developmental Disabilities Monitoring (ADDM) network for the period up until 2014. Using the DSM-IV-TR diagnostic criteria, they reported a prevalence rate of 16.8 in 1,000, or one in 59 in children over eight years. However, the report highlighted marked variability, ranging between 13.1 per 1,000 to 29.3 per 1,000 across the different sites, and concluded that this related to differences in sex, race, and ethnicity across the sites. Since Lotter (1966) reported an ASD prevalence rate '4.5 per 10,00' in 1966 there have been significant changes in diagnostic criteria, and this may in part explain the large increases in prevalence rates. However, it should be noted that even within one country, rates can show large variability across clinical settings.

## HETEROGENEITY IN THE PRESENTATION OF ASD

Much of the earlier research into ASD used the terms high-functioning autism (HFA) and low functioning autism (LFA) to acknowledge intellectual variations within this disorder. However, during the last twenty years there has been an increasing acceptance that heterogeneity in ASD goes far beyond differences in IQ, and the most recent revision of DSM formally acknowledges this by including different levels of symptom severity and requiring clinicians to provide information on language and intellectual skills and impairments, and co-morbid conditions. Co-morbidity between ASD and other developmental conditions is also becoming a topic of interest for researchers. For example, Charman et al. (2011) showed that it is more common for individuals to present with ASD and other developmental difficulties than with ASD in isolation. This finding poses significant challenges for cognitive models of ASD. Heterogeneity and co-morbidity may impact on perceptual and cognitive skills in distinct ways and homogeneity, at the cognitive level, can no longer be assumed. The following section will provide a brief review of some of the studies investigating co-morbidities in ASD.

## STUDIES OF LANGUAGE IN ASD

Research into language has shown that profiles of language skills and impairments differ across and within neurodevelopmental disorders. Impairments in the use of language, pragmatics or the appropriate use of language within social and situational contexts (Martin & McDonald, 2003; Rapin, 1996) are characteristic within a range of developmental disorders (Bishop, 1998; Norbury et al., 2004; Towbin et al., 2005) and are not uniquely associated with ASD. Language and intellectual abilities show considerable variability in ASD and DSM-5 criteria states that clinicians should specify whether individuals present with or without accompanying language and intellectual impairments. Prizant (1996) and Rapin (1991) reported that around 50% of individuals with ASD never acquire functional speech, whilst Tager-Flusberg et al. (2005) reported that this was the case for around 25% of individuals. Many studies investigating language acquisition in ASD have reported delays in reaching early milestones, especially the onset of words and phrases. However, some individuals show accelerated language development in their third or fourth year of life (Szatmari et al., 2000) and may achieve chronological age-appropriate scores on standardised language tasks (Kjelgaard & Tager-Flusberg, 2001). Pickles et al. (2009) reported a pattern of deterioration where individuals start to use spoken words at 12 – 15 months but then become mute towards the end of the second year. This study showed that some, but not all individuals subsequently regained the use of language.

Studies of visual attention in infants at risk for ASD have revealed an early corrosion of attention to social stimuli during the first year of life (Klin et al., 2015) and this links with work on language acquisition in ASD. Kuhl et al. (2005) conducted an EEG study in preschool children with ASD with chronological age (CA) and mental age (MA) matched TD comparison children. The children were sub-grouped on the basis of their preference or non-preference for ‘motherese’ over a non-speech analogue stimulus and were then testing for phonetic discrimination using mismatch negativity (MMN), an event-related potential (ERP). The findings revealed strong links between the children’s auditory preferences and their language processing. Children who failed to show a preference for ‘motherese speech’ also failed to show MMN activity in response to syllable change. However, within the ASD group, a subgroup of children showed a preference for ‘motherese’ and their pattern of MMN activity in response to syllable change was similar to that of TD children.

Several studies have investigated associations between levels of symptom severity and language in ASD. Charman et al. (2005) studied inter-relationships between symptom severity, cognitive and language skills at 2, 3 and 7 years in children with ASD. The results revealed a significant negative relationship between early receptive and expressive language scores and later levels of symptom severity. In ASD, protodeclarative pointing (to share an interest with another) is weakened while proimperative pointing (to communicate a request) is relatively intact, especially in older children (Baron-Cohen, 1989). Toth et al. (2006) studied the development of communication skills in 60 preschool children with ASD and reported a significant association between prodeclarative joint attention, immediate imitation, and language abilities in children between 3-4 years of age. Kjelgaard & Tager-Flusberg (2001) carried out an extensive screening study of language abilities in children with ASD. They found that around half of the children were able to complete the full battery of language tests. Of these, a significant proportion performed well on tests of receptive and productive vocabulary but struggled with the grammatical, semantic, and pragmatic aspects of language. Surprisingly, a small group of children with ASD achieved scores that were commensurate with chronological age on all tests. A second important finding to emerge from this study was that a subgroup of children showed the cognitive profile characteristic of Specific Language Impairment (SLI). These children performed poorly on tests measuring receptive vocabulary (PPVT), overall language skills (CELF) and auditory short-term memory. This finding was consistent with results from family studies showing a significant overlap between ASD and SLI (Tomblin et al. 2003; Hafeman & Tomblin, 1999). In Kjelgaard and Tager-Flusberg's (2001) study, intelligence and memory were associated with patterns of language and the literature on intelligence and memory in ASD will be briefly reviewed in chapters two and three.

## MOTOR IMPAIRMENTS IN ASD

Motor difficulties have been widely reported in ASD. Fournier et al. (2010) conducted a meta-analysis which incorporated data from 51 studies investigating motor skills in ASD and reported highly significant motor coordination deficits across a wide range of behaviors. Children with reduced motor skills are more likely to experience difficulties related to learning which include attention, reading, writing, and spelling (Dewey et al., 2002). In one study of ASD, Bedford et al.

(2016) set out to explore links between the onset of walking and speed development. The results from the study showed that gross motor skills were a significant predicator of both expressive and receptive language development in ASD. Motor difficulties in ASD have also been linked with social isolation (Asonitou et al., 2012; Gomez & Sirigu, 2015; Huau et al., 2015; Poulsen et al., 2008) and an increased incidence of mental health difficulties in childhood, adolescence, and adulthood (Kirby et al., 2013).

## PERCEPTUAL AND SENSORY DIFFICULTIES AND THEIR BEHAVIORAL CORRELATES IN ASD

Experimental studies motivated by theoretical models of perception in ASD have highlighted unusually fine-grained discrimination of auditory (Bonnel et al., 2003; Heaton, 2003; Heaton, 2005; Heaton et al., 2008) and visual stimuli (Mottron et al., 2006) and have been taken as evidence for perceptual strengths in ASD. However, the earliest description of autism (Kanner, 1946) referred to sensory processing abnormalities. Sensory difficulties, characterised by hyper- or hypo-reactivity to sensory input, are classified as restricted/repetitive behaviours in DSM-5. Sensory under and over-responsiveness appears to be characteristic across sensory modalities in ASD. For example, Baranek et al. (2006) reported that children with ASD seek or avoid auditory, tactile and/or vestibular input. The associations between sensory and other behavioural difficulties have recently been investigated by Wigham et al. (2015). The results from this study showed that sensory under-responsiveness and sensory over-responsiveness are highly correlated with repetitive motor behaviours and an insistence on sameness. The results also showed that anxiety and intolerance of uncertainty mediated the relationships between sensory abnormalities and restricted/repetitive behaviours.

## PSYCHIATRIC COMORBIDITIES AND ASD

Research has revealed elevated levels of anxiety in individuals with ASD. White et al. (2009) conducted a systematic review and reported that 40-45% of school-aged children and adolescents with ASD experience anxiety problems. Studies have shown that anxiety contributes to social disability (Kleinhans et al., 2010; Myles et al., 2001) and awkward, unsuccessful, or negative interactions with others which contributes to heightened anxiety (Bellini, 2006) in ASD. Some evidence suggests that anxiety problems may be more marked in ASD than in other neurodevelopmental disorders. For example, Rodgers et al. (2012) conducted a study in which 34 children with ASD and 20 children with Williams Syndrome (WS) were assessed using tasks measuring anxiety and repetitive behaviors. The results showed that the ASD group reported higher levels of anxiety than the WS group, and for this group levels of anxiety significantly correlated with the severity of repetitive behaviors. Ghaziuddin et al. (2002) reviewed studies investigating depression in ASD and reported that depression may be the most common psychiatric condition seen in individuals with ASD. The study also showed that depression is most prevalent in adults and young adolescents. Depressed individuals with ASD are found to present with a wide range of symptoms ranging from irritability and sadness to aggressive outbursts and suicidal behavior. In line with this study, Ghaziuddin & Zafar (2008) reported that 80% of adults with ASD had a comorbid psychiatric condition. In the sample tested in their study ASD participants were affected by depression (50%), anxiety (21%), attention deficit hyperactivity disorder (ADHD) (18%), psychosis (7%) and tourette syndrome (4%).

## THEORETICAL MODELS OF COGNITION IN ASD

Theoretical models have provided accounts of both social and non-social cognition in ASD. As the studies in this thesis investigate selective attention, perception, cognition and memory, the following section will provide a brief overview of the cognitive theories of ASD.

The earliest account of the Weak Central Coherence theory (WCC) was put forward by Frith in 1989 in her book titled “Autism: Explaining the Enigma”. In this book Frith hypothesised that people with

ASD experience difficulties integrating information into a coherent whole, focusing instead on isolated features in the environment. Early experimental studies using the block design (Shah and Frith,1993) and embedded figures tests (Shah & Frith, 1983; Jolliffe & Baron-Cohen, 1997), showed that children with ASD were advantaged compared with typically developing (TD) children and this was taken as evidence for a local bias in this group. Building on these and other studies showing cognitive strengths in ASD, Happé (1999) shifted the focus of the WCC theory from a deficit account to an account in which ASD is characterised by a cognitive style that is biased towards local rather than towards global information.

The idea that attention was focused on local information has been extensively tested by researchers interested in understanding cognition in ASD. The Navon task (Navon, 1977) is a hierarchical stimulus in which multiple small letters (local level) form a large letter (global level). Using this paradigm, Ozonoff et al. (1994) showed that children with ASD, like TD controls, were quicker to identify global than local stimuli and were equally disadvantaged by local interference. Plaisted et al. (1999) replicated this finding but also showed that on a divided attention task, where participants were instructed to focus on the local or global level of the stimuli, children with ASD showed an advantage in the local condition.

Mottron, Burack and colleagues developed the Enhanced Perceptual Functioning (EPF) model as an alternative to the WCC theory (2001; 2005). According to this model, global processing is unimpaired, whilst perceptual processing, across modalities, is enhanced. Mottron and colleagues were also interested in explaining savant skills, some of which rely on the encoding and analysis of higher order information (e.g. mathematics and music). The EPF model therefore proposed that enhanced perception extends beyond simple feature detection to pattern recognition. In 2002, Baron-Cohen proposed that systematizing, defined as an ability to arrange information according to an organized system is characteristic in ASD. These ideas were later formalised in the hyper-systematizing theory of ASD (Baron-Cohen et al., 2009). According to this theory systematizing creates an advantage in situations where information is organised in a lawful or systematic way (e.g. mathematics). In common with WCC, the model also proposes that ASD is characterised by a local bias.

## THEORETICAL MODELS AND HETROGENEITY IN ASD

Diagnostic criteria for ASD are clearly documented in DSM-5, and theoretical models attempt to explain cognition in this population using a single model. However, as the literature review makes clear, a diagnosis of ASD is not enough to ensure homogeneity in participant samples in experimental studies. For example, increased anxiety has been reported in ASD (Mazurek et al., 2013) and this is associated in shifts in attentional focus (Cisler & Koster, 2010). Similarly, a proportion of children with ASD also meet the criteria for SLI and experience difficulties with auditory short-term memory not typically observed in children with ASD (Kjelgaard & Tager-Flusberg, 2001). These examples highlight the importance of considering individual and well as group level performance in studies aiming to test theoretical models. Whilst consideration of all ASD comorbidities is beyond the scope of this PhD thesis, the initial aim of the study was to investigate low-level perceptual processing in the context of individual differences in intelligence, memory, and sensory processing. However, parents/carers were unwilling or unable to complete the sensory profile test, so this potential source of heterogeneity could not be investigated directly. In the following section the content of the chapters comprising the thesis will be described.

Chapter two will provide information about the standardised tests of intelligence and memory used in the study. Memory and intelligence are important sources of heterogeneity within the ASD population and were assessed using the Children's Memory Scale (CMS; Cohen, 1997) and the Weschler Abbreviated Scale of Intelligence (WASI-II: Wechsler, 2011). The rationale for this assessment was that individual differences in patterns of memory and intelligence subtest performance may enable a better understanding of patterns of performance on the experimental paradigms used in the studies. Details about participants, participant recruitment and testing, and ethics will also be provided in this chapter. The analysis of the data from the memory and intelligence tests will be presented in chapter three. Data from ASD and TD groups will be presented and individual variability within the groups, on the different subtests, will also be explored. The aim of the studies presented in chapter four is to explore selective attention, across visual and auditory modalities in ASD and TD. Studies of selective attention have aimed to test perceptual models of ASD but have produced very mixed results. In chapter four the potential impact of variability in visual and auditory memory skills on selective attention tasks will follow on from the between-group (ASD/TD) comparison. A further aim of the studies presented in this chapter was to determine whether atypical perceptual responses, if in evidence, will generalise across domains. Correlations will therefore be carried out on participants' responses to congruency/incongruency in auditory and visual stimuli. Theoretical models of ASD propose that perception is locally biased, and chapter five will present the results from a Navon task assessing local/global processing. In addition to comparing ASD and TD groups, the analysis will attempt to identify cognitive and memory characteristics associated with atypical perceptual processing. Performance on the selective attention task and memory and intelligence subtest data will be explored in this context.

The EPF theory, outlined by Mottron and colleagues propose that pattern recognition is enhanced in ASD, and the experiment described in chapter 6 will investigate perceptual averaging in participants with ASD and TD. Variability in visual memory and intelligence, and a local bias may influence visual averaging performance, and this will be further investigated. Chapter seven will be the final chapter, and here results from the studies will be discussed in the context of theoretical models of ASD.

## AIMS AND RATIONALE

The first aim of the study is to explore profiles of cognitive and memory skills in children and adolescents with ASD and TD matched for full scale IQ (FSIQ) and chronological age (CA). Between-group differences and within-group variability will be assessed, and the potential impact of cognitive and memory strengths and weaknesses on the experimental paradigms will be explored throughout the thesis.

The aim of the experiments presented in chapters four and five is to investigate selective attention in the visual and auditory domains. Participants will complete visual and auditory flanker tasks (Murphy et al., 2013) as well as a Navon task (Caparos et al., 2013). Prior studies examining selective attention in individuals with ASD have yielded somewhat conflicting findings. So, whilst some results suggest that superior focused attention on visual search tasks is characteristic in ASD, other studies have reported increased distractibility. In chapters four and five the patterns of performance on these tasks will be considered in the context of theoretical models of ASD and heterogeneity in memory and cognitive skills.

Theoretical models of ASD have proposed that individuals with this diagnosis show increased attention to detail and adopt a systematic approach when processing highly organised information. In chapter six, the results from a visual averaging task directly testing these assumptions will be presented. The experimental design allows for a systematic analysis of patterns of averaging performance across groups, and the extent visual averaging is influenced by a local bias, and/or by visual and verbal memory skills, will also be explored. The specific aims of the thesis are detailed below.

## AIMS

1. To examine subtest variability in intelligence and memory in ASD and TD groups.
2. To examine attention in visual and auditory domains and determine whether patterns of performance generalise across domains and are influenced by intelligence and memory.
3. To test whether participants with ASD and TD show different patterns of responses in a local/global task and identify the intelligence and memory correlates of performance across groups.
4. To compare ASD and TD groups on a test of perceptual averaging and determine whether this is influenced by attention, perceptual bias, memory, and intelligence.

There is a relatively large body of literature on perception, attention, cognition, and memory in ASD. Reviews of relevant studies will be presented at the beginning of chapter two where the intelligence and memory tests are described, and in the introductions to the three experimental chapters (four, five and six) that describe studies of perception, attention, and cognition.

# CHAPTER 2: INTELLIGENCE AND MEMORY IN AUTISM SPECTRUM DISORDER AND TYPICAL DEVELPEMENT

## ABSTRACT

This chapter provides information about participant recruitment, testing, methods, and ethics. Standardised tests used to evaluate intelligence, memory, sensory processing patterns and social communication are also described.

### PARTICIPANTS AND RECRUITMENT

The participants with a diagnosis of ASD were attending specialist schools in South London and Surrey. School A is a government school providing special needs education for 11-19-year-old students with a diagnosis of HFA, LFA and Aspergers Syndrome. School B is a county wide primary school providing special needs education for 3 – 16-year-old students with HFA, LFA, Asperger Syndrome, and students with moderate learning difficulties. The typically developing (TD) participants were attending a mainstream school in Surrey.

Initial contact with parents/carers was made via letters to the head teachers of the three schools. Parents/carers who expressed an interest in the research were provided with further information about the aims of the studies, and parents who agreed to their children's participation were asked to complete a written consent form. The form included a description of the proposed studies, and in line with British Psychological Society Guidelines provided information on confidentiality and the participant's right to withdraw from the study. Dates for testing sessions were discussed at the initial meeting with teachers and/or parents. All testing was carried out within the participants' schools.

### ASD

The target ASD sample consisted of 27 males and 2 females. The final ASD sample consisted of 15 males and 2 females with ASD which were recruited to the study and were successfully able to complete all background testing measures and experimental tasks. They were aged between 12 years 8 months to 15 years 4 months (mean = 13.90, SD = 0.84). All had been diagnosed with ASD prior to enrolling in their school and taking part in the study. The children's reports recorded that they had been assessed by a variety of professionals (e.g. paediatricians, clinical psychologists and psychiatrists) using a range of diagnostic tools, including the autism diagnostic interview-revised (ADI-R; Lord et al., 1994), the diagnostic interview for social and communication disorders (DISCO; Wing et al., 2002) and the developmental, dimensional and diagnostic interview (3di; Skuse et al., 2004). All participants had received a diagnosis of autism, ASD or Asperger syndrome. Whilst the participants' records did not detail intellectual difficulties; levels of intellectual ability and memory were screened using the standardised tests described in this chapter.

### Typically developing comparisons

The target TD sample consisted of 29 males and 4 females. The final TD sample consisted of 15 males and 2 females also aged between 12 years 8 months to 15 years 4 months (mean = 14.00, SD = 0.84). None of the participants in this group presented with developmental or psychological disabilities and none had an immediate family member with an ASD diagnosis. This was confirmed by the parents at the beginning of the study. Recruitment documents are provided in the appendix.

### Group matching

In the large majority of studies testing perception and cognition in ASD and TD, groups are matched for intelligence (verbal and/or non-verbal intelligence) and CA. As can be seen from the data presented here, participant groups were matched for CA, FSIQ including both VIQ and PIQ. Given the importance of achieving consistency with previous research in the area, group matching formed a significant part of the recruitment and early testing phase of the study.

### Participant testing

All testing was completed at the participants' schools with regular breaks scheduled in between testing sessions. The experimental sessions were counterbalanced to deal with order effects for both ASD and TD groups. The experimental paradigms were administered on a Lenovo Laptop, and Sennheiser HD 202 headphones were used for the auditory flanker task presented in chapter 4 and to block out external noise in the visual studies.

The experimenter was present in the same room with each participant throughout all the testing sessions, offering praise and encouragement where appropriate. Before each testing session, participants were provided with a brief overview of the experiment and reminded of their right to withdraw from the study should they so wish. During the testing sessions the participants were carefully monitored for signs of discomfort or stress. At the end of each testing session, participants had the opportunity to ask any questions and received verbal feedback. In the final testing session, they were thanked for their participation and parents were provided with an information sheet that included full contact details should they have any further questions about the study.

## STATISTICAL ANALYSIS

The data from the experimental tasks were analysed using parametric statistical procedures. Where relevant assumptions were met, one-way ANOVA, repeated measures ANOVA and t-tests were conducted. The statistical approach taken in the experimental studies (chapters 4, 5 and 6) is to carry out an initial group comparison using ANOVA. The data will be tested to ensure that it meets assumptions on normality and homogeneity of variance. Following on from the group comparisons, correlations will be carried out within groups on the experimental and background data to identify cognitive mechanisms involved in experimental task performance. The data used in the correlation analyses will be checked for normality.

## ETHICS

The study was assessed and granted approval by the Ethics Committee of the Psychology Department at Goldsmiths, University of London.

## STANDARDISED ASSESSMENTS OF INTELLIGENCE AND MEMORY

The WASI-II (Wechsler, 2011) has been widely used in studies of cognition in children with ASD. The decision was made that this was a suitable task to use in the current study. The correlation between scores from the WASI-II and the WISC are relatively high (Irby & Floyd, 2013). Given that the CMS (Cohen, 1997) takes a long time to administer but it includes a broad range of subtests that are likely to provide a richer information of the cognitive profiles for the children in the study.

### Intelligence test. Wechsler Abbreviated Scale of Intelligence (WASI-II)

All participants completed the Wechsler Abbreviated Scale of Intelligence (Wechsler, 2011; WASI-II). This test is comprised of four subtests, two of which are verbal and two which measure performance. Although this is a short-form test research has shown that scores from the WASI correlate highly with the Wechsler Intelligence Scales for Children (Wechsler, 2014; WISC-V) that includes a larger range of subtests (Raiford et al., 2016). The Vocabulary and Similarities subtests are used to measure verbal IQ (VIQ), whereas Block Design and Matrix Reasoning are used to measure performance IQ (PIQ). Performance on each subtest is converted to an age adjusted T score which can be converted to a scaled score, from which VIQ and PIQ scores can be calculated. Full scale IQ (FSIQ) scores are calculated by adding together the results from all four subtests. Details of the four subtests will be described further below.

**(1) Vocabulary*:*** The Vocabulary subtest is comprised of 42 test items. Items1-4 require the participant to name pictures, presented by the examiner one after another. When presenting each picture, the experimenter says, "look at the picture on this page, tell me what the picture shows" or "tell me what this is". Items 5-42 are written words read aloud by the examiner and these are also displayed visually, so that the individual can define them using their own words. The experimenter says "now, I am going to ask you to tell me the meanings of some words. Listen carefully and tell me what each word means". The experimenter points to each written word in the stimulus booklet whilst pronouncing it, with the assumption that this will encourage the participant to read the words. The experiment monitors performance and after 5 consecutive scores of 0, testing is discontinued. The aim of the Vocabulary subtest is to measure the participants expressive language and verbal knowledge. This test is believed to provide a measure of crystallised intelligence and general intelligence.

**(2) Block Design*:*** The Block Design (BD) subtest is comprised of a set of 13 two-dimensional geometric patterns; participants are instructed to reproduce pictures of designs which they are shown one by one within a given time frame, using coloured cubes. Participants between the ages of 9-89 start the task from design number 3 and are provided with 4 coloured cubes. The designs are graduated for difficulty and participants are provided with more blocks later on in the trials. After 3 consecutive scores of 0, the experimenter must discontinue testing. The BD subtest is used to assess spatial visualization, visual-motor coordination, and abstract conceptualization. Consequently, it is a measure of perceptual organization and general intelligence.

**(3) Similarities*:*** The Similarities subtest is made up of 4 picture items (items 1-4) and 22 verbal items. For items 1-4 the participant is shown a picture of three common objects on the top row and four response options are shown on the bottom row. The participant is asked by the experimenter to respond by pointing to only one of the pictures which is in the similar category to the three target objects above it. For the verbal items, a pair of words are read aloud, the participant is instructed to say what is similar between these objects. This task is used as a measure of verbal concept formation, abstract verbal reasoning, and general intellectual ability.

**(4) Matrix Reasoning*:*** The Matrix Reasoning subtest is made up of 35 incomplete gridded patterns which the participant is instructed to complete by selecting the correct pattern from a choice of 5. This task has been widely used as a measure of non-verbal reasoning and fluid intelligence.

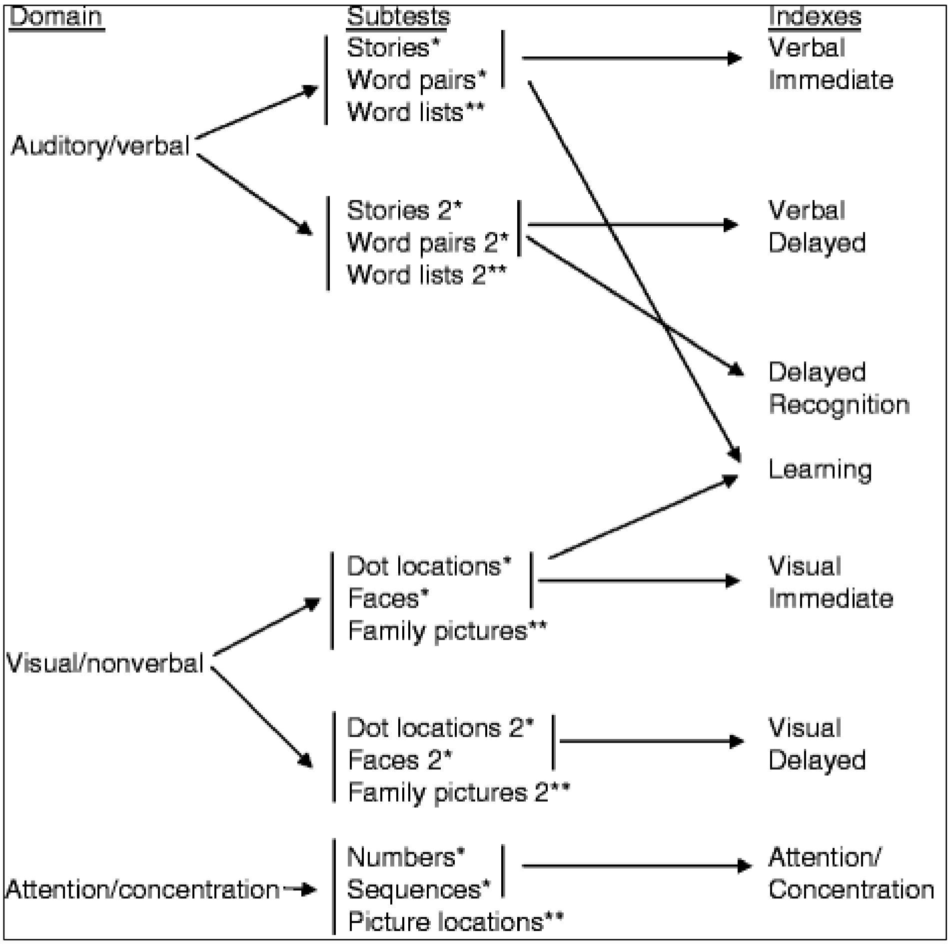
### Memory test. Children's Memory Scale (CMS)

The Children's Memory Scale (CMS) was originally developed and published in 1997 by Cohen (Cohen, 1997). It is a comprehensive tool which has been widely used to assess learning and memory in 5-16-year-old children and adolescents. The CMS tests memory in auditory/verbal, visual/nonverbal and attention/concentration domains. The auditory/verbal domain is tested using the verbal immediate index, verbal delayed index, delayed recognition index and learning index tasks. The visual/non-verbal domain is tested using the visual immediate index, visual delayed index and learning index tasks. Finally, the attention/concentration index is tested using attention/concentration index tasks. The indexes are each comprised of 2 subtests and 1 supplemental test. The core subtests in the verbal index include Stories and Word pairs subtests. The core subtests in the visual index include Stories and Faces subtests. Supplemental subtests include Word lists, Family pictures and Picture locations. Index scores are categorised as impaired (CMS index score 69 and below; subtest scaled score 3 and below), borderline (CMS index score between 70-79; subtest scaled score between 4-5), low average (CMS index score between 80-89; subtest scaled score between 6-7), average (CMS index score between 90-109; subtest scaled score between 8-11), high average (CMS index score between 110-119; subtest scaled score between 12-13), superior (CMS index score between 120-129; subtest scaled score between 14-15) and very superior scores (CMS index score 130 and above; subtest scaled score 16 and above).

The test also provides a general memory factor, which is made up by totalling together the Verbal Immediate index, Verbal Delayed index, Visual Immediate index, and the Visual Delayed index scores, but this factor will not be considered in the current study as it does not directly relate to the research questions being investigated.

The following section will describe the subtests and the supplemental subtest/s which make up the Auditory/Verbal domain, Visual/Nonverbal domain, and Attention/Concentration domain.

Figure 2-1 below presents a visual representation of the factors included in the CMS tests.




Note: *core subtest, **supplemental subtest

**Figure 2-1.** Breakdown of the different CMS domains. Figure extracted from Cohen (1997)

The following sections will provide details of the index scores and subtests included in the CMS.

## AUDITORY/VERBAL DOMAIN

### Verbal Immediate Index

This index includes Word pairs 'immediate', and stories 'immediate' subtests and the Word lists supplemental subtest. The Word pairs task is used to investigate a child's ability to learn a variety of words which are not related, and random in context (e.g. listen-magic) across a set of three consecutive learning trials. For the immediate recall section of the task, the child is instructed to listen to a list of 10 words which are spoken aloud by the examiner (10-word pairs for children aged 5-8 years old, 12-word pairs for children 9-16 years of age). The examiner then reads the first word of each word pair aloud (e.g. soft) and the child is instructed to complete each statement by putting forward the matching word (i.e. hope). This part of the experiment is repeated three times for each of the word pairs. The child is then asked to recall as many of the completed word pairs that they can from memory, they are also instructed to remember all of these as they need to be recalled later. After a delay onset of 25 to 30 minutes, the child is then instructed to recall as many of the word pairs as they can remember from memory.

The Stories immediate subtest assesses the recall of expressive and semantic information presented in two verbally presented stories. In the immediate part of the task, the child is instructed to recall the story from memory as accurately as they can. The child is then read aloud a second story and is also asked to recall the second story from memory as accurately as possible (stories A & B are implemented with children who are aged 5-8 years old, C & D for 9-12, and E & F for 13-16). The child obtains marks for retelling the story correctly and as accurately as well as for thematic comprehension. The child is then instructed to keep in mind both stories for later.

In the Word lists immediate subtest, the child is instructed to learn a list of words which is made up of 14 items. In the first trial, the words are read aloud the list and the child is instructed to recall as many words as possible in any order. For the second, third and fourth trials, the words are only read aloud to the child which were omitted in the previous trial. The child is then instructed to recall as many words as possible including those which they had previously recalled.

### Verbal Delayed Index

This index includes the Stories delayed and Word pairs long delay subtests, and the Word lists long delay supplemental subtest.

For the Stories delayed subtest, which usually takes place around 30 minutes after the stories 'immediate' recall task, the child is instructed to repeat both stories as accurately as they can.

In the Word pairs long delay subtest, after a delay onset of 25 to 30 minutes, the child is then instructed to recall as many of the Word pairs as they can remember from memory.

In the Word lists delayed subtest, participants are instructed to recall as many words as they can remember from the list of words which they previously went over consecutively over four trials.

## VISUAL/NONVERBAL DOMAIN

### Visual Immediate index

This index includes Dot locations immediate and Faces immediate subtests, and the Family pictures supplemental subtest. The immediate Dot locations subtest assesses the participants ability to learn and recall the spatial position of a sequence of dots after viewing over three learning trials. On the immediate trial, the participants were shown an image made up of 8 blue dots within a white box for 5 seconds. After the image is removed, participants were asked to replicate the image using a set of counters on a given grid. This is followed by two more learning trials following the same instructions. For the second part of the task, a new stimulus plate which is known as the distractor is presented with a series of red dots which are positioned in different areas. Once again after a 5 second exposure, the participants are instructed to use the counters to replicate the design. This trial is not included in the test. In the final part of the task, the participants are prompted to recall the positions of the original blue dots and to use the counters to replicate them on the given grid.

The Faces immediate subtest is used to evaluate the participants' ability to recall and identify faces. In the immediate part of the task, the participants are presented with 16 photographs of people's faces. Each face is shown for 2 seconds, and the participants are instructed to memorise them.

After this, participants are presented with a second sequence of 48 photographs of faces. Half of these faces had been viewed in the immediate phase of the test and the other half are new distracter faces. The participants are required to identify which of these faces were in the original set and which are new faces by saying ‘yes’ they had been asked to remember the face or ‘no’ if they were not asked to remember the face.

In the Family pictures supplemental subtest, the participant is firstly shown a portrait of characters in which the family members are identified and pointed to by the examiner (grandmother, grandfather, father, mother, son, daughter, and the dog). The participant is told that they will be shown four scenes with these family members and the dog in them. Participants are asked to remember as much as they can about each scene until it is taken away from them. Participants are presented with four different scenes: picnic scene, department store scene, yard scene and a meal scene. Each scene is shown for 10 seconds after which participants are presented with a blank page. They are then told that they are going to be shown the same picture with family members missing; the participant is instructed to point to a family member on the card and where they were and what they were doing. The participant is then asked if any other family members were present, where they were and what they were doing. This is repeated for all four scenes.

## ATTENTION/CONCENTRATION DOMAIN

### Attention/Concentration Index

This index includes Numbers total and Sequences total subtests, and the Picture locations subtest which is a supplemental subtest. The numbers task centres upon attention and concentration and evaluates an individual’s ability to repeat a sequence of numbers which have the tendency to increase in quantity. The child is instructed to repeat Sequences of digits both forwards and backwards ranging between 2 and 8 numbers. Fifteen items are divided across two portions. For numbers forward, the child is instructed to repeat the numbers aloud that they have just heard being spoken by the examiner. For Numbers backward, the child is instructed to verbally repeat the numbers in the reverse order which they have they heard being spoken by the examiner. For Numbers forward, there are two trials for each of 8 items. For Numbers backward, there are two trials for each of 7 items. The examiner is instructed to stop the Numbers forward task with a score of 0 on both trials of an item, but the numbers backward should always be delivered irrespective of the score on the Numbers Forward task. However, testing of Numbers Backward is stopped upon scores of 0 on both items of a trial.

The Sequences task is used to investigate the speed at which a child can mentally order information that is delivered verbally. The child is given 12 tasks which involve arranging them in a certain manner. These tasks include stating the alphabet, counting backward from 20-1, delivering the 6 times table and ordering the months of the year in reverse. The most difficult task involves the child being asked to verbally state the alphabet whilst counting. At the most difficult level, children are asked to recite the alphabet whilst counting concurrently (i.e. A1, B2, C3, D4 etc). Points are awarded the further they get.

The Picture locations supplemental subtest assesses visual spatial processing and memory abilities. Participants are presented with a 3x4 and 4x4 grid and on the practice trials are instructed to place the blue chips in the same place where they see the picture in the box. Participants are then instructed that they will be shown a box with a picture inside, they are then told to look very carefully as when the page is turned, they will need to place the blue chip(s) in the same place as they saw the picture inside the box. For 12 of the 16 items, participants used the 3x4 grid and for four last items they used the 4x4 grid.

All participants completed all subtests from the WASI-II (Wechsler, 2011) and some compartments of the CMS (Cohen, 1997) which were deemed relevant and directly related to the aims of this thesis.

### Sensory Profile (Dunn, 1999)

The Sensory Profile (SP) is a questionnaire which is completed by parents/caretakers which is used to assess and evaluate sensory processing patterns from birth to 14 years and 11 months. It is comprised of 125 items that are divided into three main categories. Sensory processing is further subdivided into 6 subsections that evaluate sensory processing in difference modalities i.e. auditory, visual, vestibular, touch, multisensory and oral sensory processing. Modulation is further divided into 5 subsections that evaluate sensory processing related to endurance/tone, modulation related to body position and movement, modulation of movement affecting activity level, modulation of sensory input affecting emotional responses and modulation of visual input affecting emotional response and activity level. Behaviour and emotional responses are further subdivided into 3 subsections that evaluate emotional/social responses, behavioural outcomes of sensory processing and items indicating thresholds for response.

Parents/caregivers are instructed to rate the frequency of behaviours using a 5-point Likert Scale, with 1 indicating high frequency and 5 indicating an absence of sensory abnormalities. Factor scores for each of the main sensory domains are calculated alongside a total section summary score which reflects difficulties across all sensory domains.

### Social Communication Questionnaire (Rutter et al., 2003)

The Social Communication Questionnaire (SCQ) was previously referred to as the Autism Screening Questionnaire (ASQ) (Berument et al., 1999). It is a 40-item questionnaire, completed by a parent/caregiver that screens for the symptoms of ASD. It is suitable for use with children who are over the age of 4 years with a minimum mental age of 2 years. Although the SCQ is a short-form test is very similar to the more extensive Autism Diagnostic Interview (ADI-R) (Lord Rutter & Le Couteur, 1994), and has significant validity which is not influenced by age, gender, or levels of language and non-verbal IQ (Berument et al., 1999). A cut off score of 22 or above on the historical lifetime questionnaire is known to confirm the historical onset of ASD, and a cut off score of 15 and over confirms the diagnosis of a Pervasive Developmental Disorder (PDD). Scores on the SCQ range between 0-30 for verbal and 0-33 for non-verbal children; higher scores are known to be indicative of ASD.

The Sensory Profile (SP) and the Social Communications Questionnaires (SCQ) were sent to all parents, but despite follow up contacts, very few were returned.

Given that the numbers of completed SP and SCQ forms was insufficient for the data analysis, the results will not be discussed. The results from the WASI-II and CMS tests are reported in the following chapter. For the CMS test, the Visual Delayed, Delayed Recognition and Learning indexes were removed from the analysis as they were not deemed relevant for the cognitive mechanisms being studied.

# CHAPTER 3: MEMORY AND INTELLIGENCE PROFILES IN AUTISM SPECTRUM DISORDER AND TYPICAL DEVELOPMENT


## ABSTRACT

This chapter includes a brief review of research into intelligence and memory in ASD and describes the results from the intelligence and memory assessments described in chapter two. Whilst the ASD and TD groups did not differ on full scale intelligence (WASI-II; Wechsler, 2011), VIQ or PIQ test scores, analysis of the intelligence subtests showed significantly higher matrix reasoning subtest scores for the ASD group. On tests of memory, the ASD group scored significantly lower than TD participants on immediate story recall, digit span and memory for sequences subtests. The ASD group scores were higher than those of TD participants on the immediate recall of family pictures subtest. However, marked heterogeneity within the ASD group was observed on several of the subtests included in the intelligence and memory batteries, the results from the analyses are considered in the context of previous studies of intelligence and memory in ASD.


## PREVELANCE OF INTELLECTUAL IMPAIRMENT IN ASD: EVIDENCE FROM EPIDEMIOLOGICAL STUDIES

Studies investigating intelligence in ASD suggest that the prevalence of intellectual disability in this group is lower than was previously thought. For example, Schalock, et al. (2007) reported that 75% of participants with ASD scored lower than 70 on standardised IQ tests and met the criteria for intellectual impairment. However, epidemiological studies carried out by Bertrand et al. (2001) and Chakrabarti & Fombonne (2005) reported a far lower rate of intellectual disability in ASD, with approximately 50% of participants achieving IQ scores that were in the normal range. In a recent UK-based epidemiological study (Charman et al., 2011), 156, 10-14-year-old children who were participating in the Special Needs Autism

Project (SNAP) were assessed for intelligence. Consistent with results by Bertrand et al., (2001) and Chakrabarti & Fombonne (2005), 50% obtained IQ scores in the unimpaired range. Moreover, the results from the study also suggested that severer forms of intellectual impairment are relatively rare in ASD. Less than 1 in 5 participants scored lower than 50 on the IQ tests used in the study.

## MEASURING INTELLIGENCE IN ASD: THEORETICAL ISSUES

The Wechsler Intelligence Scales, in their different versions, have been widely used to assess children and adults with ASD. The original Weschler Adult Intelligence Scale (WAIS) was published in February 1955 by David Wechsler as a revised version of the Wechsler-Bellevue intelligence test (1939). The Weschler Abbreviated Scales of Intelligence (WASI-II) was published in 2011 and includes four subtests: two based on performance and two based on language. In each version of the Wechsler Intelligence tests, subtests are used to calculate a Verbal IQ factor (VIQ) and a Performance IQ (PIQ) factor. VIQ and PIQ both rely on language comprehension and PIQ subtests also require language production. The composite of VIQ and PIQ factors comprise the Full-Scale IQ score (FSIQ). Early work using the Weschler tests to assess to assess intelligence in ASD reported that VIQ was lower than PIQ, with lowest scaled scores on the Comprehension subtest and highest scaled scores on the Block design (BD) subtest (Rumsey, 1992; Yirmiya & Sigman, 1991).

In a subsequent study Siegel et al. (1996) administered WISC-R and WAIS-R to 45 children and 36 adults with HFA. The results from the study did not support previous studies reporting a VIQ<PIQ pattern of performance in either group. However, they did note a pattern of performance that was typical within both groups. Participants achieved their highest score on the BD subtests and their lowest scores on the Comprehension subtest. Happé (1994) further investigated Wechsler intelligence test profiles in a group of 38 children with ASD. She replicated the pattern of scores reported by Siegel et al. (1996) and proposed that low comprehension scores reflect impairments in Theory of Mind (ToM) deficits whilst good performance on the BD subtest represents an “islet of ability” in Autism (Shah & Frith, 1993, p. 1351). According to the earliest version of the WCC model (Frith, 1989), islets of ability result from a reduced propensity to process information in context in ASD. According to this

model, participants with ASD can access information that typically developing people may fail to notice.

DSM-IV included Asperger Syndrome (AS) as a Pervasive Developmental Disorder (PDD) and it was initially thought that participants with this diagnosis could be distinguished from those with autism on the basis of their cognitive development. Specifically, it was proposed that AS and autism differed in their development of primary speech. Ehlers et al. (1997) administered the Swedish version of the WISC-R with 120 children with AS, Autistic disorder and attention disorders. The AS group were defined by impaired perceptual ability with lower results on the performance subtests object assembly and coding. However, they displayed good verbal ability which was demonstrated by their performance on the verbal subtests of Information, Similarities, Comprehension, and Vocabulary. They achieved significantly lower results on the arithmetic subtest, and this may have reflected increased distractibility in this group. In contrast the participants in the autism group obtained significantly higher scores on the BD subtest in comparison with the AS group, reflecting superior visuospatial abilities. The autism group presented with poorer verbal abilities than the AS group which was reflected by their low scores on the Comprehension and Vocabulary subtests.

Ozonoff et al. (2000) conducted a study in which they assessed levels of cognitive functioning in participants with HFA, AS and TD. The TD control group consisted of 27 typical children, the HFA group of 23 children and the AS group of 12 children. Both clinical groups had been provided with a clinical diagnosis based on the DSM-IV diagnostic criteria; they had been assessed and matched for chronological age, gender, and intellectual ability. Each participant completed a three-hour testing session which involved a range of tests presented in a specific order. These were the Tower of London subtest, the intradimensional/extradimensional shift task (ID/ED) from the Cambridge Neuropsychological Test Automated Battery (CANTAB: Robbins et al., 1994), the Clinical Evaluation of Language Fundamentals–Third Edition (CELF-III: Semel, 1995), the WISC OR WAIS-III, and the Autism Diagnostic Observation Schedule–Generic (ADOS–G: Lord et al., 1999).

The study revealed differences across groups on the Wechsler subtests. Both the AS and HFA groups scored lower than the control group on the Coding subtest, though the AS group scored higher than the HFA group. The AS group scored higher than the HFA group and the control group on the Comprehension subtest, and this was recorded as one of their highest scores. Both clinical groups performed higher on the Information subtest than the BD subtest, and the AS group performed higher than the HFA group on the information subtest. The control group performed the lowest on the Information subtest. Interestingly, only 22% (5/23) of the HFA children and 25% (3/12) of the AS children achieved their highest scores on the BD subtest. The authors also analysed differences between the verbal and performance IQ scores and reported that 35% of the HFA group and 50% of the AS group demonstrated higher VIQ than PIQ scores. The VIQ-PIQ discrepancy was largest in the AS group. For language and communication, they reported significant group differences on the expressive language scale of the CELF-III, the HFA group scored lower than the AS group. However, no group differences were reported between the groups on the receptive language scale.

Merchán-Naranjo et al. (2012) conducted a study in which they assessed intelligence levels in participants with AS using the Spanish versions of the WAIS-III and Wechsler Intelligence Scale for Children revised (WISC-R: Wechsler, 1974, 1997). The results showed that VIQ and PIQ scores did not differ for adults with AS. Younger participants (up to 16 years of age), tested using the WISC-R scored higher on the Information subtest and low on Digital Symbol-Coding, and showed impairments in 5 verbal subtests: Similarities, Arithmetic, Vocabulary, Comprehension and Digit Span. The low digit span scores may reflect difficulties in applying strategies to retain information which could have a significant impact on attention and concentration. The studies cited above suggested that individuals with AS present with impaired perceptual abilities and good verbal abilities, whereas individuals with autism perform at higher levels on tasks measuring visuospatial abilities than on verbal tests. The merging of HFA and AS under the heading of ASD in DSM-5 (American Psychiatric Association, 2013) may have increased heterogeneity at the cognitive level in this group which could have influenced the results of the study.

During the last twenty years some researchers have raised questions about how results from standardised tests of intelligence, developed for use with TD individuals, should be interpreted in the context of ASD. Individuals from within the autism community have claimed that cognitive strengths in ASD have been interpreted as deficits, and that good performance on tests presumed to measure intelligence, have been taken as evidence for atypical information processing in this group. An example of such thinking is reflected in the way results from studies using the Raven's Progressive Matrices (RSPM) to test levels of intelligence in ASD have been interpreted. For TD people, this test is considered to be a "paradigmatic" measure of fluid intelligence (Mackintosh, 1998, p. 228).

However, good performance on this test in ASD has been attributed to atypical perceptual processing, and the other components of task performance have been largely disregarded (Soulières et al., 2011). Dawson et al. (2007) administered the RSPM and WISC-III to a group of 38, 7-16-year-old participants with ASD and showed that they scored between 30 to 70 points higher on the RSPM than on the WISC-III. This discrepancy was not reported in the control group. Furthermore, when the pattern of performance over simple to increasingly complex items was analysed, it showed the same pattern across the ASD and control groups, suggesting that the test measured the same cognitive processes in the two groups. The results for the ASD group also showed that BD scores were highly correlated with their performance on the other Wechsler subtests.

Although good BD test performance has been viewed as an 'island of ability' in autism (Shah & Frith, 1983) it involves problem solving and may qualify as a test of fluid intelligence. Hayashi et al. (2008) studied levels of fluid intelligence in children with AS using the RSPM. They reported that the group of children with AS displayed greater level of accuracy than a TD control group matched on gender and FSIQ using the WISC. These results suggest that fluid intelligence is superior in ASD and highlights the problem of how best to measure intelligence in these individuals.

As an extension to their study of intelligence in ASD, (Dawson et al., 2007), Soulières et al. (2011) also investigated intelligence in AS. The aim of the study was to determine whether superior performance on the RSPM was a fundamental and defining characteristic across the whole ASD spectrum. Groups of 32 adults and 25 children with AS, together with groups of 39 TD adults and 27 children, completed the RSPM, the Wechsler Intelligence Scale for children (WISC-III) and the Wechsler Adult Intelligence Scale for adults (WAIS-III). Consistent with results from the study of ASD (Dawson et al., 2007), the results revealed an advantage on the RSPM relative to Wechsler FSIQ, PIQ, and VIQ scores for children and adults with AS. However, whilst adults with AS showed a significant advantage, compared with TD controls in RSPM scores compared with Wechsler FSIQ and PIQ scores, this advantage was only evident in PIQ scores for children with AS. RSPM scores were associated with peaks of ability on Wechsler subtests for both adults and children with AS. The authors concluded that, for participants on the autism spectrum, RSPM measures cognitive skills that are applied to different facets of cognition. They further suggested that results from intelligence tests carried out with this group had been interpreted in the context of theoretical models of ASD, and that this had led to an underestimation of their intelligence. All participants who completed the experimental studies described in this thesis also completed the WASI-II (Wechsler, 2011) matrices subtest and the implications of strong and poor performance on this subtest will be considered in the final discussion chapter.

Intelligence in ASD has also been studied using Inspection Time (IT) paradigms. Inspection time tasks assess the participants' speed and efficiency during information processing (Deary et al., 2004; Waiter et al., 2008). Scheuffgen et al. (2000) carried out a study in which groups of adolescents with ASD (n=18), Moderate learning difficulties (MLD) (n=21) and TD (n=29) completed an IT task involving perceptual discrimination. Levels of IQ were measured using the third revised edition of the Weschler Intelligence Scale for Children; WISC-III (Wechsler, 1991). In the study participants were shown two lines and had to decide whether both lines were the same or different lengths. Stimuli were presented with four different variations of a line task: both antennae short, both antennae long, right antennae longer and left antennae longer. The ASD group included 3 individuals with a diagnosis of AS, and their pattern of performance did not differ from that of the ASD participants. The results showed that WISC scores were lower in the ASD group than the TD group, but IT task scores did not differ across these groups. This finding is very interesting and may support previous findings suggesting that the Weschler tests underestimate levels of intelligence in ASD (Dawson, 2007).

In a second study investigating the relationship between IT and FSIQ in ASD, Wallace et al. (2009) tested groups of 23, 9-18- year-old participants with and without ASD using WISC-III (Wechsler, 1991). Both groups included 5 participants with mild intellectual impairment (MLD). In the study the ASD and TD groups were divided based on lower (IQ <100) and higher (≥100) scores on the WISC-III (Wechsler, 1991). IT was tested using a computer task. Participants were presented with a space invader on the computer screen with 2 antennae of either the same or different lengths. Participants were told that the space invader would only be visible for a short period and would then disappear behind a bush. The four different types of antennae consisted of left antennae short-right short, left short-right long, left long- right short and left long-right long. Participants had to indicate whether the two antennae were the same or different lengths by pressing the correct key on the keyboard. Wallace et al. (2009)

reported that information processing, measured using the IT task, was comparable across the ASD and TD groups. However, the results from the study showed some differences to those obtained by Scheuffgen et al. (2000). Firstly, participants with ASD did not achieve faster IT rates than TD participants as reported by Scheuffgen et al. (2000). The second difference was that Scheuffgen et al. (2000) reported that the ASD group scored higher than the group with intellectual impairment but scored similarly with the age-matched TD controls on the task. Even though Wallace et al. (2009) further subdivided the participants into groups depending on their IQ, they found no such relationship between IQ and IT rate. Even participants in the low-IQ ASD subgroup performed as well as the TD controls. Whilst the different methodologies used in the two IT studies may in part explain the different results, other, uncontrolled differences associated with cognitive heterogeneity in ASD may also have influenced the results.

With the background of the research studies reported above, the following section gives the results from the WASI-II (Wechsler, 2011) test for which the methodology was described in chapter 2.

## RESULTS

At the beginning of the study, the participants all completed the WASI-II (described in chapter 2). The results are shown in table 3-1.

**Table 3-1.** Mean scores for the ASD and TD group for WASI-II subcategories

| | FSIQ | VIQ | PIQ |
|---|---|---|---|
| | **Mean SD Range** | **Mean SD Range** | **Mean SD Range** |
| ASD Group | 97.88[4] (11.56) 82 - 123 | 97.06[4] (14.98) 78 - 126 | 99.35[4] (14.98) 89 - 116 |
| TD Group | 95.82[4] (10.27) 85 - 125 | 95.47[4] (9.30) 79 - 117 | 97.18[4] (12.14) 75 - 128 |

Categories: extremely low[1], borderline[2], low average[3], average[4], high average[5], superior[6], very superior[7]

Independent samples t-tests were carried out to compare the scores from the WASI-II subcategories across groups. These showed that groups did not differ on FSIQ ( $t$ = .549, df = 32, $p$ = .587 ), PIQ ( $t$ = .609, df = 32, $p$ = .547) or VIQ ( $t$ = .371, df = 32, $p$ = .713 ).

Scores for the subtests comprising the WASI-II are shown in table 3-2.

**Table 3-2.** Mean scores for the ASD and TD group for WASI-II subtests

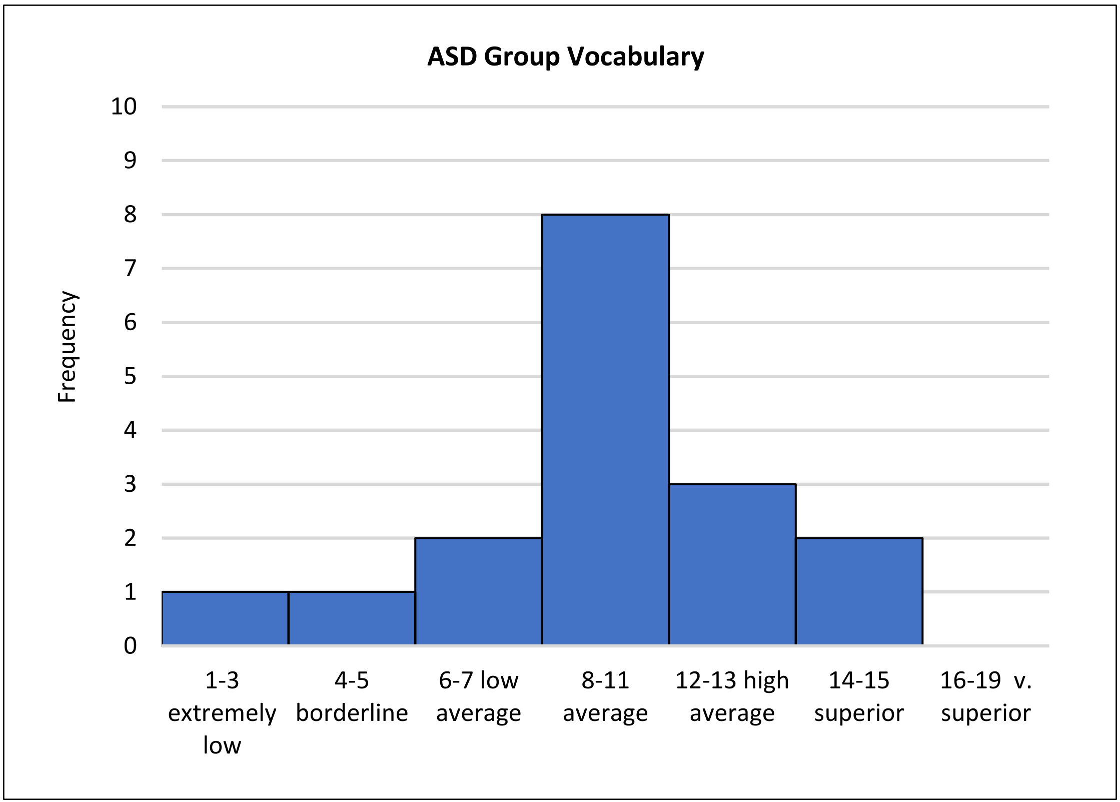
| | WASI-II Subtest scores<br>Mean SD Range | |
|---|---|---|
| | **ASD** | **TD** |
| Vocabulary | 9.29[3] (3.31) 4 - 13 | 8.84[3] (2.45) 6 - 14 |
| Similarities | 9.47[3] (2.12) 6 - 12 | 10.18[4] (1.51) 7 - 12 |
| Block Design | 10.41[4] (2.06) 6 - 14 | 11.12[4] (3.02) 5 - 15 |
| Matrix Reasoning | 10.82[4] (1.94) 7 - 15 | 7.76[3] (2.36) 4 - 14 |

Categories: extremely low[1], borderline[2], low average[3], average[4], high average[5], superior[6], very superior[7]

Independent samples t-tests carried out on the WASI-II subtests showed that groups did not differ on Vocabulary ( $t$ = 0.88, df = 32, $p$ = 0.38 ), Similarities ( $t$ = - 1.12, df = 32, $p$ = 0.27 ) or Block Design ( $t$ = - 0.80, df = 32, $p$ = 0.43 ). However, groups significantly differed on the Matrix Reasoning subtest ( $t$ = 4.13, df = 32, $p$ = 0.00 ) with higher scores in the ASD (average range) than the TD group (low average range).

As the range of scores were fairly large on some WASI-II subtests, data were inspected for variance. Histograms showing ranges of scores within subtests are shown in figures 3.1, 3.2, 3.3 and 3.4 below.

**Vocabulary**



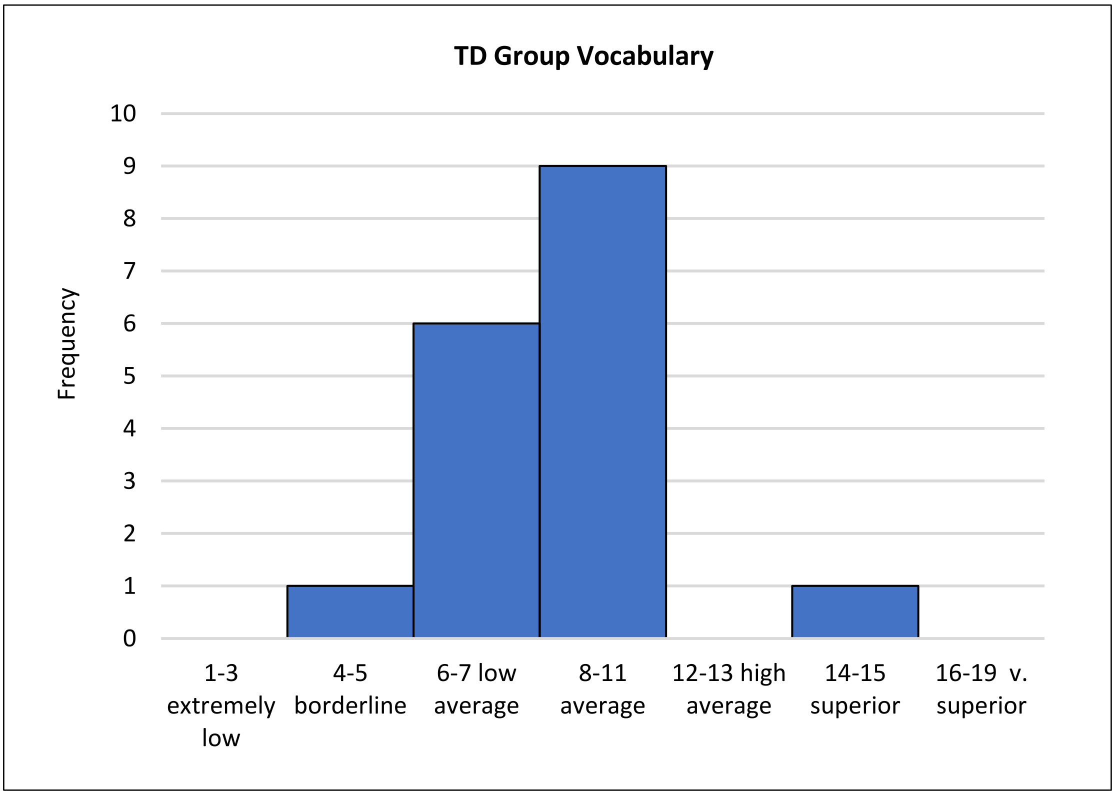
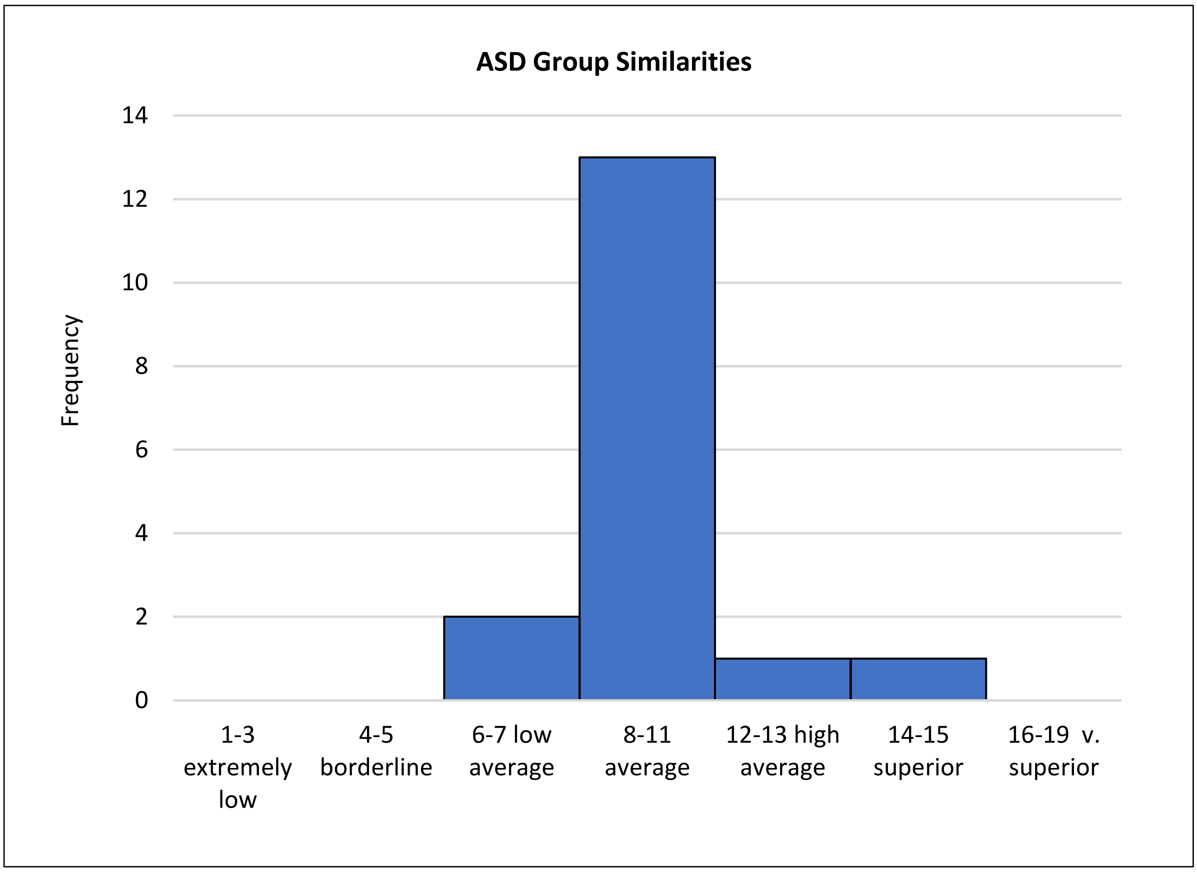




**Figure 3-1.** Histograms representing group scores for the WASI-II Vocabulary subtest

The difference between groups on the Vocabulary subtest was not significant, the main difference between groups was that more individuals with ASD scored in the extremely low range. However, more participants with ASD than the TD group scored in the high average and superior ranges. The Vocabulary scores appeared to be more widely distributed in the ASD group whereas a greater proportion of TD participants scored in the higher ranges.

**Similarities**



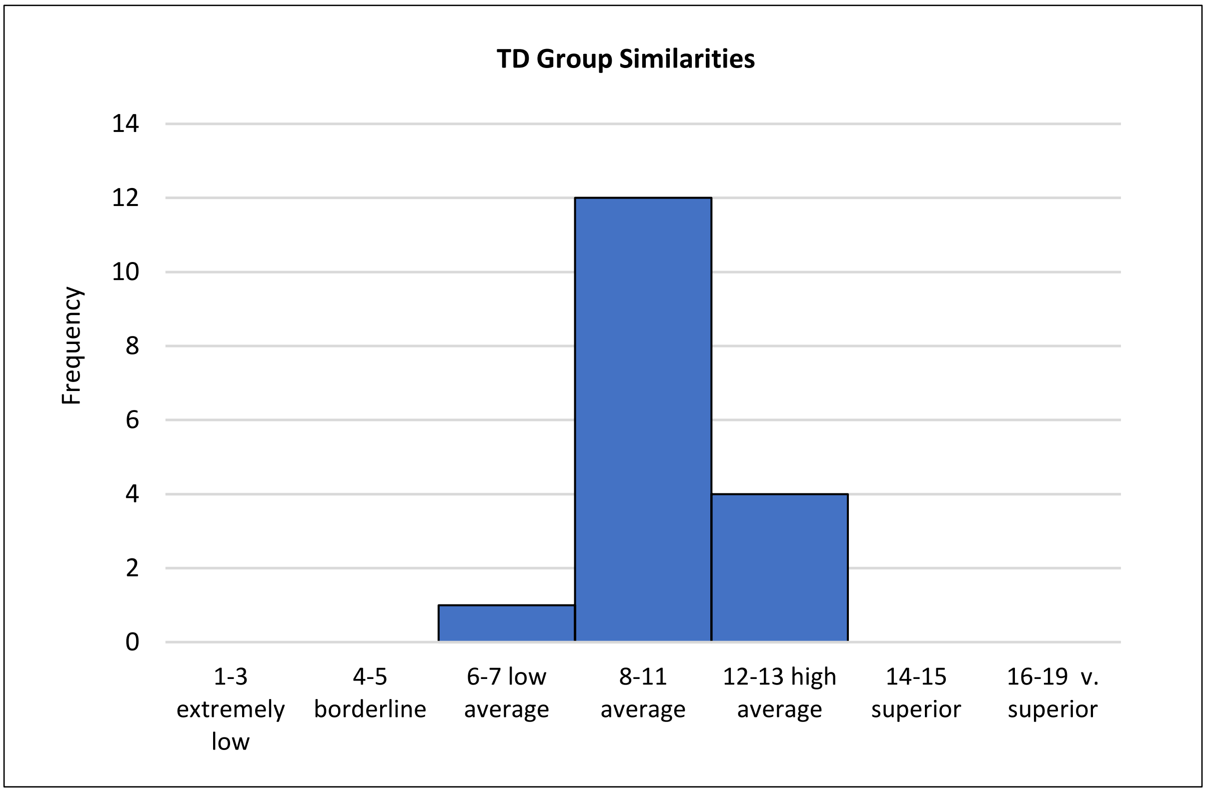
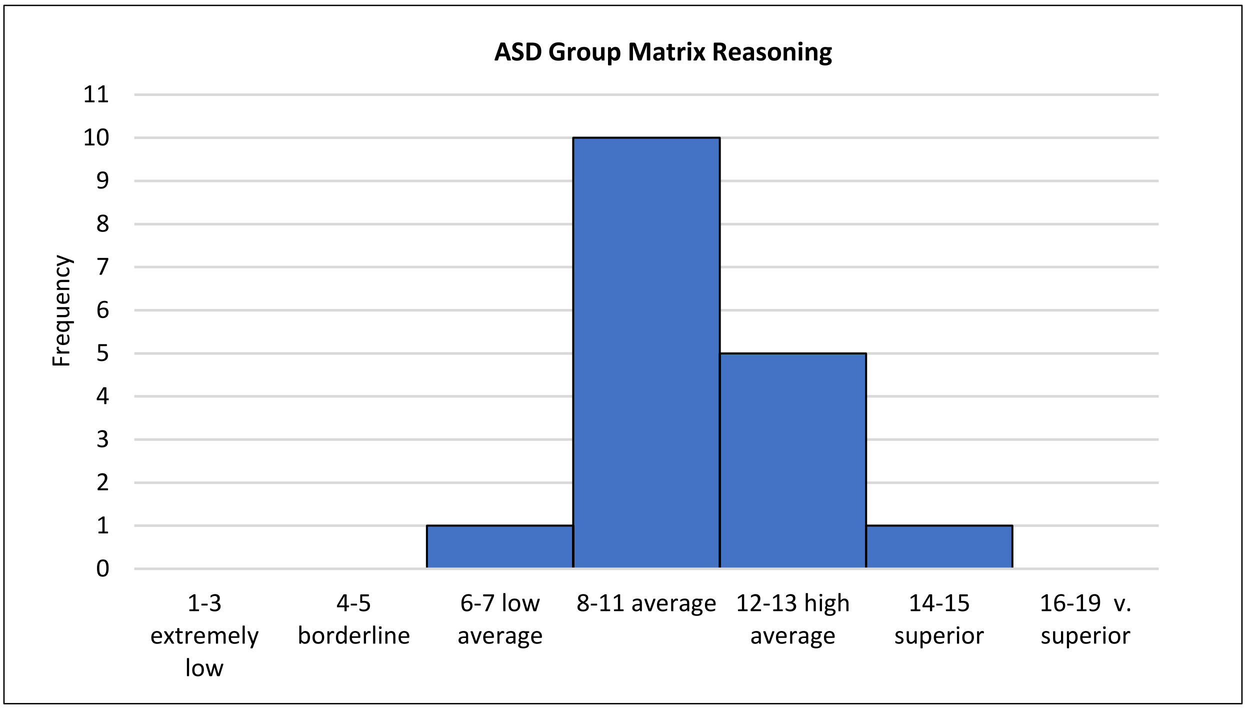




**Figure 3-2.** Histograms representing group scores for the WASI-II Similarities subtest

The difference between groups on the Similarities subtest was not significant, a similar proportion of participants in both groups scored in the average range though a higher proportion of participants with ASD scored in the superior range which was not evident in the TD group. Again, scores in the ASD group were more widely distributed across the ranges.

**Matrix Reasoning**



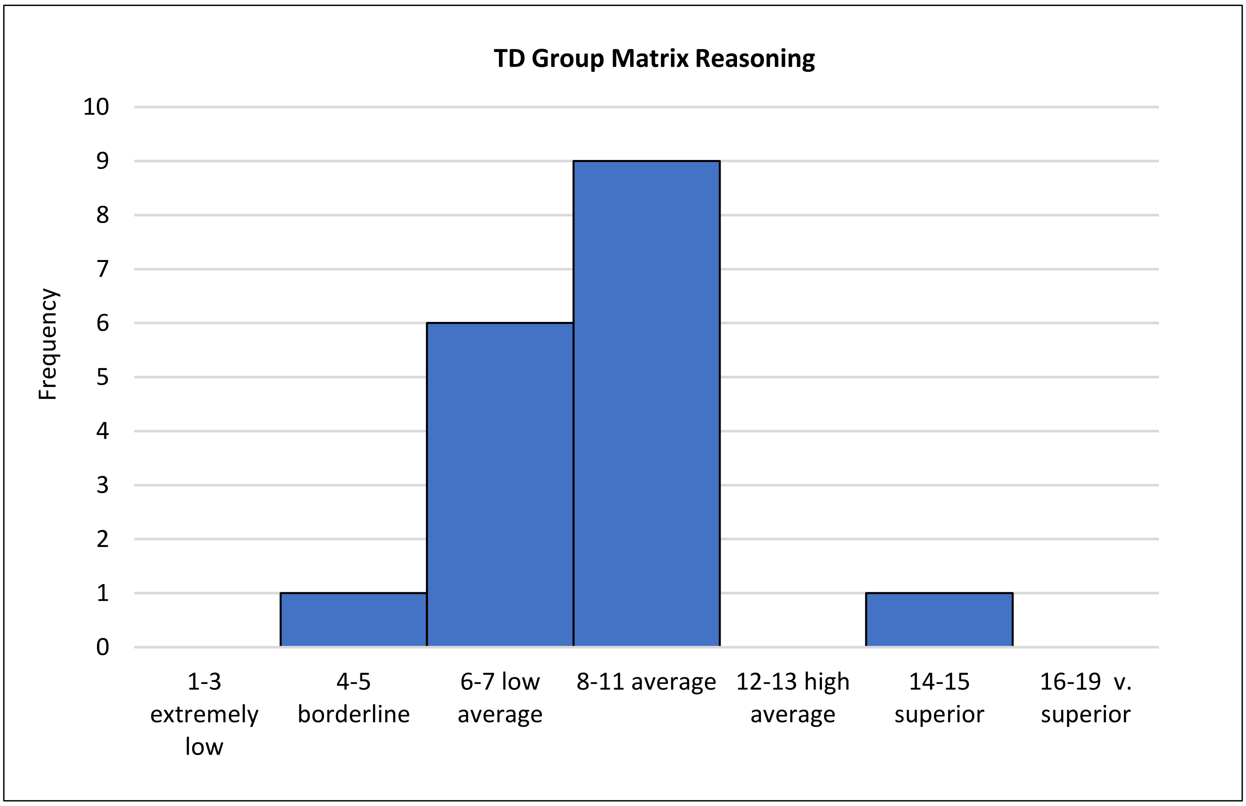
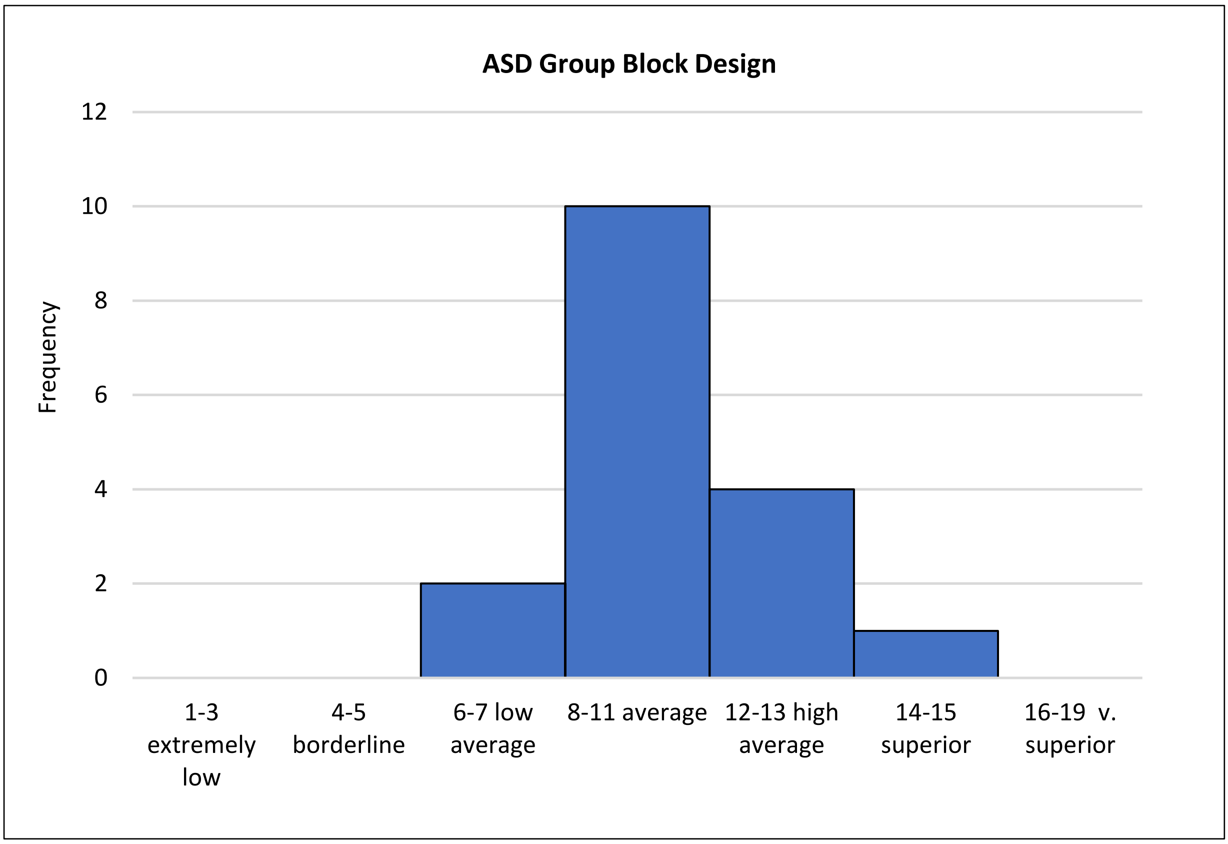




**Figure 3-3.** Histograms group scores for the WASI-II Matrix Reasoning subtest

The group difference was significant on the Matrix Reasoning subest with higher scores in the ASD group, a small number of participants with ASD scored in the high average and superior ranges whilst only one TD participant did this well. Moreover, levels of low average and borderline scores were high in the TD group and low in the ASD group (only one participant). Matrix Reasoning appears to be a key strength within the ASD group.

**Block Design**



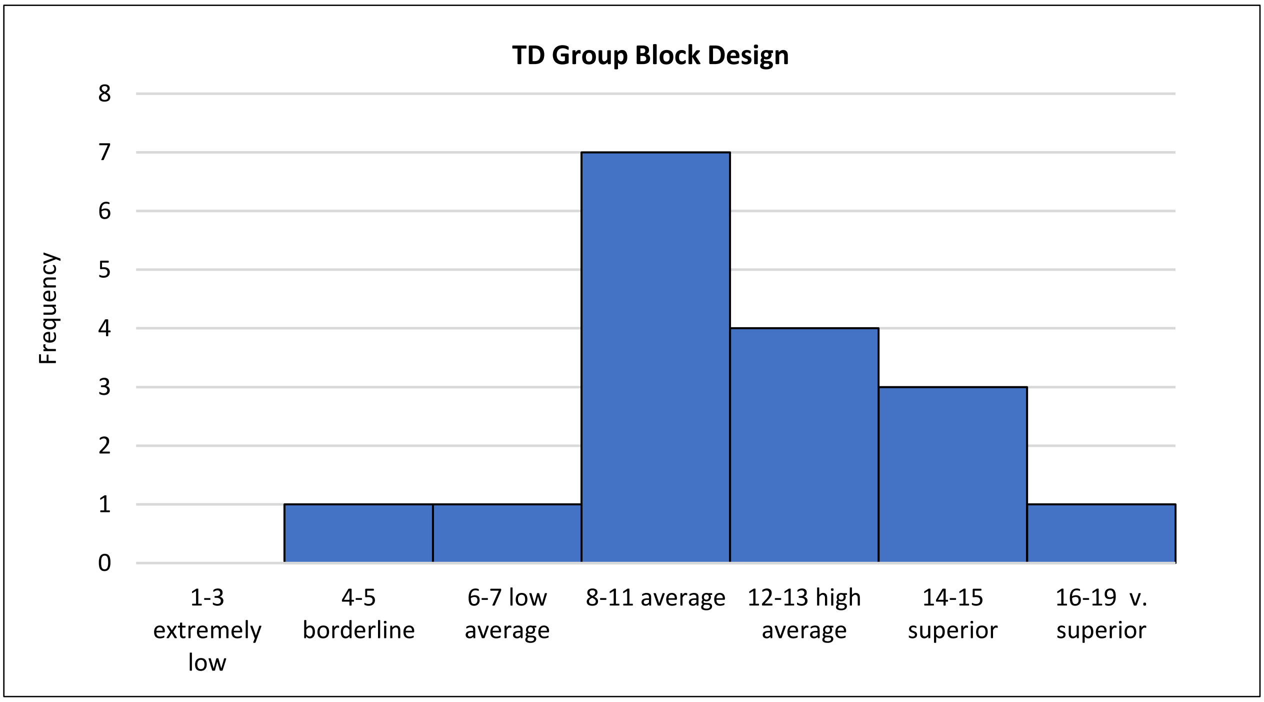




**Figure 3-4.** Histograms representing group scores for the WASI-II Block Design subtest

The group difference was not significant on the Block Design subtest and most participants scored within the average ranges. The distribution of scores was wider in the TD groups with borderline and very superior scores. A very small proportion of individuals, within each group, scored in the superior range. The results from the IQ testing will be further considered in the discussion to this chapter.

## MEMORY

All participants completed the full Children's Memory Scale (CMS; Cohen, 1997). This test includes a large number of subtests that screen memory in Auditory/Verbal, Visual/Nonverbal and the Attention/Concentration domains. The results from memory subtests that recruit similar mechanisms to those recruited in the experimental tasks described in chapters 4, 5 and 6 are analysed in this chapter. Subtests from the Visual Immediate index were chosen because three out of the four experiments rely on visual attention and memory. Subtests from the Verbal Immediate and Delayed index were analysed because difficulties remembering task instructions could influence performance on the experimental tasks. Attention/Concentration subtests were included because impairments in these skills would impact performance on all of the experimental tasks.

## WORKING MEMORY IN ASD

The working memory model (WM) was originally developed by Baddeley in 1986. According to this model, WM comprises three components: (a) the phonological loop, which processes auditory/verbal stimuli; (b) the visuo-spatial sketchpad which processes visual or spatial features and (c) the attention/concentration component which is responsible for sustaining attention and concentration levels whilst processing target stimuli in the presence of auditory or visual internal/external distractors. Researchers investigating WM in ASD have used a wide range of assessment tools to test populations that vary in age and full-scale intelligence. Whilst this research has produced somewhat conflicting findings, a recent meta-analysis, carried out by Habib et al. (2019) suggests that WM impairments are characteristic in ASD. The analysis was carried out on 34 studies measuring accuracy and error rates in phonological and visual spatial WM domains. The results from the meta-analysis showed that scores on both components were impaired, relative to TD control groups, and this difference could not be explained by differences in age or intelligence.

## ATTENTION/CONCENTRATON IN ASD

To date, attention and concentration levels have been primarily assessed using the digit span subtest from the Wechsler Intelligence tests. Goldstein et al. (2001) conducted a study in which 35 individuals with HFA and 102 individuals with a learning disability (LD) completed the WAIS-R. They reported that the HFA group were more impaired than the LD group with subtests which involved processing numerical digits and numbers. Spek et al. (2008) conducted a study in which they analysed WAIS-III (Wechsler, 1997) profiles of adults with HFA and a comparison TD group. They also reported from their findings that scores for the digit span subtest were significantly lower for the HFA group compared to the TD group.

Poirier et al. (2011) conducted a study in which they assessed STM in a group of adults with ASD and a TD control group. Both groups had been matched on verbal IQ, participants ages ranged between 18 - 60 years. In the first experiment, participants were administered a forward and backward digit span. In the second experiment, participants completed an immediate word recall ask, each list consisted of six different words, participants were required to remember the order of recall which they had to write down. The third experiment involved an order recognition task in which participants were presented with six words at a time sequentially, half the time the words were repositioned. Participants were required to detect the change in the word order. They reported from their findings that in all three experiments, the TD group scored higher and outperformed the ASD group.

From the total sample of 34 participants (TD n = 17; ASD n = 17) described in chapter two, all the participants were able to complete all of the CMS (Cohen, 1997) tasks, the comprehensive methodology has been described in chapter 2 and the results are shown below.

## RESULTS

Figure 3-5 below shows a visual representation of the auditory/verbal domain from the CMS (Cohen, 1997).

### AUDITORY/VERBAL DOMAIN

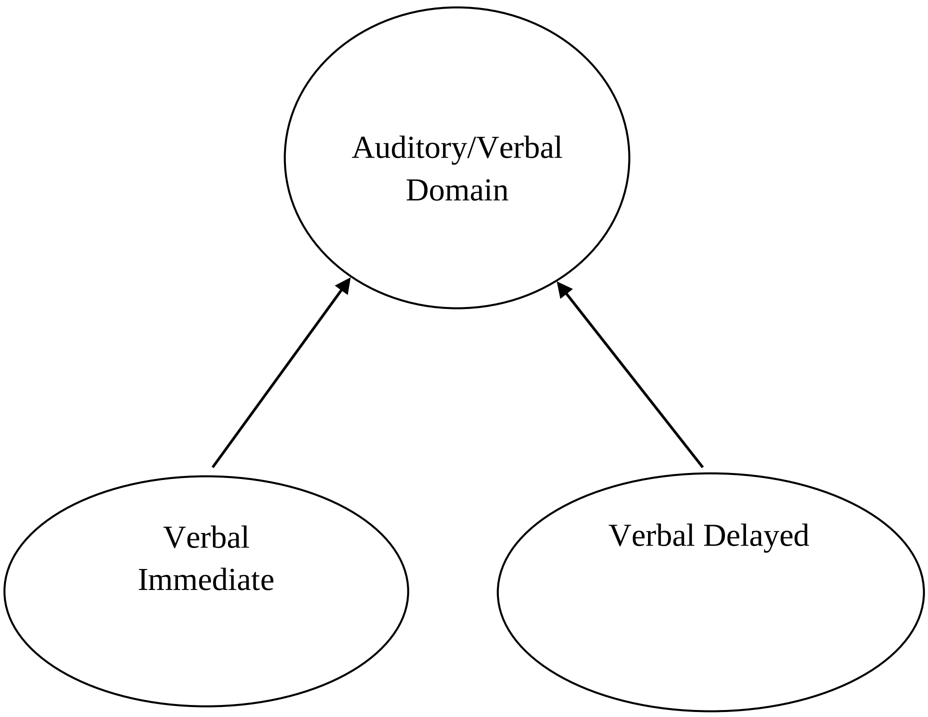



**Figure 3-5.** Structure of the Auditory/Verbal domain from the CMS (Cohen, 1997)

**Verbal Immediate and Verbal delay**

**Table 3-3.** Mean total Verbal Immediate and Verbal delay index scores for ASD and TD group

| | **Total Verbal Immediate index Score** | **Total Verbal Delayed index Score** |
|---|---|---|
| | **Mean SD Range** | **Mean SD Range** |
| ASD Group | 83.12[3] (20.30) 51 - 122 | 81.65[3] (20.27) 50 - 125 |
| TD Group | 94.94[4] (13.02) 63 - 115 | 88.29[3] (15.92) 54 - 112 |

Categories: extremely low[1], borderline[2], low average[3], average[4], high average[5], superior[6], very superior[7]

Immediate recall scores were in the low average range for the ASD group and the average range for the TD group. This difference was statistically significant ( $t$ = - 2.02, df = 32, $p$ = 0.05 ) . Delayed recall scores remained in the low average range for the ASD group and fell to the low average range for TD participants. This difference was not significant ($t$ = - 1.06, df = 32, $p$ = 0.29). The TD group appeared to show a steeper decline on the delayed condition than the ASD group.

Scores for subtests comprising the verbal index are shown in table 3-4.

**Table 3-4.** Mean Verbal Immediate and Verbal delay subtest scores for ASD and TD group

| | Verbal Immediate Index | Verbal Delayed Index |
|---|---|---|
| | **Mean SD Range** | **Mean SD Range** |
| **ASD** | | |
| Word pairs* | 10.58[4] (4.03) 1 - 15 | 8.82[4] (3.96) 2 - 14 |
| Stories* | 5.59[2] (4.02) 2 - 16 | 5.18[2] (4.05) 1 - 15 |
| Word lists** | 7.24[3] (5.36) 1 - 19 | 8.29[4] (3.50) 4 - 13 |
| **TD** | | |
| Word pairs* | 10.18[4] (1.74) 7 - 13 | 8.47[4] (3.84) 2 - 13 |
| Stories* | 9.88[4] (3.18) 5 - 13 | 8.77[4] (2.33) 4 - 11 |
| Word lists** | 9.29[4] (3.62) 3 - 15 | 9.24[4] (4.02) 5 - 14 |

Categories: extremely low[1], borderline[2], low average[3], average[4], high average[5], superior[6], very superior[7] Note: *Core subtest, **Supplemental subtest

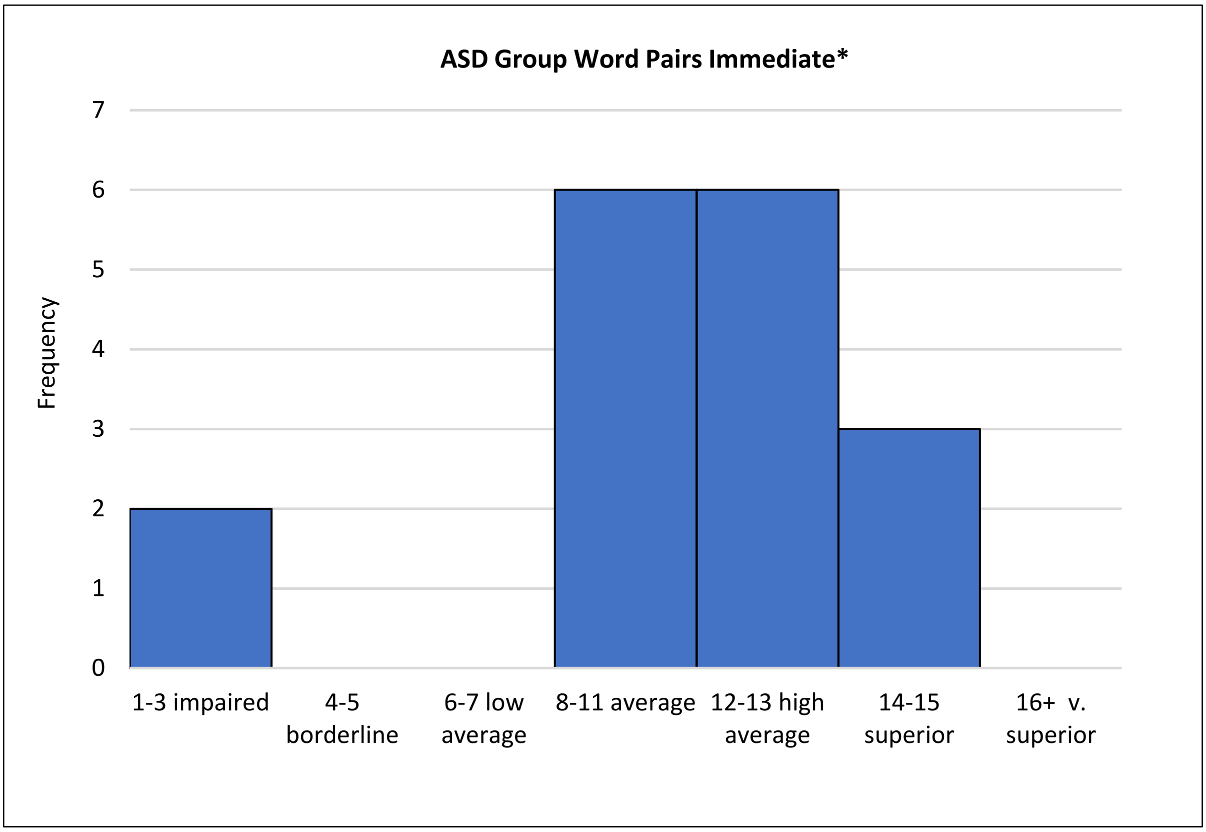
Scores on the immediate and delayed Word pairs subtests were in the average range for both groups. Independent samples t-tests showed that groups did not significantly differ on immediate ( $t$ = .39, df = 32, $p$ = .70) or delayed ( $t$ = 0.26, df = 32, $p$ = .79) conditions.

The ASD group performed at lower levels than TD group on the Stories subtest. On both immediate and delayed conditions, the ASD group scored in the borderline range whilst the TD group scored in the average range on both conditions. The between-group difference reached significance on the immediate ( $t$ = - 3.46, df = 32, $p$ = .00) but not on the delayed recall condition (*t* = - 1.41, df = 32, *p* = .17). As was observed on the Word pairs subtests, TD participants showed a greater decline in scores than the ASD participants.

On the immediate Word lists subtest, the ASD group scored in the low average range and the TD group scored in the average range. This difference was not statistically significant (*t* = - 1.31, df = 32, *p* = 0.19). On the delayed wordlist subtest, the ASD group improved and were in the average range whilst the TD group scores stayed in the average range. The group difference was not statistically significant (*t* = - .73, df = 32, *p* = 0.47).

The only marked between group difference to emerge in the analysis of auditory-verbal memory skills was on the immediate recall of stories, with significantly poorer performance in the ASD group. The analysis suggested that the ASD group showed smaller decreases in scores on the delayed conditions than TD participants. The ranges of scores within the two groups was large and individual data is shown below. Immediate conditions are shown first.

**Word Pairs Immediate**



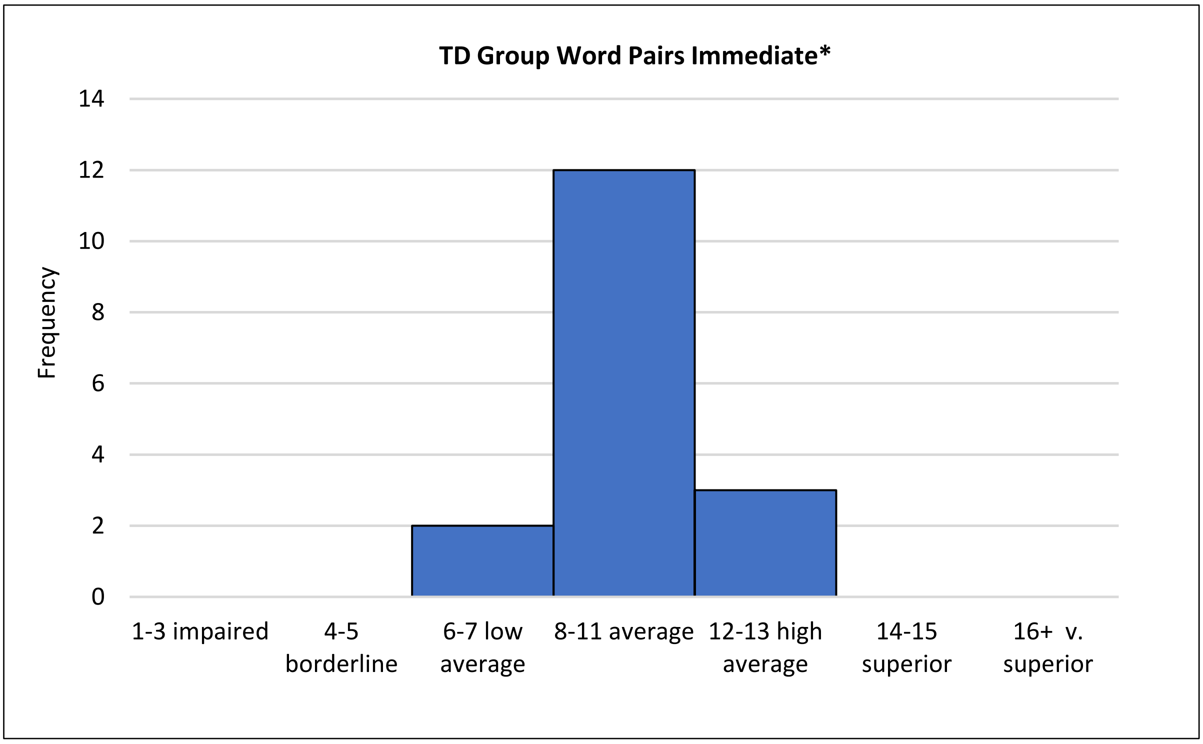
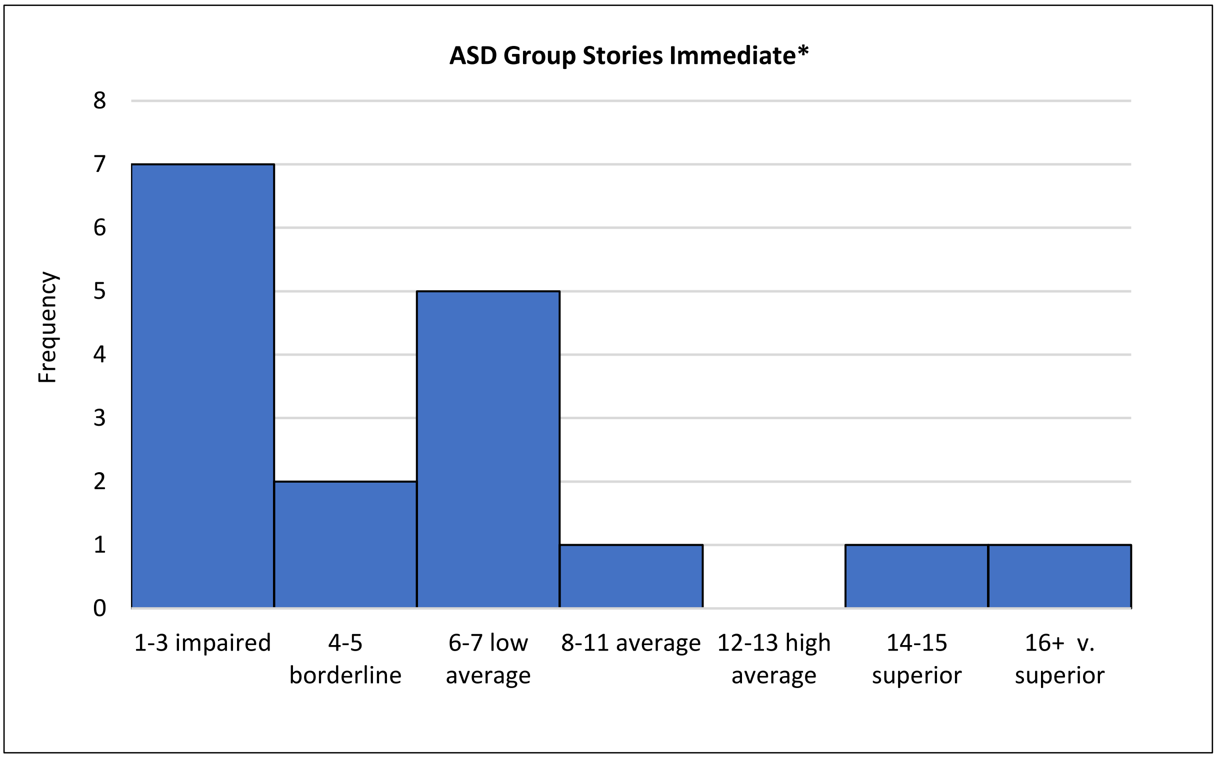




**Figure 3-6.** Histograms representing a breakdown of scores for the ASD and TD group on the CMS Word pairs immediate subtest Note: *Core subtest, **Supplemental subtest

The groups did not significantly differ on the Word pairs immediate subtest. However, scores were more widely distributed in the ASD group. The large majority of TD participants scored in the average and high average ranges, with no scores in extremely low, borderline, or superior ranges. Although a large proportion of ASD scores were in the average or high average range, some individuals scored in the extremely low and superior ranges.

**Stories Immediate**



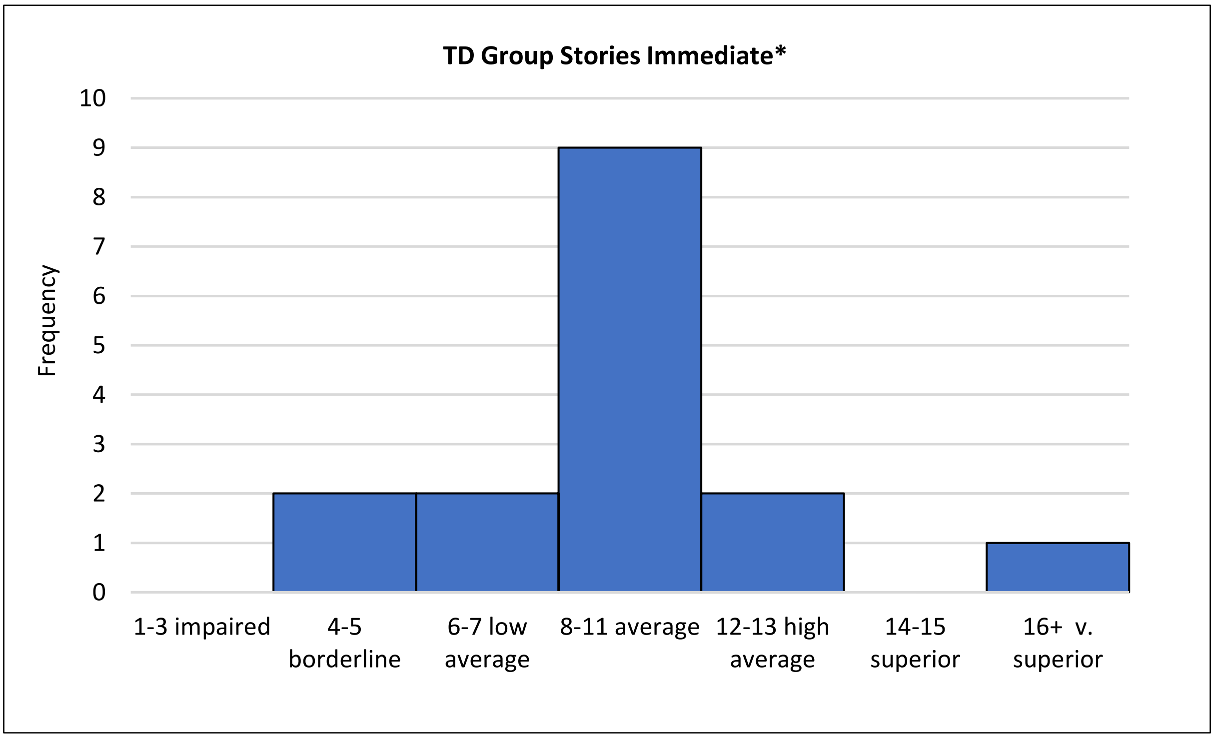
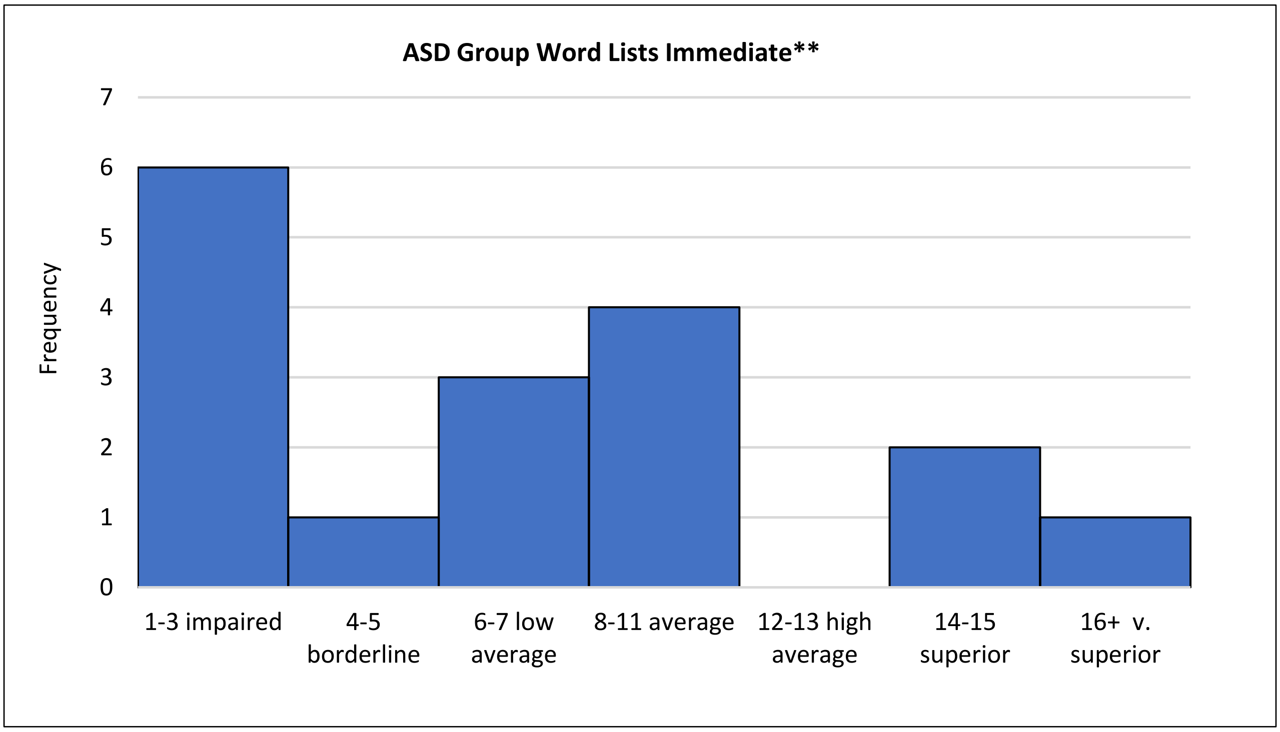




**Figure 3-7.** Histograms representing a breakdown of scores for the ASD and TD groups on the CMS Stories Immediate subtest Note: *Core subtest, **Supplemental subtest

The group difference was significant for the Stories immediate recall subtest, and the majority of participants with ASD scored in the lower average, borderline, and extremely low ranges on this subtest. In contrast, majority of TD participants scored between the high average, average, and low average ranges. However, scores were very widely distributed within the ASD group, and some participants in both the ASD and TD groups scoring in the very superior ranges.

**Words Lists Immediate**



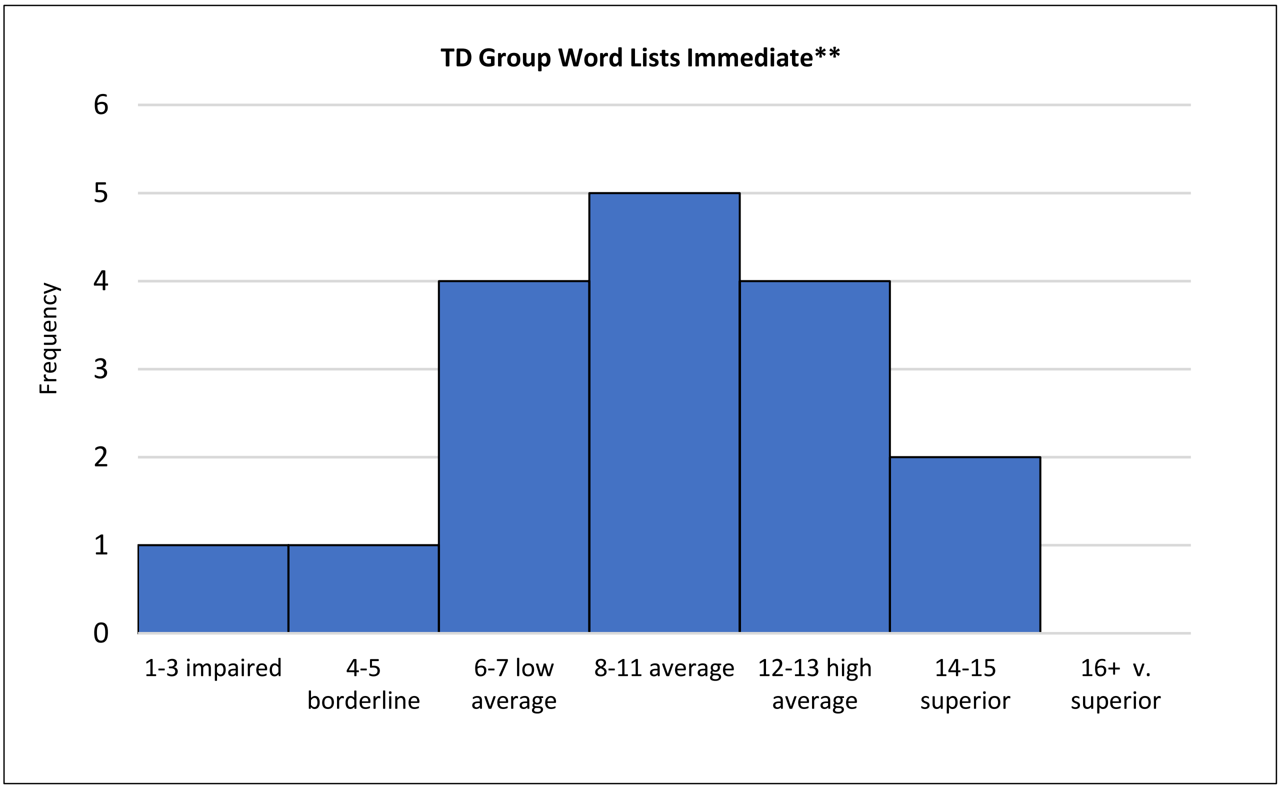
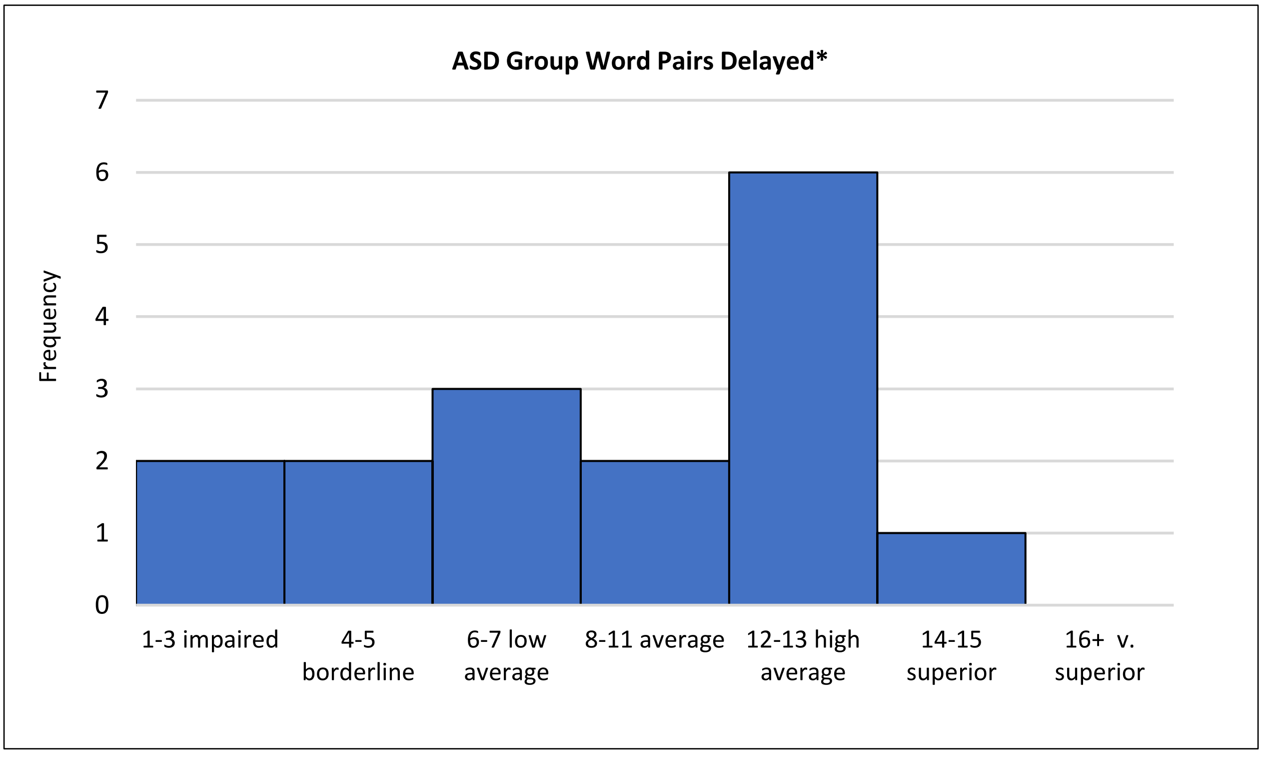




**Figure 3-8.** Histograms representing a breakdown of percentage scores for the CMS Word Lists Immediate subtest Note: *Core subtest, **Supplemental subtest

The group difference was not significant for the Word lists immediate recall subtest. More participants with ASD scored in the lower ranges compared to the TD group, though again, similar number of participants with ASD and TD scored in the superior range. A small proportion of the ASD group scored in the very superior range. No participants in the TD group scored in the very superior range.

**Word Pairs Delayed**



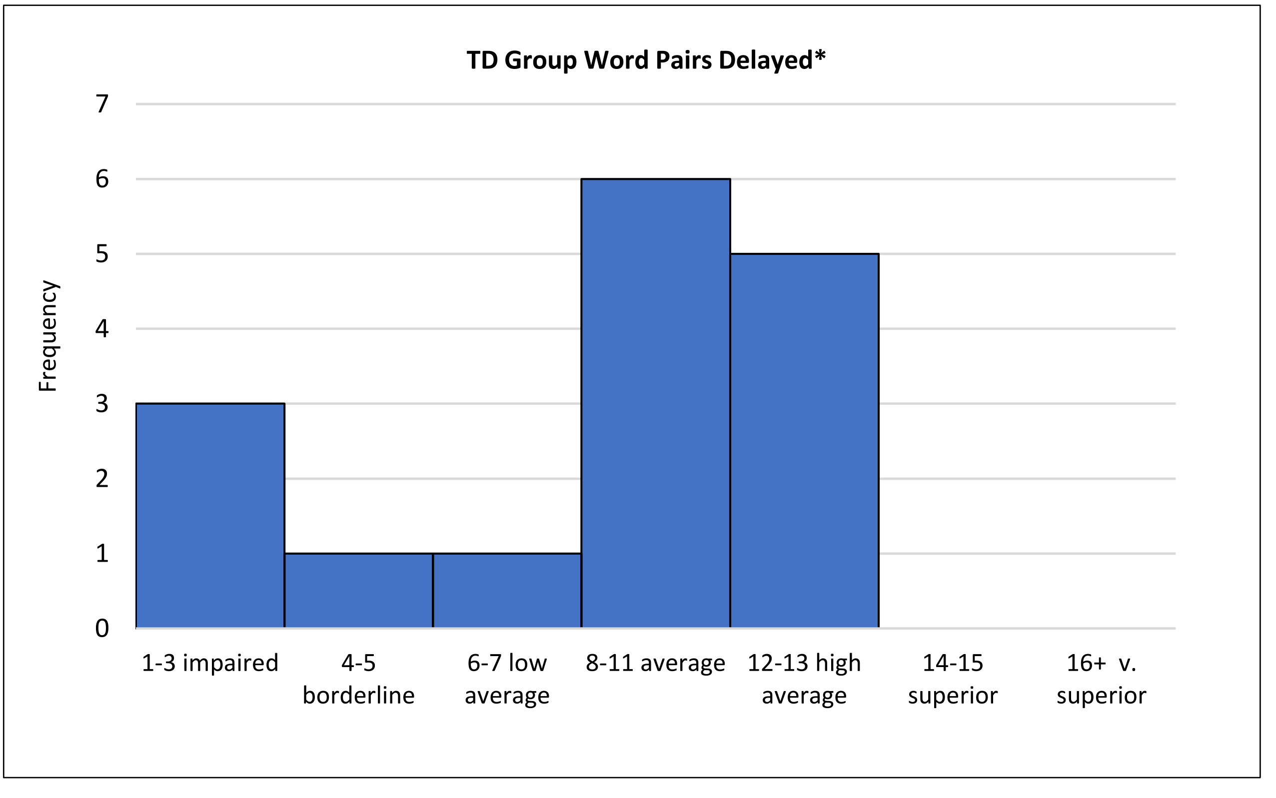
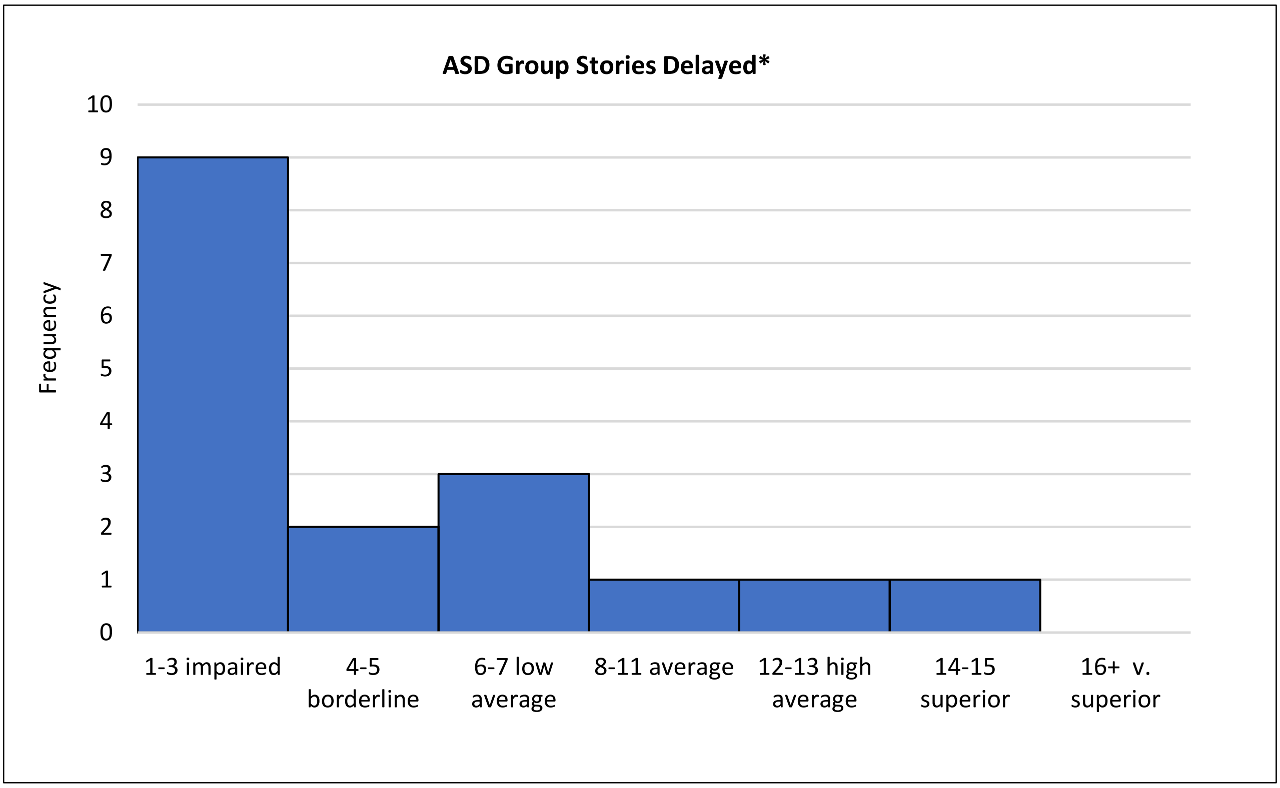




**Figure 3-9.** Histograms representing group scores for the CMS Word Pairs Long Delay subtest Note: *Core subtest, **Supplemental subtest

The group difference was not significant for the Word pairs delayed subtest. Some participants in both groups group scored in the low and impaired ranges. The majority of TD participants scored in the average and high average ranges on this subtest, whilst the scores for the ASD group were more widely distributed. One participant, in the ASD group, scored in the superior range.

**Stories Delayed**



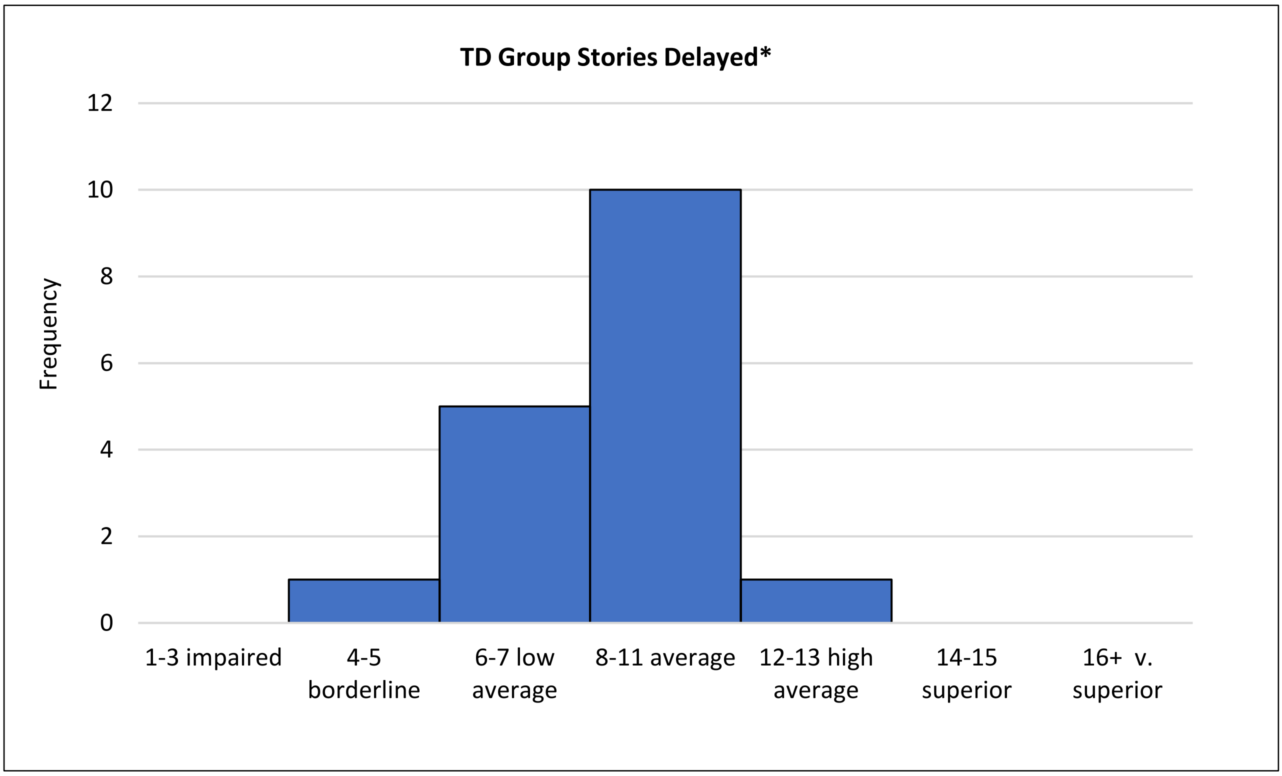




**Figure 3-10.** Histograms representing group scores for the CMS Stories Delayed subtest Note: *Core subtest, **Supplemental subtest

The group difference was not significant for the Stories delayed subtest.  The majority of TD participants scored in the average ranges whilst the majority of ASD participants scored in the lower ranges.  However, a similar proportion of individuals from ASD and TD groups scored in the high average range and one participant with ASD scored in the superior range.

**Word Lists Delayed**

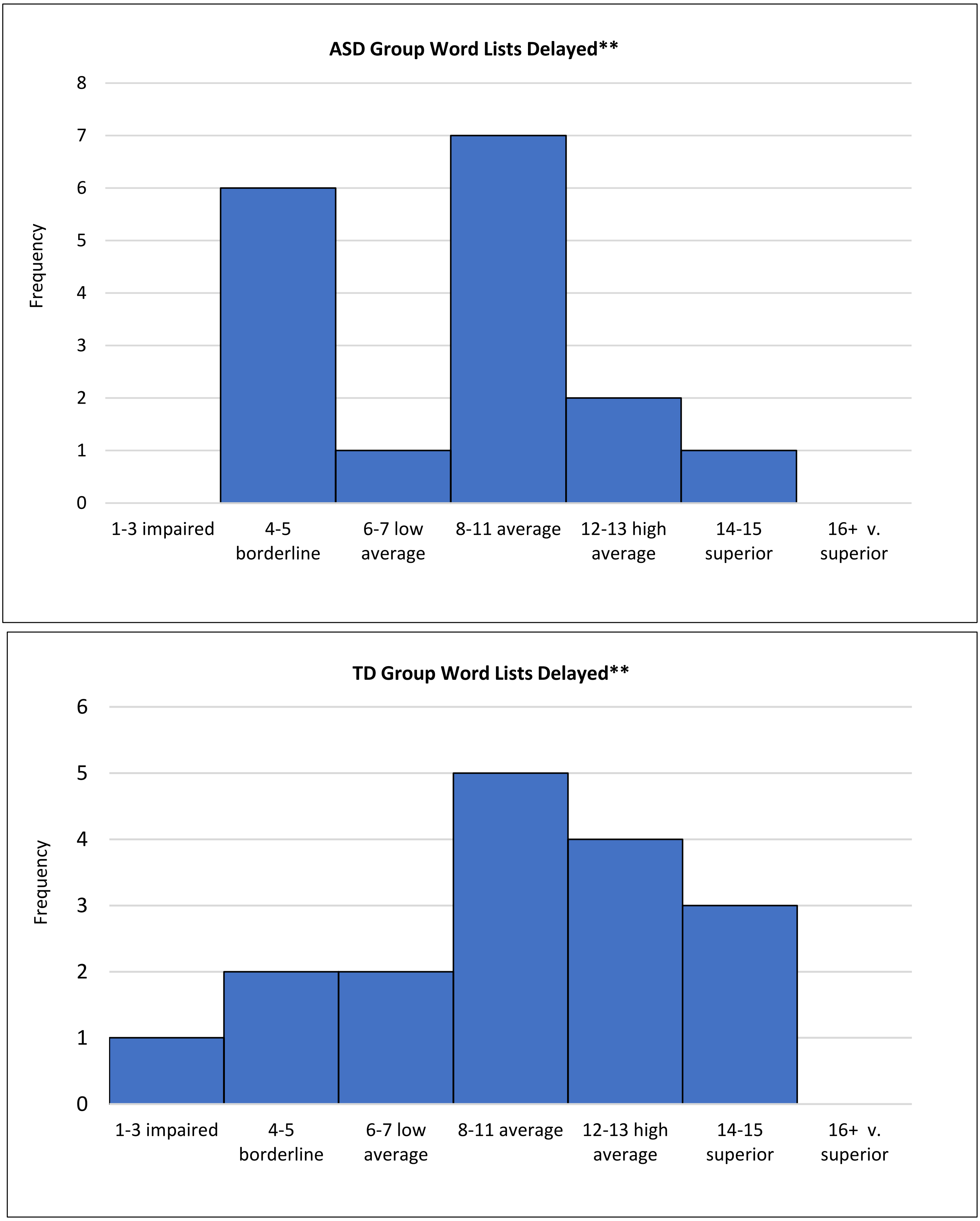



**Figure 3-11.** Histograms representing group scores for the CMS Word Lists Delayed subtest

Note: *Core subtest, **Supplemental subtest

The group difference was not significant for the Word lists delayed subtest. For the TD group the scores were widely distributed. For the ASD group, six participants scored in the borderline range with a greater proportion scoring in the average range. Only one participant scored in the superior range

**Verbal domains summary**

Whilst the results from the IQ assessment revealed no VIQ score differences between groups, the analysis of the auditory/verbal memory tests suggested that verbal memory skills were more variable in the ASD group than the TD group. The only comparison that reached significance was on the immediate recall of Stories subtest which probed complex semantic information, and this may suggest that verbal memory difficulties in ASD increase in line with linguistic complexity. However, inspection of individual data showed that a small proportion of individuals in the ASD group scored in the higher ranges on all verbal subtests.

## VISUAL/NONVERBAL DOMAIN

The structure of this domain is shown in figure 3-12 below.

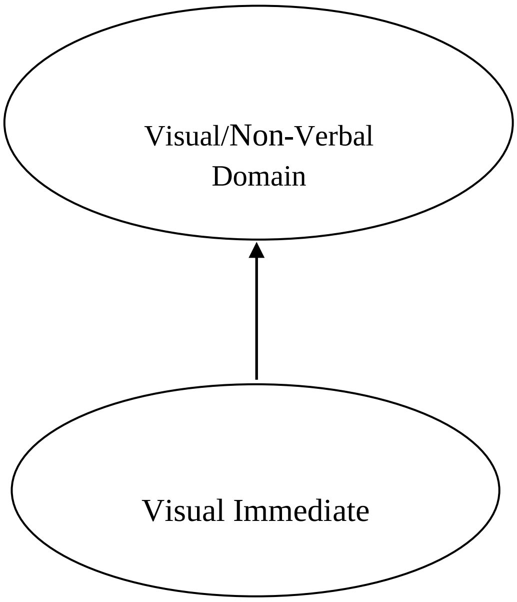



**Figure 3-12.** Structure of Visual/nonverbal domain from the CMS (Cohen, 1997)

**Visual Immediate**

**Table 3- 5**. Mean total Visual Immediate scores for ASD and TD group

| | **Visual Immediate Index Mean SD Range** |
|---|---|
| ASD Group | 92.94[4] (19.58) 50 - 118 |
| TD Group | 97.06[4] (12.95) 69 - 115 |

Categories: impaired[1], borderline[2], low average[3], average[4], high average[5], superior[6], very superior[7]

Visual immediate index scores were in the average range for both groups. Although the group mean was higher in the TD group than the ASD group this was not significant ( $t$ = - .72, df = 32, $p$ = 0.48 )

Scores for the subtests comprising the visual immediate index are shown in table 3-6 below.

**Table 3-6.** Mean Visual immediate index subtest scores for ASD and TD group

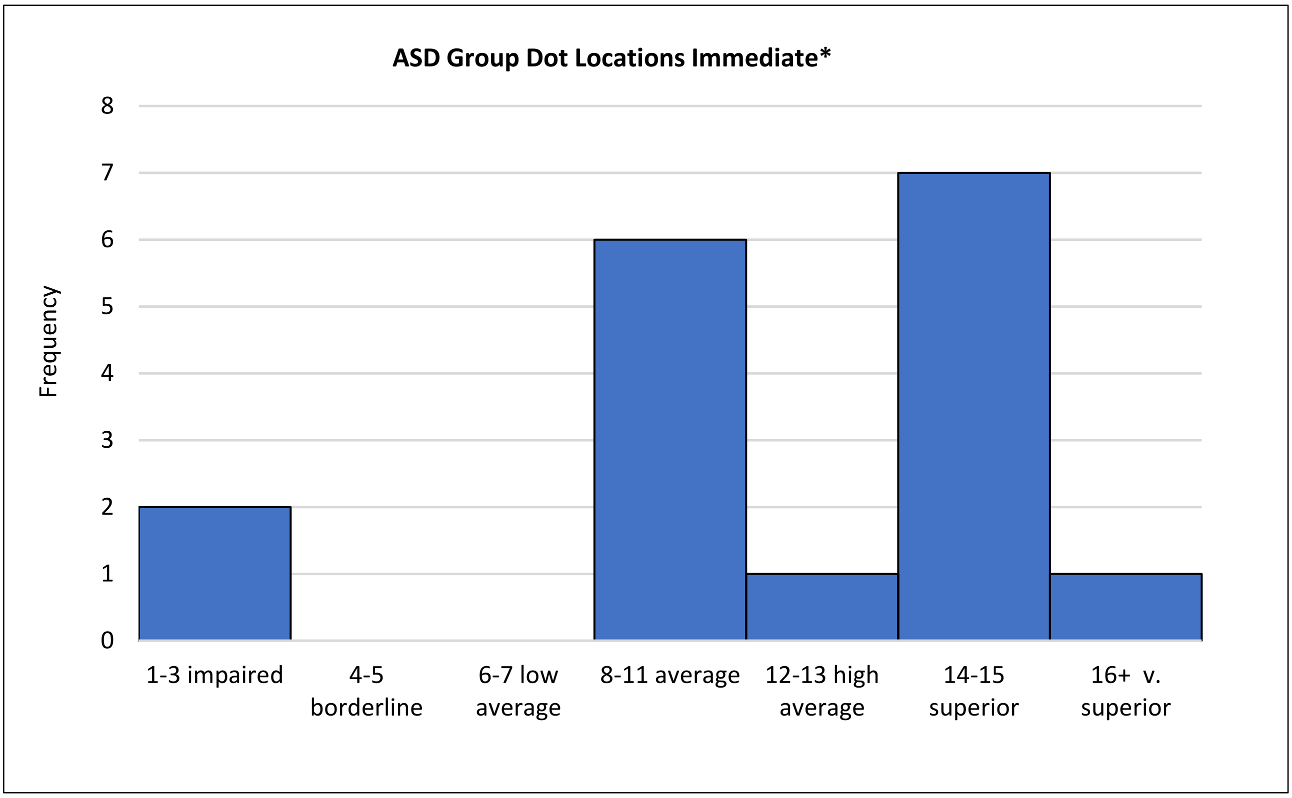
| | **Visual Immediate Index**<br>**Mean SD Range** | |
|---|---|---|
| | **ASD** | **TD** |
| Dot locations* | 11.12[4] (4.59) 1 - 18 | 12.12[5] (2.29) 7 - 14 |
| Faces* | 6.59[3] (3.66) 1 - 12 | 7.41[3] (2.96) 3 - 13 |
| Family Pictures** | 13.59[5] (4.05) 1 - 16 | 11.24[4] (1.86) 8 - 14 |

Categories: impaired[1], borderline[2], low average[3], average[4], high average[5], superior[6], very superior[7]
Note: *Core subtest, **Supplemental subtest

On the immediate recall of Dot locations subtest scores were in the average range for the ASD group and the high average range for the TD group. This difference was not statistically significant ($t$ = - .80, df = 32, $p$ = 0.43). Both groups scored in the low average range on the Faces subtest and scores were not significantly different ( $t$ = - .72, df = 32, $p$ = 0.48). On the Family pictures subtest ASD group scored in the high average range whilst the TD group scored in the average range. This difference was statistically significant ( $t$ = 2.18, df = 32, $p$ = 0.04).

Individual data for the three visual subtests are shown in histograms below.

### Dot Locations Immediate



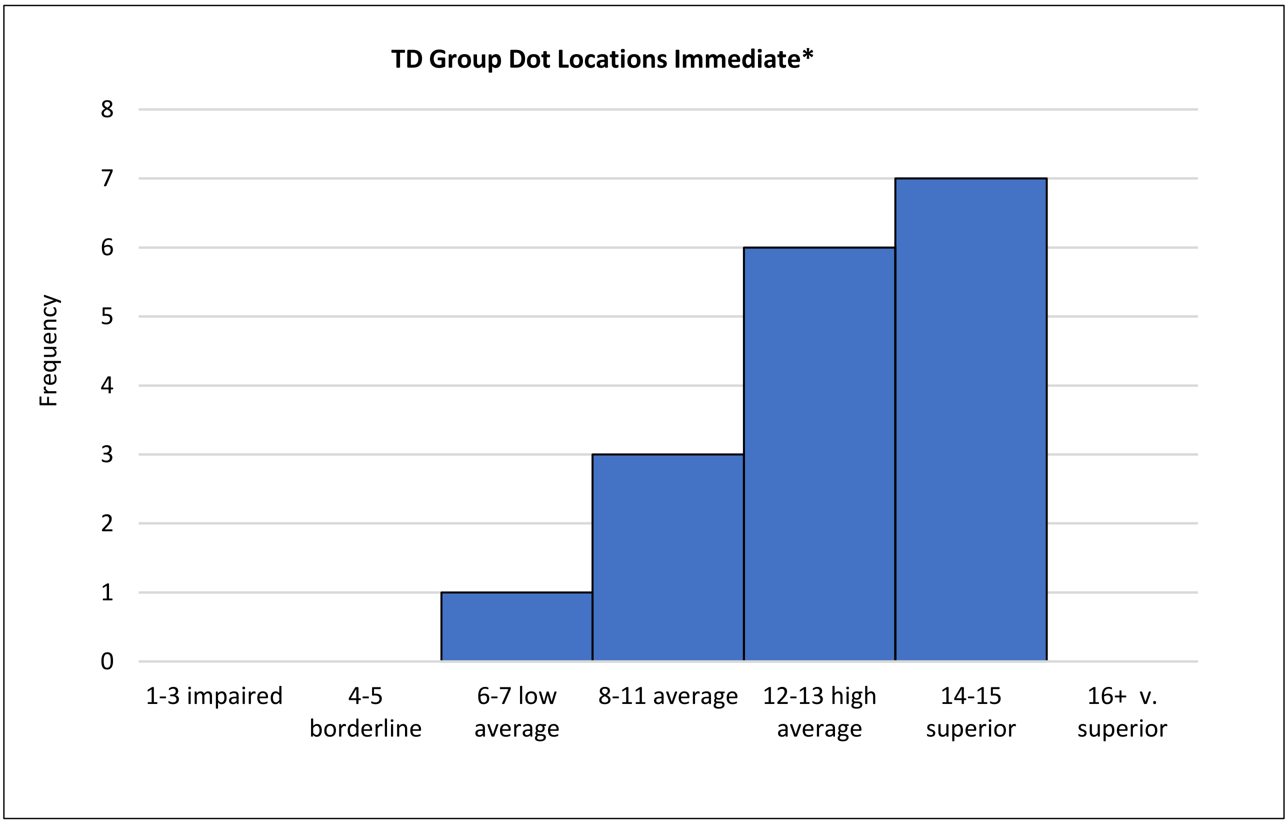
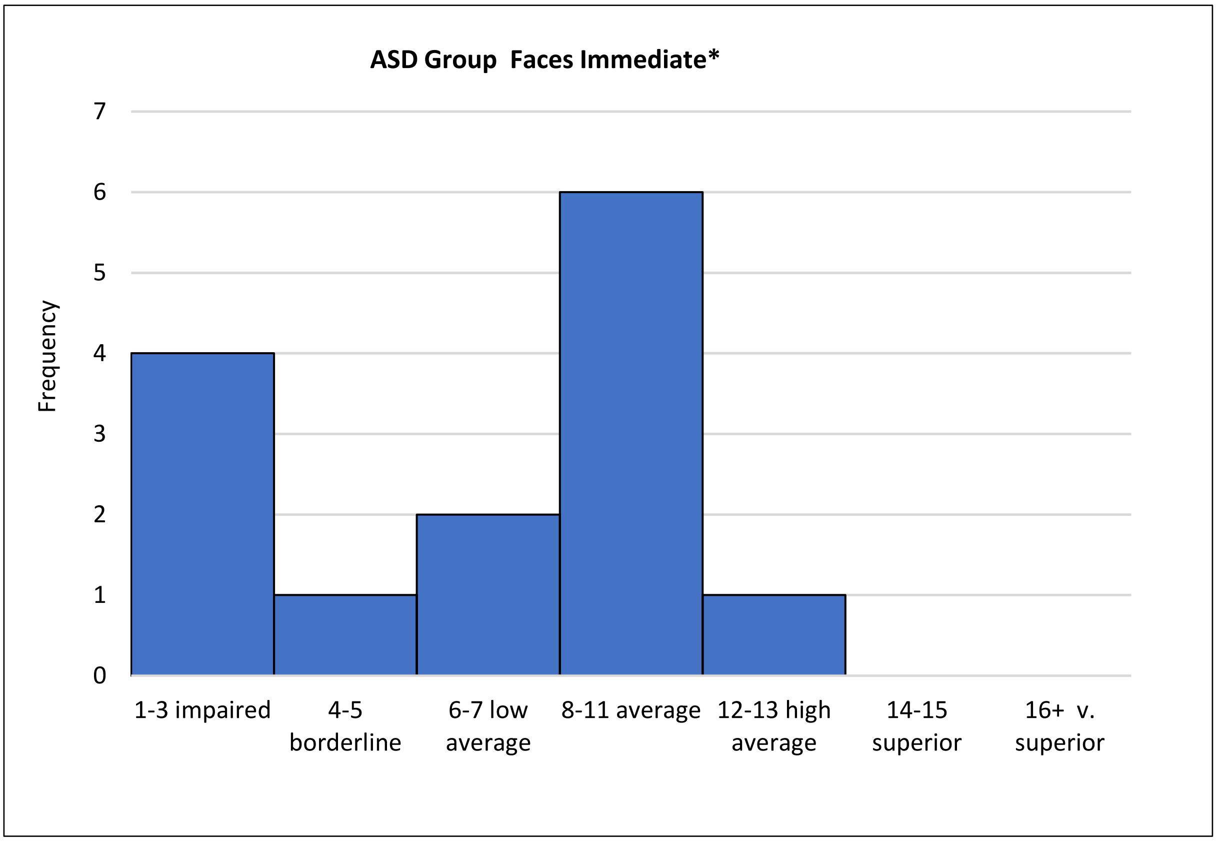




**Figure 3-13.** Histograms representing group scores for the CMS Dot Locations immediate subtest
Note: *Core subtest, **Supplemental subtest

The group difference was not significant for the Dot locations immediate subtest. The majority of the scores for the TD group ranged between high average and superior, with no participants scoring in the extremely low or borderline ranges. Within the ASD group two participants scored in the extremely low range, six participants within the average range and nine participants in the high average, superior and very superior ranges.

**Faces Immediate**



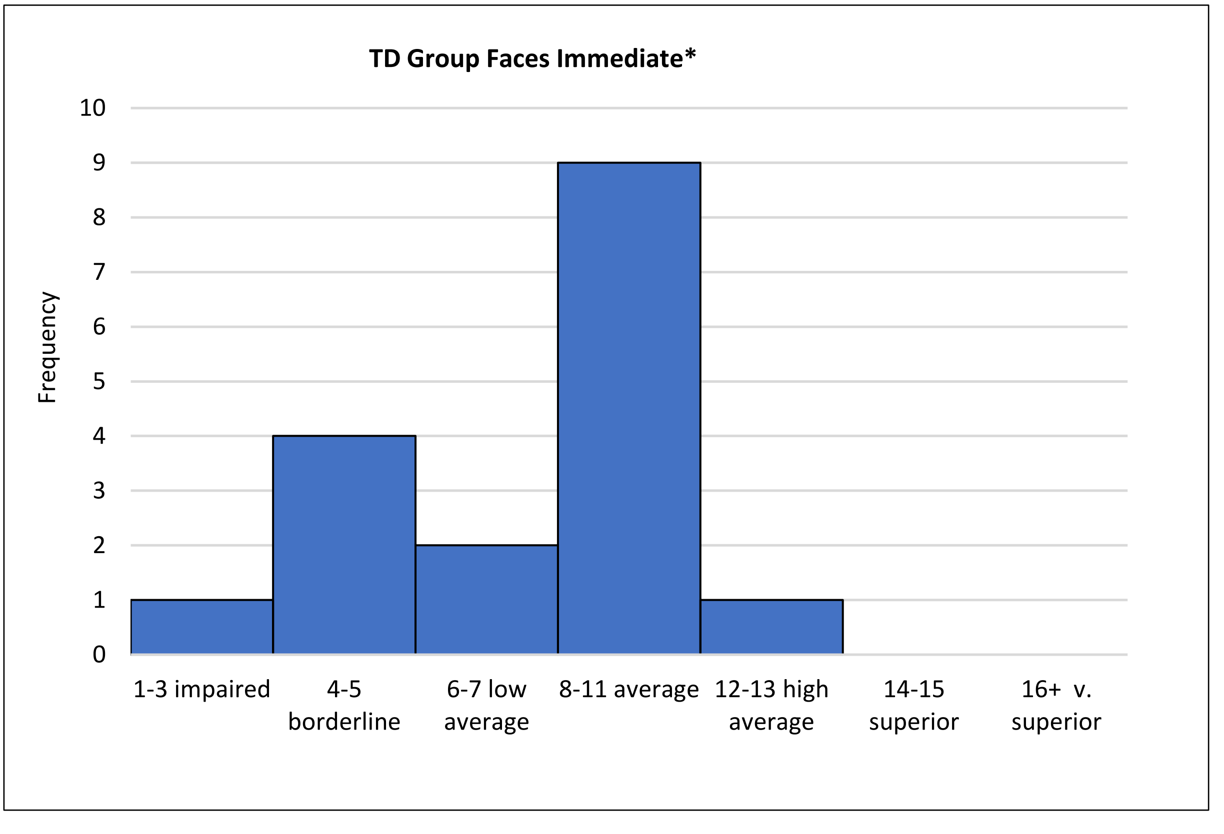
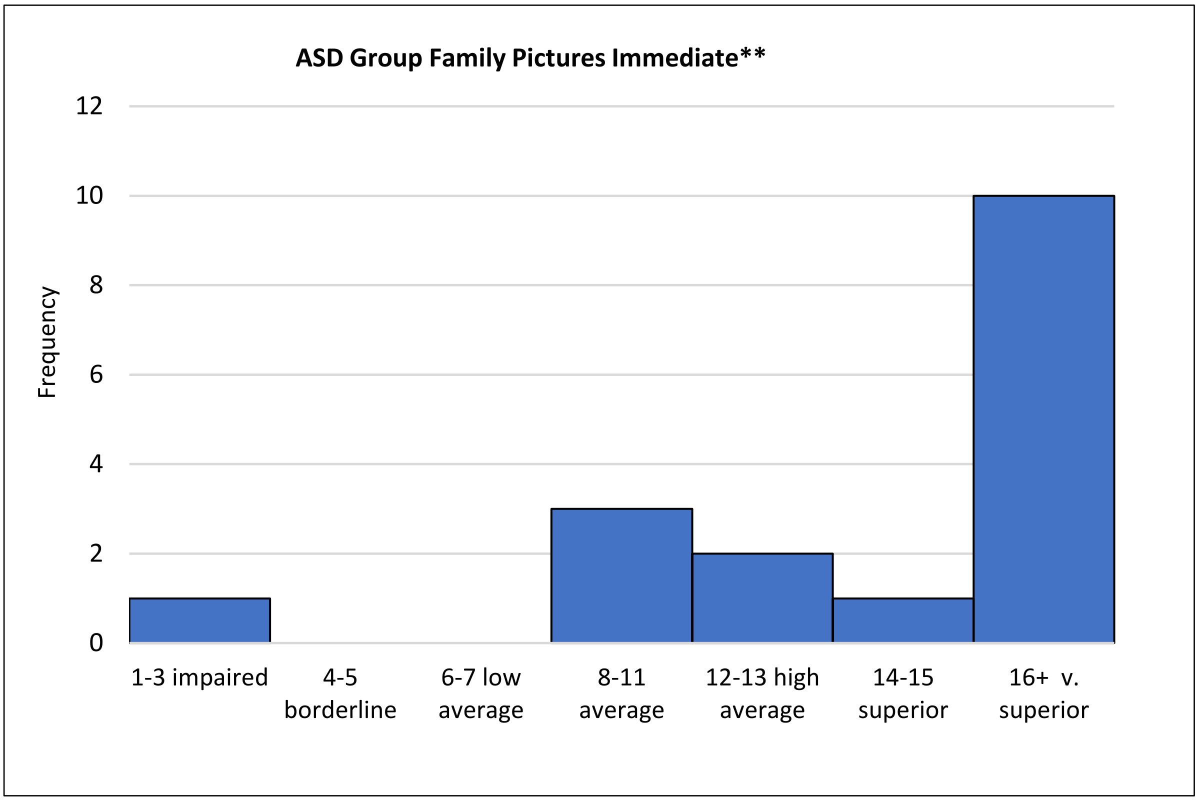




**Figure 3-14.** Histograms representing group scores for the CMS Group Faces Immediate subtest Note: *Core subtest, **Supplemental subtest

The group difference was not significant for the Faces immediate subtest. The proportion of scores falling in the extremely low and borderline categories was the same for both groups and this was also true for the high average category.

**Family Pictures Immediate**



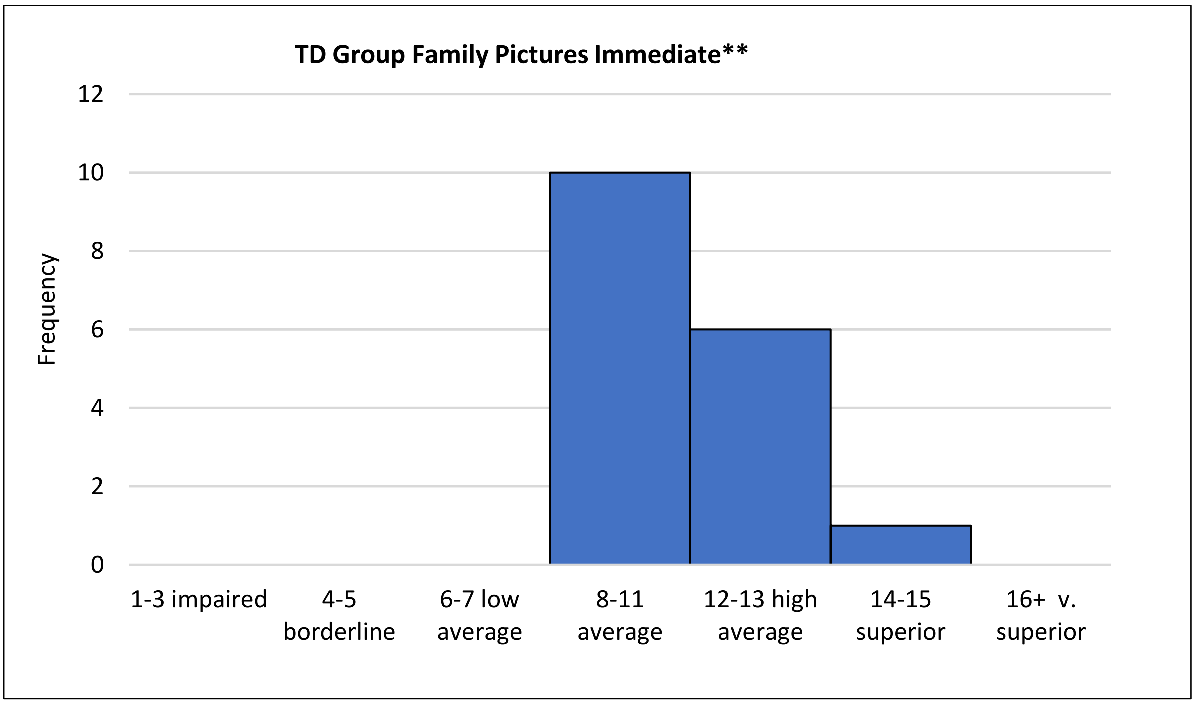




**Figure 3-15**. Histograms representing group scores for the CMS Family Pictures immediate subtest Note: *Core subtest, **Supplemental subtest

The group difference was significant for the Family pictures immediate subtest, with higher scores in the ASD group. For the ASD group, 13 participants scored between high average, superior and very superior ranges, with only four scoring in the average range and in the extremely low range. Over half the participants in the TD group scored in the average range with seven participants scoring in the high average and superior ranges.

### Visual/Nonverbal domains summary

The analysis of the visual/non-verbal memory tests revealed surprising findings. Based on previous literature and theoretical accounts of ASD, it would have been predicted that memory for Dot locations would be superior in ASD. However, this was not the case, and inspection of individual data suggested that some individuals with ASD found this task very difficult. The ASD group showed a clear advantage on the Family pictures task with more than half of the sample scoring in the superior and very superior range. Whilst the results from the Dot locations task did not immediately suggest enhanced processing of visual detail, this test had a larger spatial component than family pictures, and the qualities of the low-level visual features were very different for the two tests. The experimental paradigms described in chapters 4, 5 and 6 probe visual perception and the results may help explain the pattern of results on these memory tasks.

**ATTENTION/CONCENTRATION DOMAIN**

**Attention/Concentration**

**Table 3-7.** Mean total Attention/Concentration index scores for ASD and TD group

| | Attention/Concentration Index Mean SD Range |
|---|---|
| ASD Group | 84.29[3] (23.73) 50 - 118 |
| TD Group | 105.18[4] (14.47) 75 - 131 |

Categories: impaired[1], borderline[2], low average[3], average[4], high average[5], superior[6] , very superior[7]

Scores comprising the attention/concentration index were in the Low Average range for the ASD group and in the Average range for the TD group. This difference was statistically significant ( $t$ = -3.10, df = 32, $p$ = 0.004 ).

Scores for subtests comprising the attention/concentration index are shown below in table 3-8.

**Table 3-8.** Mean Attention/Concentration index subtest scores for ASD and TD group

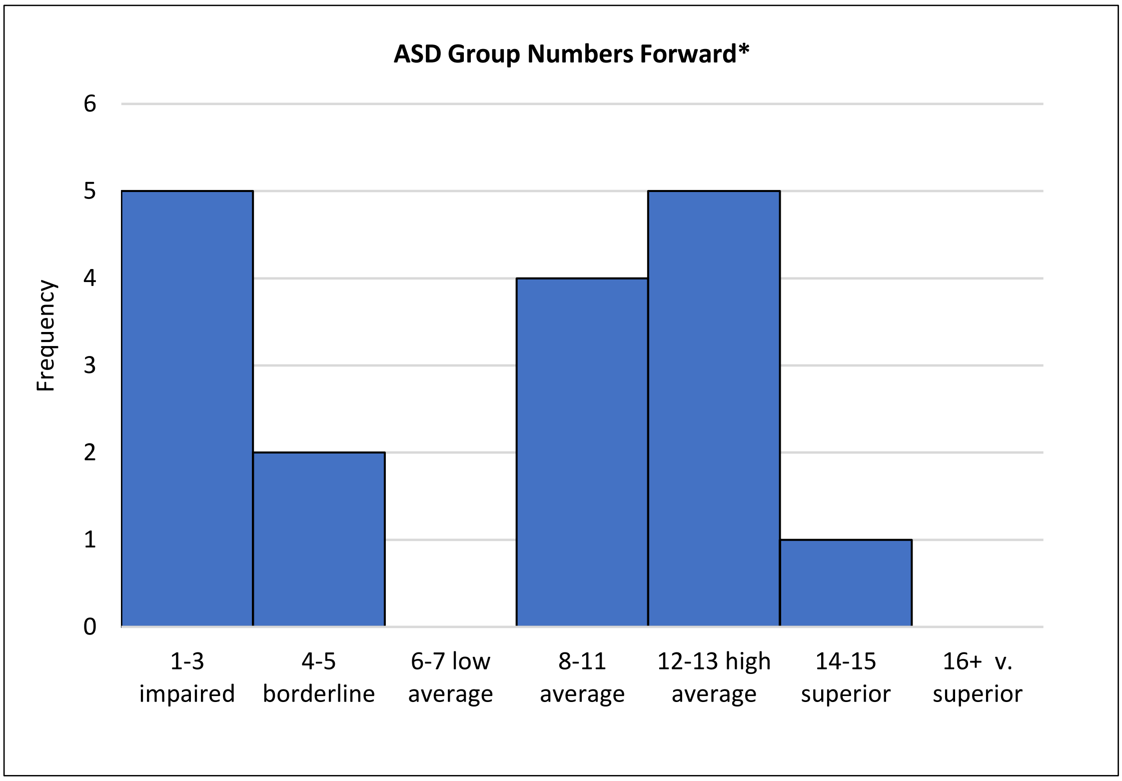
| | **Attention/Concentration Index** **Mean SD Range** | |
|---|---|---|
| | ASD | TD |
| Numbers* | 7.18[3] (3.96) 1 - 11 | 10.94[4] (3.75) 4 - 15 |
| Numbers Forward | 7.71[3] (4.31) 2 - 14 | 10.41[4] (3.74) 3 - 17 |
| Numbers Backward | 5.47[2] (5.29) 1 - 15 | 9.41[4] (3.26) 6 - 15 |
| Sequences* | 7.94[3] (4.13) 1 - 15 | 11.29[4] (1.96) 8 - 14 |
| Picture Locations** | 9.89[4] (5.33) 1 - 17 | 12.59[5] (4.14) 5 - 18 |

Categories: impaired[1], borderline[2], low average[3], average[4], high average[5], superior[6], very superior[7]
Note: *Core subtest, **Supplemental subtest

Groups significantly differed on the Numbers subtest ($t$ = - 2.85, df = 32, $p$ = 0.008) with the ASD group scoring in the low average range whereas the TD group scored in the average range. On the Numbers forward subtest, the groups approached significance ( $t$ = - 1.95, df = 32, $p$ = 0.059 ), but their scores significantly differed on the Numbers backward subtest with lower scores in the ASD group ( $t$ = - 2.61, df = 32, $p$ = 0.01). On the Sequences subtest, the ASD group scored in the low average range whereas the TD group scored in the average range and this difference was significant ($t$ = - 3.02, df = 32, $p$ = 0.005). Groups did not significantly differ on the Picture locations subtest ( $t$ = - 1.65, df = 32, $p$ = .108), the ASD group scores were in the average range whereas the TD group scores were in the high average range.

A high percentage of participants in the ASD group showed particularly poor performance on the backward digit span of the numbers subtest and in the following histograms, forward and backward digit span scores are shown separately.

**Numbers Forward**



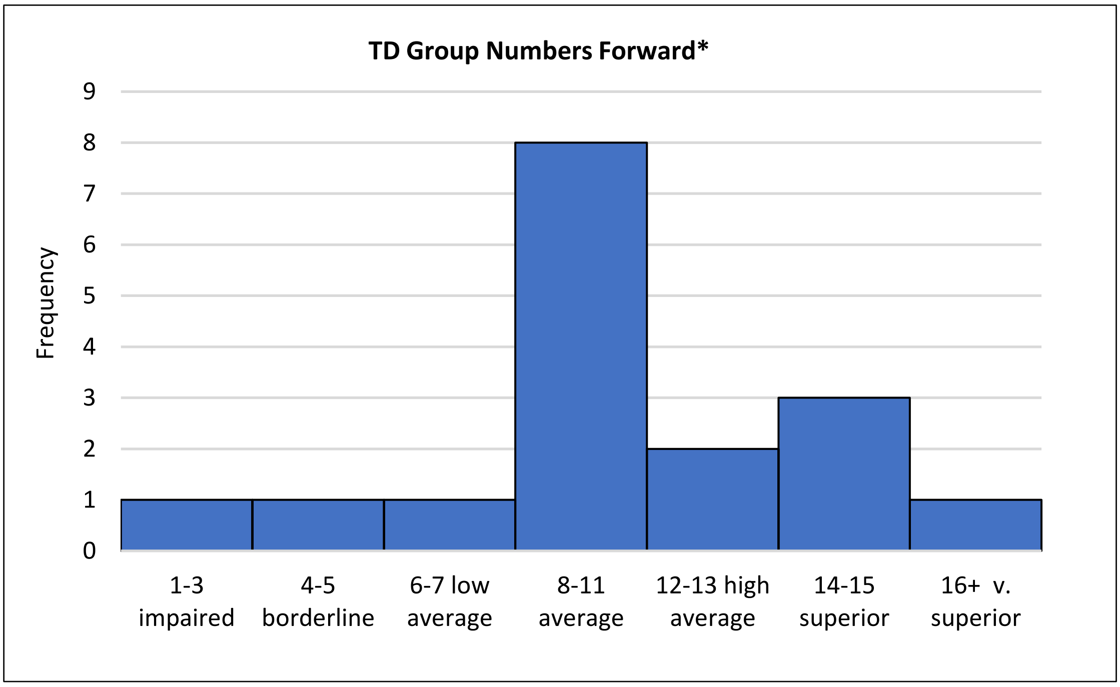
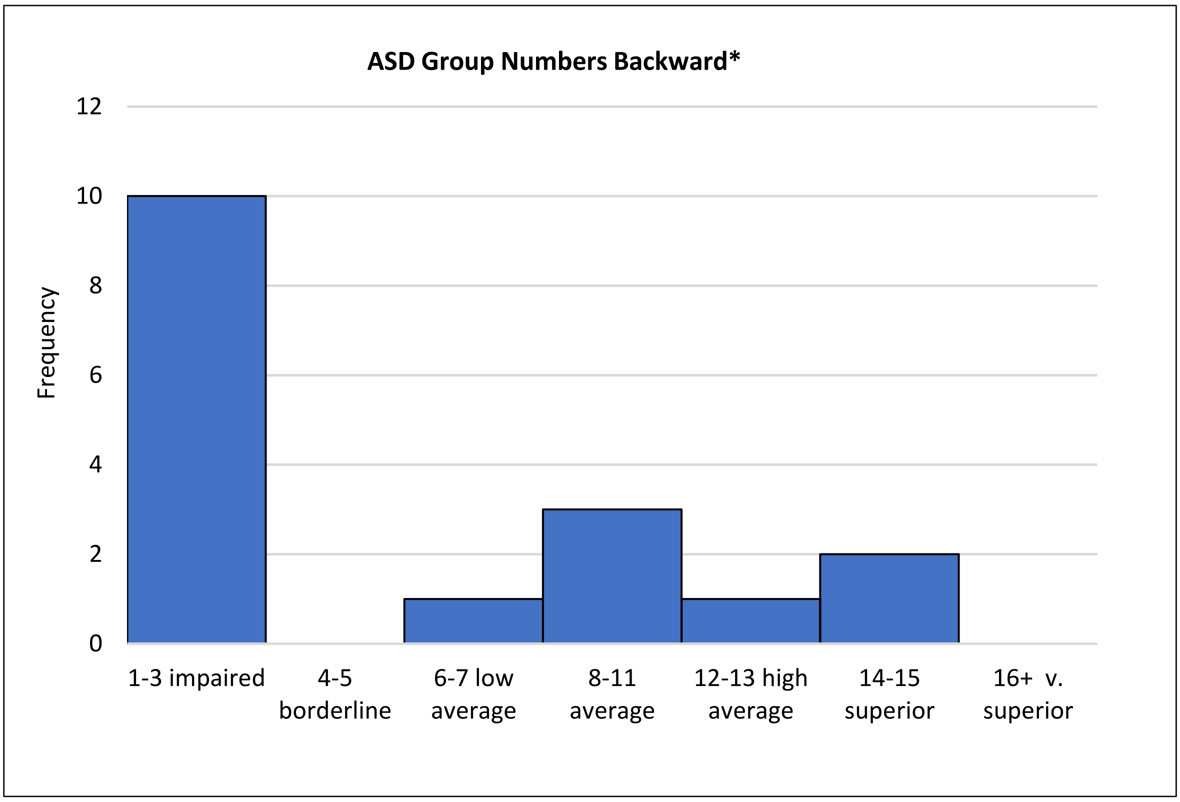




**Figure 3-16**. Histograms representing group scores for the CMS Numbers Forward subtest

Note: *Core subtest, **Supplemental subtest

The group difference approached significance with lower scores in the ASD than the TD group. Within the ASD group seven of the individuals scored in the borderline to extremely low range whilst six participants scored in the high average to superior range. The majority of TD scores scored in the average and higher ranges with one participant scoring in the very superior range.

**Numbers Backward**



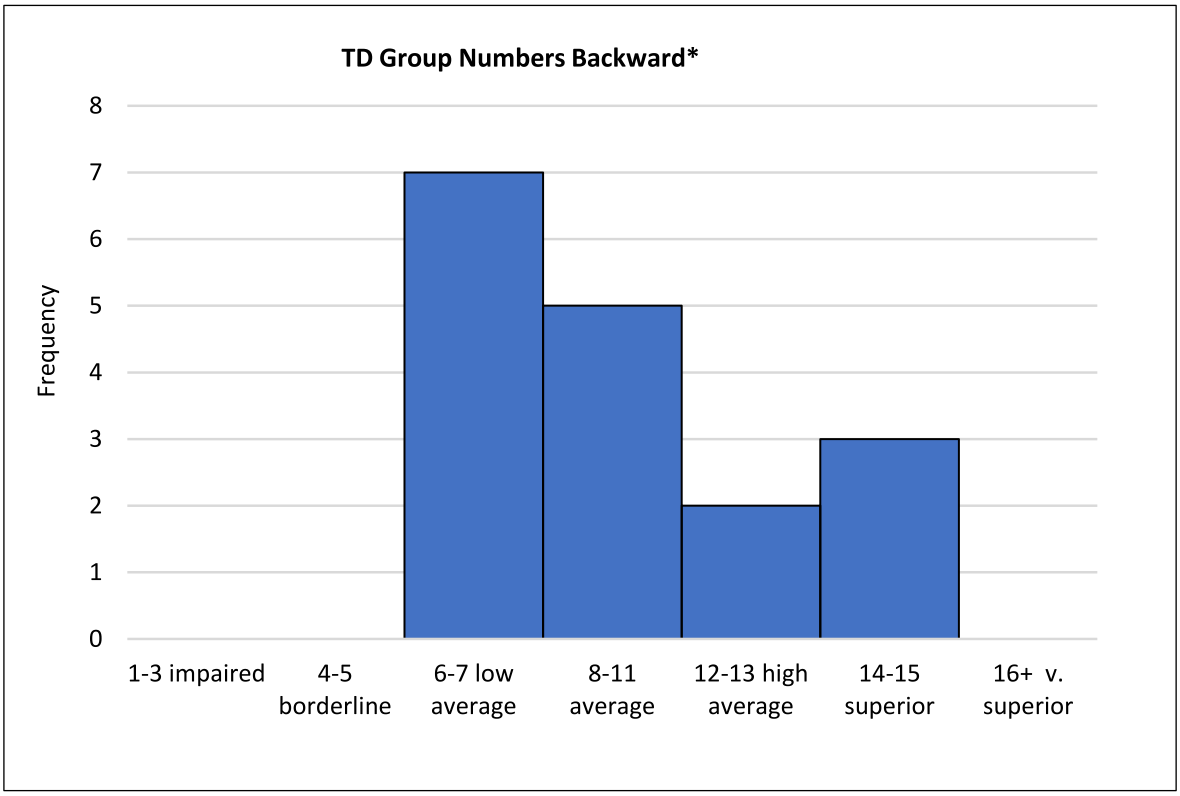
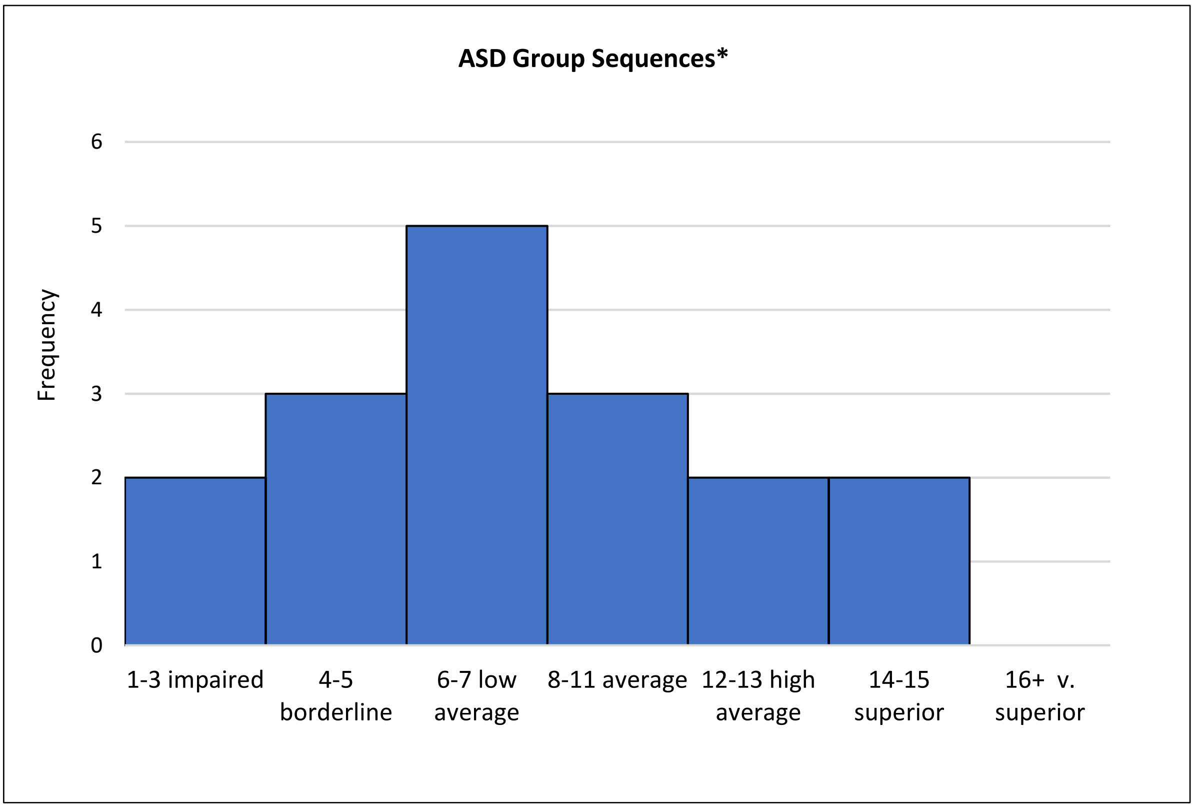




**Figure 3-17.** Histograms representing group scores for the CMS Numbers Backward subtest Note: *Core subtest, **Supplemental subtest

The group difference was highly significant with lower scores in the ASD group. A large distribution of scores for the ASD group were in the extremely low range compared to the TD group, for whom seven participants scores were in the low average range. Despite generally poorer scores in the ASD group it was interesting to note that a small proportion of participants scored in the superior range.

**Sequences**



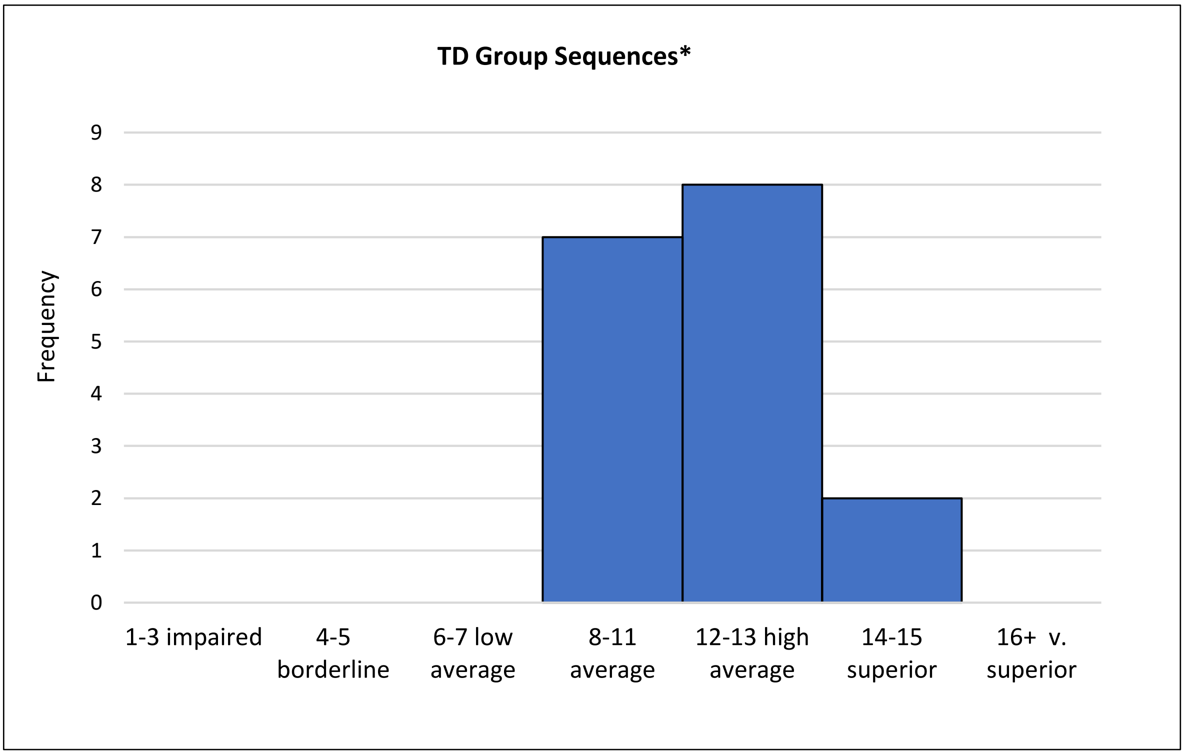
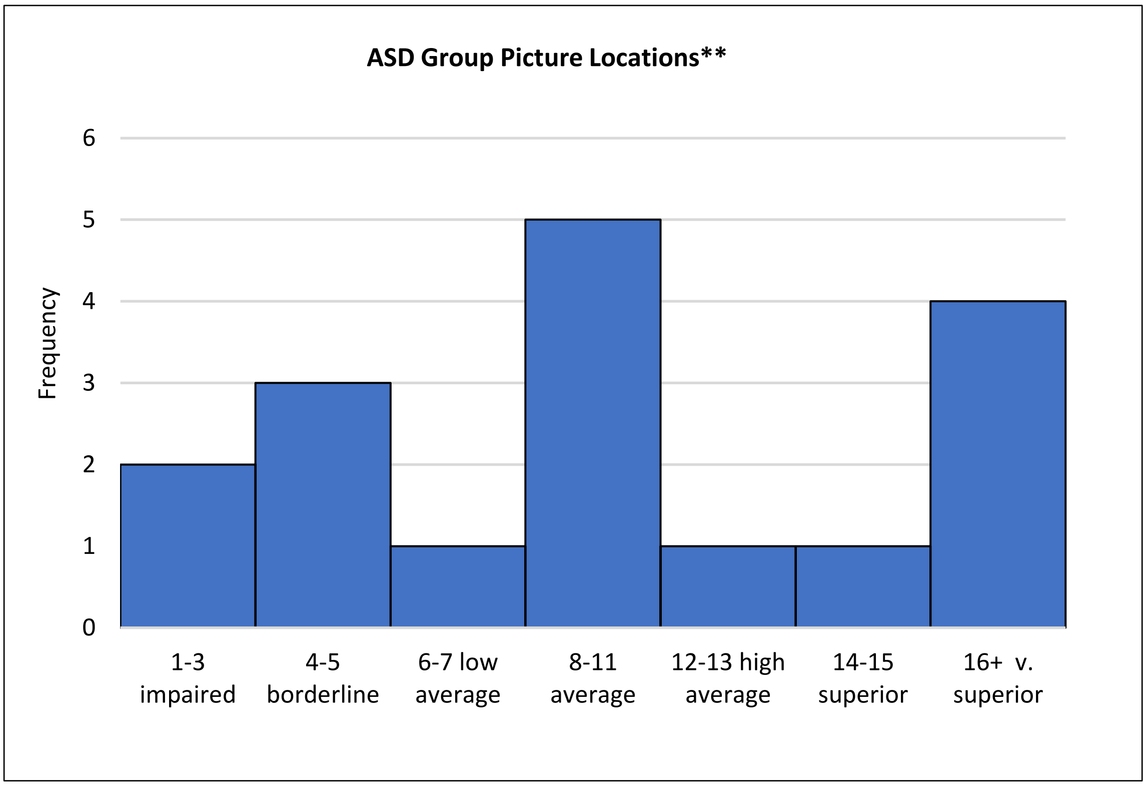




**Figure 3-18.** Histograms representing group scores for the CMS Sequences subtest Note: *Core subtest, **Supplemental subtest.

The group difference was significant, and more than half of the participants in the ASD group scored in the average, low average, borderline, and impaired ranges. The majority of TD participants scored in the average and higher ranges. Within both groups the same number of participants scored in the superior range.

## Picture Locations



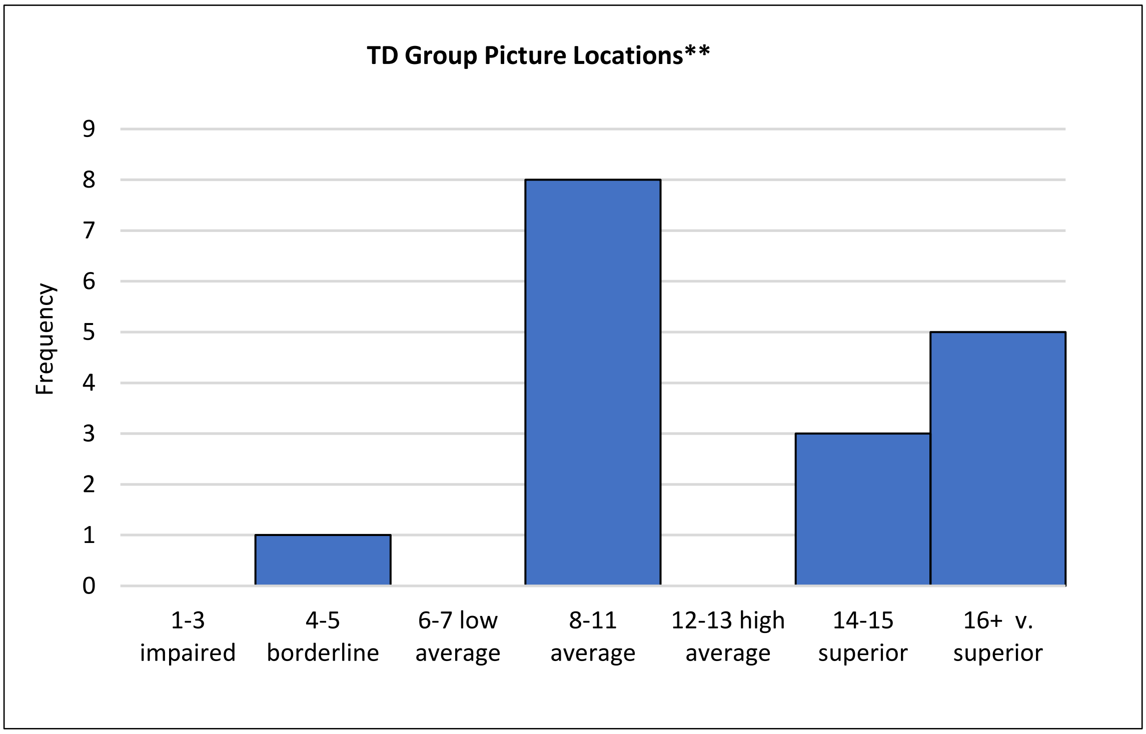




**Figure 3-19.** Histograms representing group scores for the CMS Picture Locations Total subtest Note: *Core subtest, **Supplemental subtest

The

The group difference was not significant for the Picture Locations subtest. The ASD groups scores were dispersed throughout all the ranges whereas for the TD group, the majority of the participants scored within the average, superior and very superior ranges.

**Attention/Concentration domain summary**

Performance on the attention/concentration factor showed the most marked differences between groups. As impairments in attention/concentration are likely to influence performance on tests of perceptual processing, these results will be considered in some detail here. The subtests included in this index test immediate memory and are both auditory and visual. For the auditory recalling Numbers forward test; the ASD participants scored in the extremely low and borderline and average and high average ranges, with a small number scoring in the superior range. For the auditory recalling numbers backward test, the ASD participants scores were in the extremely low and low average, average, and high average ranges with a small number scoring in the superior range. For the Sequence's subtest, the ASD participants' scores were also in the extremely low and borderline, low average, and average and high average ranges, with a small number scoring in the superior range. On the Picture Locations supplemental subtest, some of ASD participants performed in the high average to very superior range, in the low average and average range and a small percentage scored in the extremely low and borderline ranges were reported. This suggests that the low attention/concentration index score in the ASD group is explained by poor performance on the auditory tasks and more specifically on the Backward digit span subtest of the Numbers task which is a measure of verbal WM. At the group level, visual memory processing appeared to be more efficient than auditory working memory processing in ASD. The data from the participants tested in the current study highlight the importance of considering individual differences, as well as group level performance. Despite generally poor recall of Numbers, some individuals scored in the high average and superior ranges. Scores for all memory indexes assessed in the study are shown in figure 3-20.

Figure 3-20 below shows the mean total index scores for all the domains of the CMS for both the ASD and TD group.

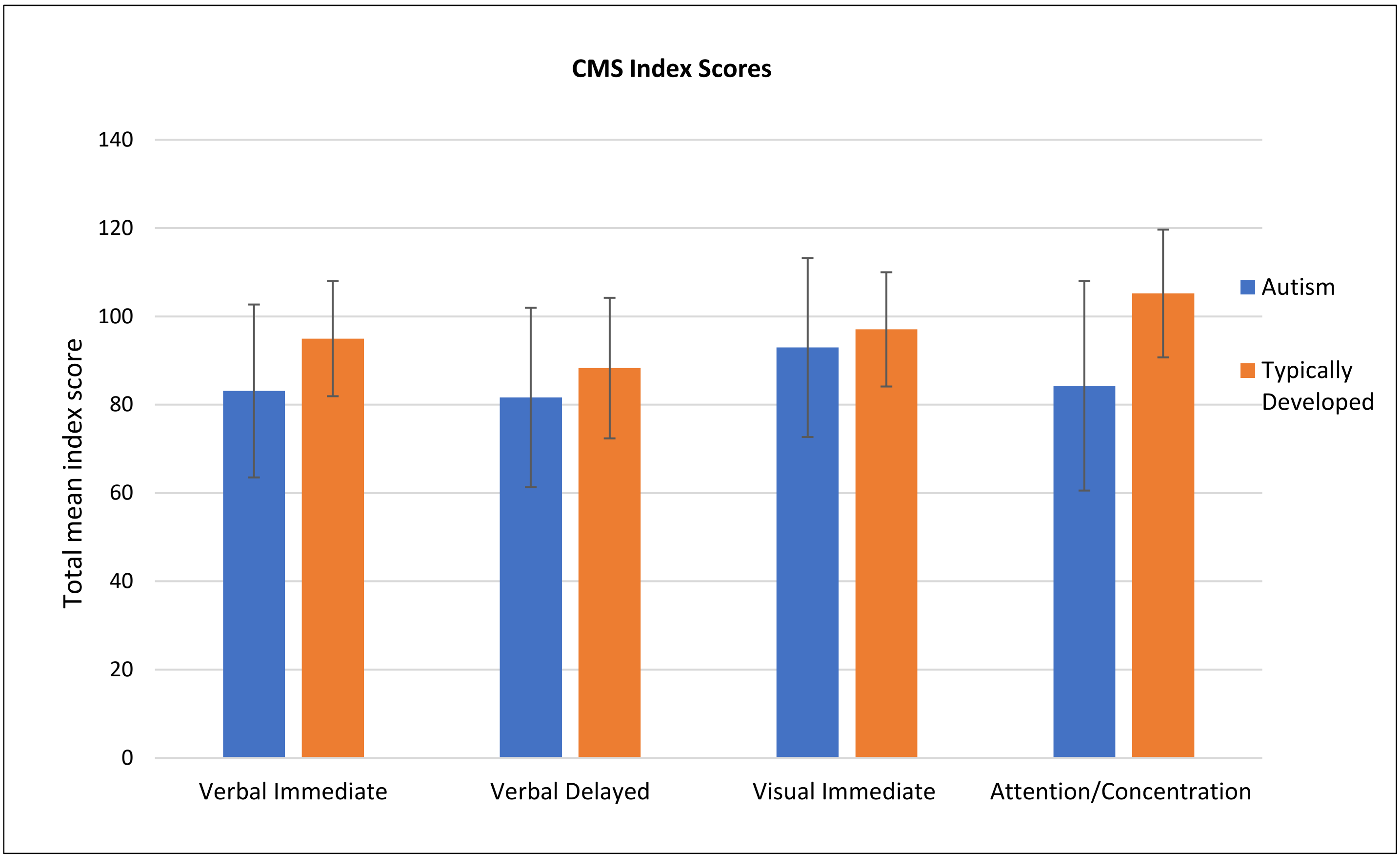



**Figure 3-20.** Children's Memory Scale Index scores for all the domains for the various subscales for both groups.

For participants with ASD three of the four index scores were in the low average range (Verbal Immediate, Verbal Delayed and Attention/Concentration) and one in the average range (Visual Immediate index) whilst for TD participants, three of the four index scores were in the average range and only one index was in the low average range (Verbal Delayed index). In summary, the analysis of the memory data revealed better retention of verbal and visual information, and poorer recall of numbers and sequences in the ASD compared with the TD group. However, inspection of individual data showed that some individuals with ASD are able to retain verbal information at superior and very superior levels.

### Discussion of memory data

The analysis of the memory data revealed some interesting differences between participant groups. Figure 3-21 shows the memory subtests that showed significant group differences. The subtests which revealed significant differences between groups included the Stories subtest from the Verbal Immediate index, the Family pictures subtest from the Visual Immediate index as well as the Numbers digit span (subdivided into forward and backward) and Sequences subtests from the Attention/Concentration index.

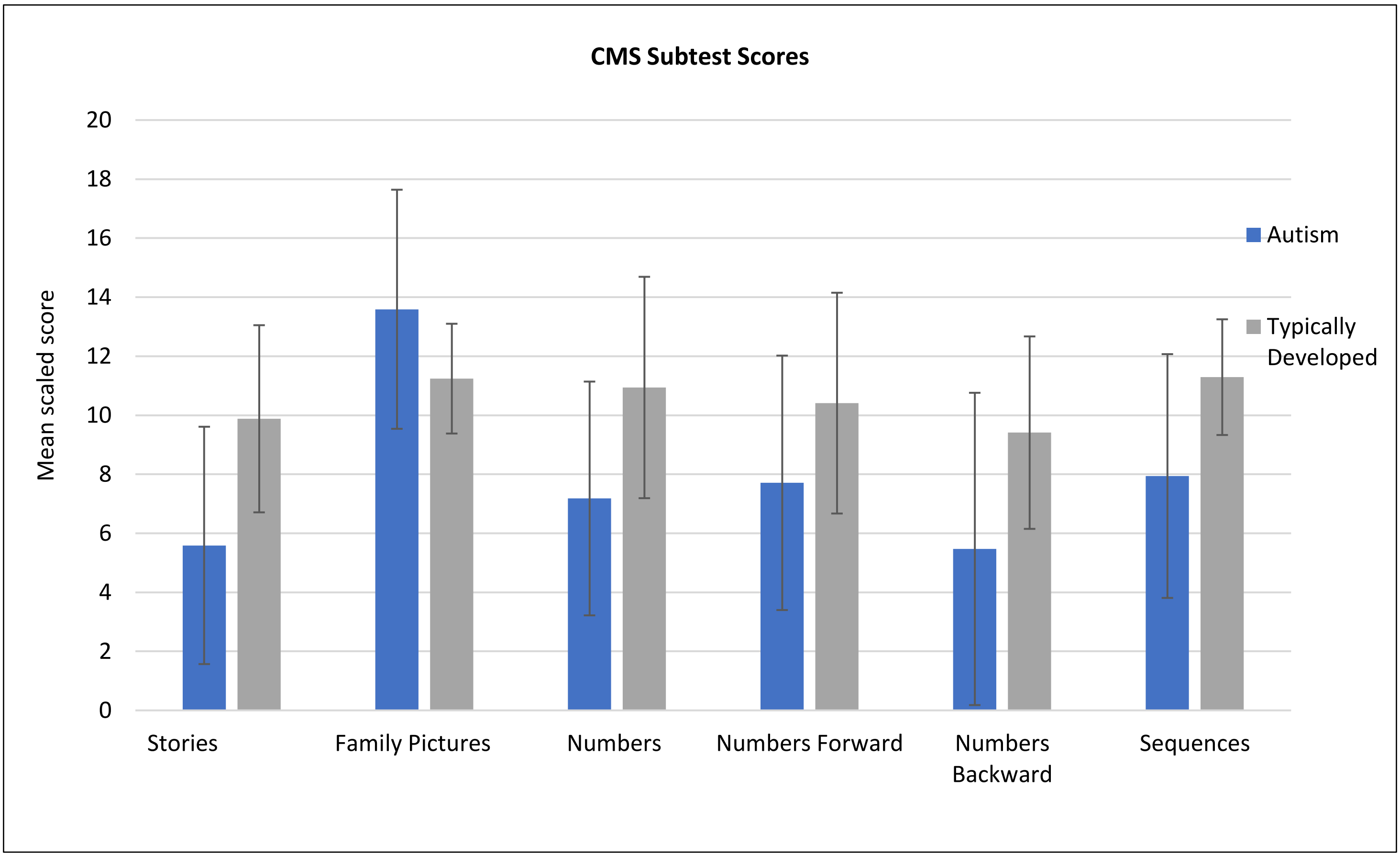



**Figure 3-21.** Representation of significant group differences on subtests from the CMS

# DISCUSSION: INTELLIGENCE AND MEMORY PROFILES IN ASD AND TD GROUPS

In this chapter the results from intelligence and memory test profiles were compared across ASD and TD groups. Based on comparison of FSIQ data the two groups were matched on intelligence. However, the analysis of the subtests, at both group and individual levels, showed that cognitive and memory profiles showed different strengths and weaknesses in the two groups. In the following section the profile of abilities and difficulties in the ASD group will be considered in the context of cognitive theories of ASD and previous research.

The analysis of the IQ data showed that groups did not differ on Full-scale, Verbal or Performance scores. However, the analysis of the subtest scores revealed superior scores in the ASD group on the Matrix reasoning subtest. This subtest measures fluid intelligence and Dawson and colleagues (Dawson et al., 2007), have highlighted strengths on Matrix reasoning tasks in ASD. In addition to a significant group difference, inspection of individual data showed that a high proportion of individuals with ASD scored well on this subtest. This further supports Dawson's ideas about the nature of intelligence in ASD.

One finding, consistently shown in early studies of intelligence in ASD was that BD scores were higher than scores on other IQ subtests (Rumsey, 1992; Yirmiya & Sigman, 1991) and this was taken as evidence for a local bias in information processing (Happé, 1999). However, since the time of these studies, changes in diagnostic criteria may have resulted in increased heterogeneity in the cognitive phenotype for ASD. More recent IQ screening has reported results that are consistent with the results from the current study. For example, Charman and colleagues (Charman et al., 2011) studied IQ profiles in a large cohort of children with ASD and did not observe superior performance on the BD subtest.

The analysis of the memory data revealed more between-group differences than the analysis of the IQ data. Verbal memory skills were included in the analysis, as difficulties remembering relatively complex task instructions may influence performance on experimental tasks. Based on the results from the meta-analysis carried out by Habib and colleagues (2019) poor performance on tasks recruiting phonological WM would be predicted for ASD participants. However, the group comparison provided only partial support for this prediction. Memory for Word pairs was remarkably similar across groups, and whilst memory for Word lists was lower in the ASD group the difference was not significant, suggesting relatively good performance at the group level.

Memory for Stories showed a large difference between groups and the ASD group were significantly impaired on the immediate recall condition of this subtest. The three verbal subtests differed on levels of semantic complexity, with ASD performance decreasing in line with increases in complexity. The impact of stimuli complexity appeared to show a different pattern across domains in ASD. The Visual Immediate index included a Family pictures task, in which the visual information was relatively complex, and a Dot locations task in which the internal features did not differ. The ASD group obtained significantly higher scores on the Family pictures task than the TD group, whilst the difference on the Dot locations task was not significantly different. The meta-analysis carried out by Habib et al., (2019) provided evidence for visual spatial working memory impairments in ASD. However, in the sample described here, two participants scored in the impaired range with the remaining participants scoring in the average to very superior ranges. This inconsistency may be due to differences between the tasks used in the studies reviewed by Habib and the Dot locations task in the current study and this will be further considered.

The most marked difference across groups emerged on the subtests comprising the attention/concentration factor and this was consistent with the results from Habib et al's meta-analysis. On the Numbers backward subtest, the ASD scores were in the borderline range and were significantly lower than those of TD controls. Scores on the Numbers forward subtest approached significance. On the Sequences subtest, the ASD scores were in the low average range and were also significantly lower than the TD group. The difference between forward and backward digit scores was more marked in the ASD group and this may be relevant to debates about the cognitive mechanisms supporting backward digit recall. It is currently unclear whether backward digit recall involves visuospatial resources or the involvement of executive control (St Clair-Thompson & Allen, 2013) and this question will be explored in the experimental chapters included in this thesis. In the following chapter the participants will complete two studies probing visual and auditory attention.

# CHAPTER 4: VISUAL AND AUDITORY SELECTIVE ATTENTION IN AUTISM SPECTRUM DISORDER AND TYPICAL DEVELOPMENT

## ABSTRACT

Research into selective attention in ASD has produced mixed findings and the aim of the two experiments described in this chapter was to investigate selective attention, and its cognitive correlates, in the visual and auditory modalities. In experiment 1, participants with ASD and TD completed the Erikson visual flanker task. Groups did not differ on accuracy (AR) and both groups showed a decrease in AR scores on the incongruent trials. Reaction times (RTs) were significantly greater in the ASD group but the pattern of RT responses across congruent and incongruent conditions did not differ across groups. In experiment 2, selective attention was tested in the auditory modality. In this experiment participants with ASD obtained significantly lower accuracy scores than the TD group but did not differ on RT rates. Both groups showed an increase in RT rates on the incongruent trials. As the pattern of performance was similar across groups, questions about the cognitive skills recruited during selective attention tasks in ASD and TD were addressed in correlation analyses. The pattern of variance on measures of visual, visual spatial, verbal and working memory was greater in the ASD group than the TD group, and the correlations showed that strengths and impairments in these skills influenced selective attention in the ASD group.

## VISUAL SELECTIVE ATTENTION IN TD

Selective attention is defined as the ability to attend to a single source of material while at the same time being able to ignore others (Portas et al., 1998). It is a crucial phenomenon required for successful cognitive and behavioural functioning for children and adults. The concept of selective attention is based on the idea that perceptual information in the environment overloads the individual's limited processing capacity. Thus, an act of selection must occur at some point in processing, with a more limited selection of information being available beyond this point. Whether selection takes place relatively early or late in the temporal sequence of information-processing operations has been vigorously debated. Broadbent's (1958) very early selection model refers specifically to the selection of perceptual features such as colour, shape, or spatial location. Deutsch and Deutsch's (1963) late selection model is concerned with the selection of internally represented, semantically interpreted information based on task demands. These two processes appear to be distinct and separable neuroanatomically as well as computationally.

## VISUAL SELECTIVE ATTENTION AND INHIBITORY CONTROL IN ASD

Inhibitory control is the ability to prevent or control impulsive (or automatic) responses and produce appropriate responses through sustaining attention and reasoning**.** This cognitive ability is categorised under the umbrella of executive functioning and contributes towards anticipation, planning, and goal setting. Examples of inhibitory control include ignoring competing information while performing a WM task (Hasher & Zacks, 1988), withholding a prepotent or a leading response (Logan, 1994) or ignoring irrelevant information while processing a target stimulus (Eriksen & Eriksen, 1974). Studies investigating selective attention and inhibitory control within the visual modality have often used the Eriksen flanker task to study resistance to distractor interference (Eriksen & Eriksen, 1974). In this task, participants are instructed to pay attention to the central target which can be surrounded by either congruent or incongruent stimuli. In the congruent condition (low conflict); the target stimuli as well as the flanker are pointing towards the same direction (e.g., <<<<<). On the incongruent condition, the flanker and the target stimuli are pointing in opposite directions (e.g., >><>>), increasing the cognitive load between cued correct and incorrect responses for the following reasons participants are typically slower and less accurate on incongruent trials compared to congruent trials. The presentation of surrounding stimuli in the congruent condition leads to automatic activation of the response channel generally associated with the flanker stimuli (Gratton et al., 1992; Gratton et al., 1988), leading to faster and a greater number of accurate responses. Whereas on the incongruent condition, the automatic activation would automatically lead to faster incorrect responses, necessitating attentional control process to overrule the incorrect automatic activation which caused an increase cognitive load as well as RT rate to acquire a correct response.

Remington et al. (2009, 2012) discussed difficulties in filtering visual stimuli in ASD, and drawing on the perceptual load theory (Lavie, 1995) hypothesized that this results in increased perceptual capacity in individuals with this diagnosis. Whilst there are methodological difficulties in assessing the perceptual load theory within clinical populations, Remington et al. (2009) have argued that results from experimental studies have validated the study of selective attention in these groups. The idea that individuals with ASD display an increased perceptual capacity has gained support from experimental studies reporting superior performance on visual search and embedded figures tasks (Shah and Frith, 1993; O'Riordan et al., 2001; O'Riordan, 2004; Hessels et al., 2014).

Several studies have used the Stroop task (Stroop, 1935) to investigate inhibition in ASD (Adams & Jarrold, 2009; 2012). In the Stroop task, participants are required to name the colour of the ink in which the word is being displayed as quickly as they can. The task is usually made up of two conditions, congruent and incongruent. In the congruent condition, the ink colour and the word refer to the same colour, whereas in the incongruent condition, the word is displayed in a different colour to the word written.

One of the first studies to test this paradigm with ASD participants and a TD comparison group was carried out by Eskes et al. (1990) and failed to reveal a group difference on incongruent trials. Christ et al. (2007) conducted an experiment in which a group of children with ASD and a control group completed three different variants of inhibitory control tasks: a Go-No Go task (Drewe, 1975), Stroop card and computer task (Stroop, 1935) and a flanker task (Eriksen & Eriksen, 1974). The ASD group included 18 children between the ages of 6 to 12 years, who were compared with a TD group of 25 7 to 18-year-old participants. The Stroop card task was made up of three conditions from Golden's (1978) colour and word test which were administered in a specific order. In the first 'word control' condition, participants were each shown names of colours e.g., RED, printed in black ink. Participants were instructed to read aloud as quickly as possible the word which was being shown to them. In the second 'colour control' condition participants were shown a page with groups of Xs in various colours and asked to name to colour as quickly as they could. In the final inhibitory condition, participants were each shown pages with names of colours being written in incongruent colours e.g., the colour BLUE being shown in red ink. Participants were instructed to name the colour of the ink being shown on each trial. On the Stroop computer task, participants were each given three large response buttons which they used to complete three experimental conditions: congruent, incongruent, and neutral. On the congruent condition, one of the three stimulus words i.e., RED, BLUE, or GREEN were displayed in their written format in their original colour e.g., the word RED being displayed in the colour red. On the incongruent condition, the stimulus words were presented in an incongruent colour, the colour BLUE being written in red ink. On the neutral condition, one of the three stimulus words (DOG, BEAR or TIGER) were displayed in red, blue, or green coloured ink.

Participants were instructed to press the correct button in relation to the colour of each stimulus being displayed on each trial. The flanker task included three conditions: congruent, incongruent, and neutral. On the compatible condition, the target was flanked in close proximity to the left and right of the same response button e.g., □O□. On the incompatible (inhibitory) trials, the target was flanked by a stimulus mapped to an alternative response button e.g., +O+. On the neutral trials, the flankers were one of two stimuli e.g., Δ or * neither of which had been linked to a response button. The go/no-go task included two conditions: go and no-go. On each trial one of the four stimuli (◊, □, Δ, O) were displayed on the screen. Prior to starting one of the stimulus targets was assigned as the non-target.

Participants were required to press the response button when the targets appeared (go trial) but ignoring and not pressing anything when the non-target was displayed (no-go trial). On the stroop task, both groups performed comparably on the inhibitory component of the task for with greater RT and lower AR. Both groups also performed similarly on the incongruent condition of the stroop card task. On the Flanker task, the ASD group were slower than the TD group in the inhibitory condition compared to the typical control group. However, both groups performed similarly in terms of accuracy scores. On the Go-No Go Task, both groups performed similarly for the go-trial and no-go trials in terms of accuracy rates. But the ASD group made more errors on the go-trials. Based on these findings the authors proposed that individuals with ASD exhibit circumscribed impairments in only certain aspects of inhibitory control. Adams & Jarrold (2009) conducted a study in which a group of children with ASD between the ages of 11 year 0 months to 16 years 10 months and a TD control group between the ages of 9 years 5 months to 10 years 2 months completed the classic Stroop task and a chimeric animal Stroop test, originally used by Wright et al. (2003). The chimeric task is made up of four experimental conditions, comprising 36 farm animals, four of which (pig, sheep, cow, and duck) comprise an experimental trial. Each animal was shown in its original colour e.g., pink pig, yellow duck, brown cow, and grey sheep. In the baseline condition, participants were only shown the heads of the animals and were asked to name them as quickly as they could. In the body baseline condition, participants were each shown the bodies of the animals, but without the heads and were prompted to name each animal as quickly as they could, In the head interference condition, participants were shown incongruent animals, participants were required to name the animals head whilst ignoring the incongruent body. In the body interference condition, participants were instructed to name the animal's body whilst ignoring the incongruent heads.

The authors noted that reading ability had a significant effect on the extent of interference on the classic Stroop task. Typically, incongruent written words are semantically distracting during colour naming, and this in turn increases participants RTs relative to baseline. The results revealed a smaller interference effect in the ASD group, suggesting that they were less distracted by incongruent colour names than TD control participants. On the chimerical Stroop test, which employed no written words, both groups performed comparably and had a similar level of interference on the incongruent conditions of the task. This finding is interesting given heterogeneity in language abilities is ASD (Kjellgard & Tager-Flusberg (2001) and raises the possibility that poor performance on some tasks of selective attention may reflect levels of reading rather than abnormalities in selective attention.

Adams & Jarrold (2012) conducted a study in which they employed a stop-signal task and a modified flanker resistance to disinhibition task to test a group of children with ASD, a group of children with moderate learning disabilities (MLD) as well as a TD control group. The ASD group included 15 children between the ages of 12 years 6 months to 17 years 4 months, the MLD group included of 15 children between the ages of 12 years 6 months to 15 years 9 months and the TD control group included 15 children between the ages of 8 years 6 months to 11 years 9 months. All participants had been matched on measures of non-verbal intelligence using the Raven's Coloured Progressive Matrices (RCPM; Raven et al., 1990). In the stop-signal task (prepotent response inhibition) participants completed three blocks of trials. The first block was made up of 20 trials and was a practise session, trials which made up the second block were used to calculate each participants' response reaction time rates which were then used to put together each participants' warning signal which was used to alert them in the third block of trials.

Participants were shown a total of 20 animal as well as non-animal pictures (e.g., tiger or a bike) and were instructed to group each picture as either an animal or a non-animal as quickly and as accurately as they could by pressing 'YES' or 'NO' response buttons. The third block consisted of 120 trials and participants had to try and respond (to inhibit the prepotent categorisation response) when they heard a warning signal on 33 out of the 120 pseudo randomly selected trials. Warning signal thresholds were determined by each participants' performance on block 2. In the resistance to distractor inhibition task (flanker task), participants were presented with an arrow in the middle of the screen with distractors on each side (congruent or incongruent). In this version of the task, 3 aspects of the original flanker task were manipulated: the size of the central arrow, spacing size between the central arrow to the immediately flanking arrows on either side as well as the congruency condition. Adams & Jarrold (2012) reported that there was no significant difference, on accuracy or RT scores, between the ASD group and the TD control group on the prepotent response inhibition task (stop-signal task). However, participants in the ASD group demonstrated a greater level of interference in the incongruent conditions of the task in comparison to the congruent conditions.

## AUDITORY SELECTIVE ATTENTION IN ASD

Studies of auditory selective attention in ASD have been motivated by experiments revealing increased perceptual capacity, in the visual modality, in this group (Remington, Swettenham, Campbell, & Coleman, 2009). For example, Tillmann et al. (2015) explored whether increasing perceptual load would have a reduced impact on auditory awareness in children with ASD. A group of children with ASD and a TD control group were instructed to decide which arm of a cross was longer in length (i.e., horizontal, or vertical) on various trials which were performed either under a low load condition (gross line discrimination) or high load condition (more subtle line discrimination). On the 7$^{th}$ trial of each condition, an unexpected sound was played through the headphones of each participant at the same time as the visual stimuli appeared on the screen. Participants were then asked if they had noticed anything additional or different.

Tillmann et al. (2015) reported from their findings that fewer children in the TD group under the high load condition noticed the auditory stimuli in comparison with the low load condition. Therefore, it was evident that visual perceptual load did have an impact on task-irrelevant auditory stimulus for the TD control group. However, for the ASD group, the percentage of children who noticed the presence of the auditory stimuli was similar across high and low load perceptual conditions and this was taken as evidence for an increased perceptual capacity across sensory modalities in ASD.

As an extension to their previous study, Tillmann & Swettenham (2017) conducted a cross-modal study of perceptual load in ASD. The participant sample included 20 TD children and 18 children with ASD, and an adapted version of the signal detection paradigm developed by Remington et al. (2012) was administered. All participants completed a visual search task under various low and high load conditions, whilst identifying the presence or absence of an auditory stimulus. The results from the study showed that under low perceptual load conditions, identification of auditory stimuli did not differ across ASD and TD groups. However, when the perceptual load was greater (absence of 4 or more items in the search array), the identification of auditory stimuli was higher in the ASD group than the TD group. When perceptual load was further increased (six search items) the group difference was no longer present.

Remington & Fairnie (2017) investigated auditory perceptual capacity in 20 adults with ASD and 20 TD controls between 17 to 34 years of age using 2 experimental paradigms. They first used an auditory dual-task paradigm which was originally developed by Fairnie et al. (2016) as well as an auditory scene task which was developed by Dalton & Fraenkel (2012). In the first experiment, participants were instructed to listen to a series of animal sounds which were presented concurrently from different imaginary locations around each participant's head. One of the sounds was a target sound (a barking dog or a roaring lion) and the other sounds were that of non-target animals (duck, cow, chicken, rooster, crow). The perceptual load of the task was altered by changing the number of non-target sounds to create numerous set sizes. Participants were also presented with a non-animal sound (a car) on half of the trials which acted as the critical stimulus.

Participants were instructed that they would hear a series of sounds and should press the correct button on the keyboard if they heard a dog or a lion as quickly as they could. They were also informed that on some of the trials they would also hear a car, and that after their initial response (to hearing a dog or a lion) they should indicate whether they also heard the car. Participants were provided with visual prompts on their screen during this experiment with when and how to respond. Error rates and reaction times were recorded on all the trials.

Remington & Fairnie (2017) reported from the findings of their first experiment that both groups performed similarly when identifying the sound of the primary target (barking dog or roaring lion). No significant differences were reported on error rates or RT rates between the ASD and TD group. However, during the detection of a critical stimulus (sound of a car) and as the auditory load of the set sizes increased, the TD groups' performance was affected, with greater levels of inaccuracy, whereas the ASD group were still able to detect the critical stimulus even under higher levels of auditory load. Thus, participants with ASD also have an increased auditory capacity.

The second experiment studied whether the enhanced capacity demonstrated in the first experiment by the ASD group would result in increased processing of task-irrelevant information under low perceptual load conditions. Remington & Fairnie (2017) hypothesized that identification of an additional auditory stimuli (male voice) would be superior in the ASD group. Participants were presented with a three-dimensional scene comprised of four characters, moving around a room whilst getting ready for a party celebration. The characters included two women, who were wrapping presents, and two men which were arranging food and drink. After 33 seconds, a male character would enter the room from the back and walk through the scene whilst continuously repeating 'I'm a gorilla". Participants were instructed to only attend to the womens' conversation as they would be asked questions immediately afterwards. The results from the second experiment revealed that 88% of the TD group failed to identify the unexpected auditory stimulus whilst 47% of the ASD group were aware of the additional male's voice.

## AIMS AND HYPOTHESES

The main aim of the studies described in this chapter is to investigate selective attention and its cognitive correlates in visual and auditory domains in children and adolescents with ASD and TD.

The hypothesis for experiment one states that individuals with ASD will show an increased level of interference on incongruent trials compared with TD participants. The rationale for this hypothesis draws on previous findings showing this effect in children with ASD (Adams & Jarrold, 2012).

The second hypothesis states that individuals with ASD will perform at a significantly lower level than TD participants on a test of auditory selective attention.  Whilst Remington & Fairnie (2017) reported that under low load conditions, identification of auditory stimuli in terms of accuracy and RT rates did not significantly differ across groups of adults with ASD and TD, other studies have reported difficulties in filtering auditory stimuli in ASD (DePape et al., 2012; Christ et al., 2011). Furthermore, the analysis of cognitive and memory profiles presented in chapter 3, showed that the participants who completed experiments 1 and 2 obtained significantly lower scores than TD participants on subtests measuring immediate recall of complex semantic information (stories), recall of digits, especially when presented backward, and recall of auditory sequential information.

## EXPERIMENT 1: INVESTIGATING VISUAL SELECTIVE ATTENTION IN PARTICIPANTS WITH ASD AND TD

## METHODS

### Participants

From the whole sample of participants described in chapter 2 (n=34), 28 participants completed the visual and auditory selective attention experiments. The sample included 14 participants with ASD (13 males, mean CA 13.99, mean FSIQ 100.00) and 14 TD controls (13 males, mean CA 14.14, FSIQ 93.93). Groups did not differ on CA (t (26) = .469, *p* = .643) or FSIQ (t (26) = - 1.653, *p* = .110).

### Materials and procedure

The experiment was conducted on a standard laptop computer using the E-Prime software package.

Stimuli were made up of 3 horizontally arranged arrowheads, making up either congruent (e.g., > > >), or incongruent (e.g., < > <) trials. The stimuli were presented in a black font on a plain white background. Participants were instructed that they would be presented with one small arrow which would appear in one of four positions on the middle vertical row. They were then told that two big arrows would appear on the right and onto the left of this centrally positioned vertical arrow. The central target stimulus was randomly presented and positioned on each trial in one of 5 positions on the vertical row. Participants were asked to ignore the big arrows and to only attend to the small arrow in the centre. Participants were instructed to respond to the central target arrowhead by pressing "c" (middle arrow is orienting left) or the "n" key (middle arrow is orienting right) on the keyboard when the arrow pointed to the left or the right, respectively. Stimuli consisted of two conditions, they could either be congruent (flanker arrows pointing in the same direction as the target arrow) or incongruent (flanker arrows in a different direction from the target). Participants were then instructed to look at the fixation cross and not to move their eyes around, and to answer as quickly and accurately as possible. Examples of congruent and incongruent stimuli conditions are shown in figure 4-1 below.

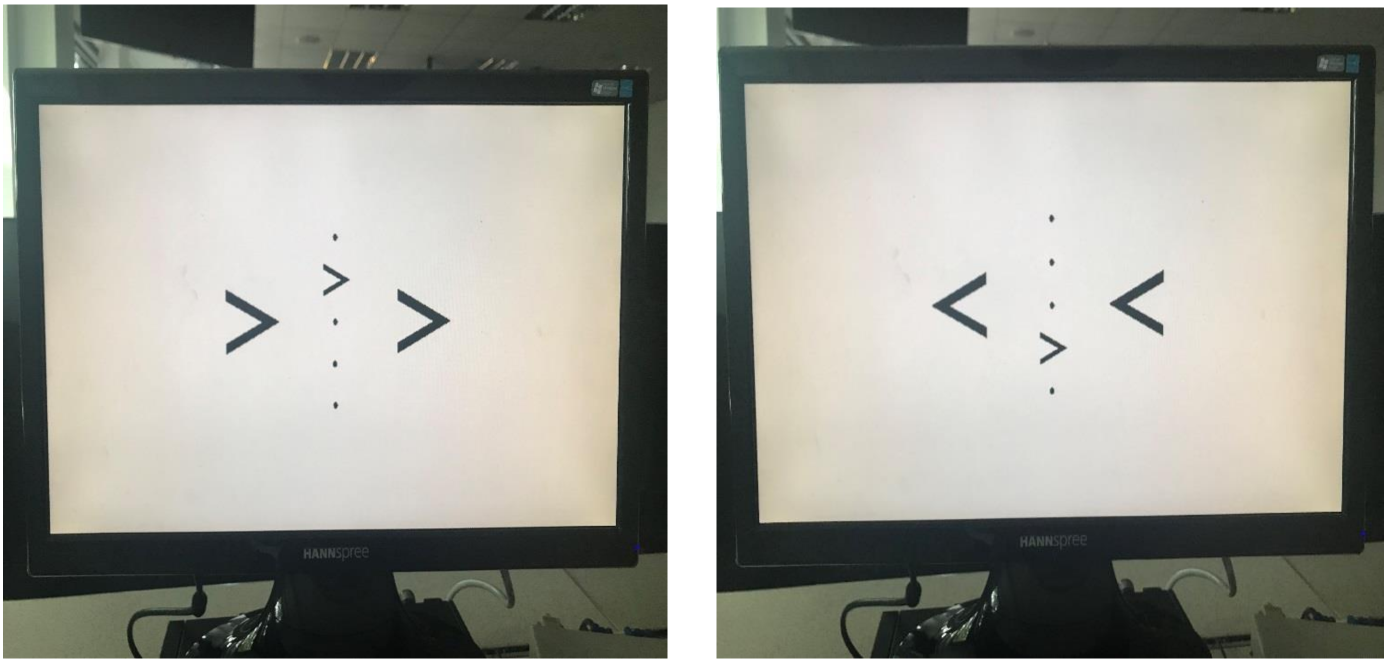


**Figure 4-1**. An example of a congruent (left) as well as an incongruent (right) trial from the visual flanker experiment

The test instruction was followed by a practice block of 24 pairs of trials consisting of all possible combinations of stimuli. Each pair of trials started with a blank interval of 1,000 msec succeeded by the first flanker stimulus, presented for a maximum of 1.500 msec, followed by another blank interval and finally the second flanker stimulus. The participants received 24 practice trials before entering the experimental phase, which consisted of 5 blocks made up of 24 trials each. In total each participant completed 120 trials.

All instructions were automated and presented on the screen. Each session lasted for approximately 15 minutes and participants were given the opportunity to take regular breaks.

Participants participated in no more than one session and completed all trials within that single testing session. Participants were not given accuracy feedback.

## RESULTS

Means and standard deviations for the ASD and TD accuracy rate scores are shown in table 4-1 below.

**Table 4-1.** Means and standard deviations for accuracy scores on the Visual flanker task for both groups (ASD/TD) under each condition

| | **Visual flanker AR score** | |
|---|---|---|
| | **Mean SD Range** | **Mean SD Range** |
| | **ASD** | **TD** |
| Congruent AR | 0.95 (0.11) 0.58 - 1.00 | 0.98 (0.03) 0.87 - 1.00 |
| Incongruent AR | 0.82 (0.31) 0.38 - 1.00 | 0.92 (0.08) 0.72 - 1.00 |
| Total AR | 1.77 (0.36) 0.96 - 1.98 | 1.90 (0.09) 1.72 - 1.98 |

An analysis of variance 2 x 2 (ANOVA) was performed on the mean correct accuracy scores with condition (congruent/ incongruent) as the within-participant factor and group (ASD vs. TD) as the between-participants factor. This revealed a significant effect of condition with lower scores on the incongruent trials ($F$ (1 ,26) = 6.00, $p$= .021). The main effect of group was not significant (*F* (1 ,26) = 1.66, *p* = .21) and the group by condition interaction was not significant (*F* (1 ,26) = .638, *p* = .432).

Reaction time data for the ASD and TD group are shown in table 4-2.

**Table 4-2.** Means and standard deviations for reaction times on the Visual flanker task for both groups (ASD/TD) under each condition

| | Visual flanker RT rate | |
|---|---|---|
| | **Mean SD Range** | **Mean SD Range** |
| | **ASD** | **TD** |
| Congruent RT | 996.88 (363.67) 637.00 - 1629.85 | 514.00 (108.49) 352.52 - 739.73 |
| Incongruent RT | 1037.03 (387.73) 495.43 - 1883.53 | 593.21 (141.46) 380.82 - 918.22 |
| Total RT | 2033.92 (735.35) 1085.31 - 3513.38 | 1107.22 (237.49) 733.34 - 1625.04 |

An analysis of variance (ANOVA) was performed on the mean correct RTs with group (ASD vs. TD) as the between-participants factor and condition (congruent vs. incongruent) as the within-participant factor. The main effect of group (ASD/TD) was highly significant (*F* (1 ,26) = 19.99 *p* < .001) with higher reaction times scores in the ASD group. The main effect of condition was also significant with higher reaction times on the incongruent trials (*F* (1 ,26) = 7.310, *p* = .012). The condition by group interaction was not significant, (*F* (1,26) = .783, *p* = .384).

## BRIEF SUMMARY OF RESULTS FROM EXPERIMENT ONE

The results were consistent with findings by Adams & Jarrold (2012) showing a reduced response to congruency in the ASD group. Whilst accuracy scores and patterns of responses to congruity/incongruity did not differ across groups, RT scores were significantly greater in the ASD group.

## EXPERIMENT 2: INVESTIGATING AUDITORY SELECTIVE ATTENTION IN PARTICIPANTS WITH ASD AND TD

## METHODS

### Participants

Same as those who completed experiment one.

### Materials and procedure

The experiment took place in a quiet testing room, the experiment was run on a PC using the PST E-Prime software v2.0.890 and Sennheisser headphones were used by each participant to block out extraneous sounds which may have been distracting.

The experimental paradigm was originally implemented by Shomstein & Yartis (2006), but it was modified for this study to just include a low load condition in which each sequence was made up of 6 letters. All the non-target letters in each sequence were X's, this meant that the target letter (G or T) spoken in the female voice could be easily distinguished.

The auditory stimuli were comprised of a female voice reading a sequence of 6 letters of which 5 were X's and one was either a G or a T. The participants were instructed to ignore the Xs and indicate on the keyboard when the female voice would say either a G or a T. The female voice saying a G or T could be played in position 2, 3, 4 or 5 with equal likelihood.

The interference effect was represented by a male voice who was saying either one G or one T within the same time frame that the female sequence was heard. The G or T spoken by the male could occur between the 3rd and 4th sound of each sequence and could be congruent and could occur at the same time as the female G or T or they may be incongruent. Therefore, the incongruency effect was predicted to occur when the male would read a T when the female would read a G.

Participants were provided with visual written feedback on their screen which consisted of "correct" presented in blue letters for correct responses, "oops" in red letters for incorrect responses and "no response detected" in blue letters if participants had failed to respond within 3000ms from the start of the letter sounds. A new trial started after the feedback, with the re-presence of the fixation cross.

The auditory stimuli were made up of 256 sequences (32 trials presented in 8 blocks). Letters were separated by silent ISIs of 60ms, resulting in total duration of 1330ms for each sequence.

The experimental paradigm is shown in figure 4-2. For a clearer comparison with experiment one, only the low load condition was administered.

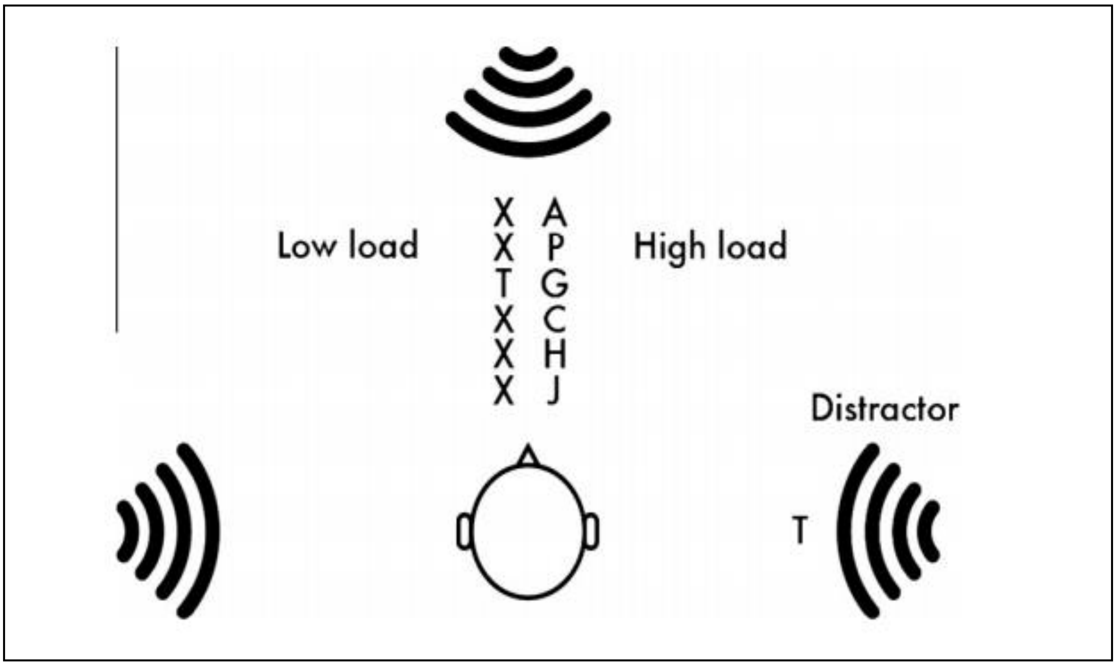



**Figure 4-2.** Example of a low load and a high load trial, extracted from Murphy, Fraenkel & Dalton (2013)

**RESULTS**

Means and standard deviations for accuracy scores on the Auditory flanker task are shown in table 4-3.

**Table 4-3.** Means and standard deviations for accuracy scores on the auditory Flanker task for both groups (ASD/TD) under each condition

| | **Auditory flanker AR score** | |
|---|---|---|
| | **Mean SD Range** | **Mean SD Range** |
| | **ASD** | **TD** |
| Congruent AR | 0.74 (0.18) 0.45 - 0.96 | 0.91 (0.10) 0.78 - 0.98 |
| Incongruent AR | 0.68 (0.18) 0.45 - 0.92 | 0.78 (0.15) 0.51 - 0.95 |
| Total AR | 1.42 (0.38) 0.92 - 1.85 | 1.69 (0.11) 1.32 - 1.93 |

An analysis of variance (ANOVA) was performed on the mean correct accuracy rates with group (ASD vs. control) as the between-participants factor and distractor congruency (congruent vs. incongruent) as the within-participant factor. This revealed a significant main effect for group ($F$ (1,26) = 4.818, $p$ =.037) with lower scores in the ASD than the TD group. The effect of condition was also highly significant ($F$ (1 ,26) = 24.575, $p$ < .001) with lower AR scores on the incongruent trials. The condition by group interaction was not significant ($F$ (1 ,26) = 2.271, $p$ = .144.

The means and standard deviations for the RT for the auditory flanker task are shown in table 4-4.

**Table 4-4.** Means and standard deviations for reaction times on the Auditory flanker task for both groups (ASD/TD) under each condition

| | Auditory flanker RT rate | |
|---|---|---|
| | Mean SD Range | Mean SD Range |
| | ASD | TD |
| Congruent RT | 849.97 (465.62) 287.76 - 1777.35 | 646.09 (182.33) 428.50 - 964.07 |
| Incongruent RT | 893.49 (482.90) 289.98 - 1696.29 | 690.55 (194.04) 424.42 - 1014.07 |
| Total RT | 1743.46 (945.61) 380.79 - 3473.64 | 1336.63 (372.95) 852.92 - 1915.06 |

An analysis of variance (ANOVA) was performed on the mean total RTs with group (ASD vs. control) as the between-participants factor and condition (congruent vs. incongruent) as the within-participant factors. The main effect of group was not significant ($F$ (1,26) = 2.242, $p$ =.146) and the main effect of condition was highly significant ($F$ (1 ,26) = 12.733, $p$ = .001) with slower reaction times in the incongruent condition. The group by condition interaction was not significant ($F$ (1 ,26) = .001, $p$ = .969.)

## BRIEF SUMMARY OF RESULTS FROM EXPERIMENT TWO

Accuracy scores were significantly lower in the ASD group, but their pattern of performance across the two experimental conditions did not differ. RTs did not differ significantly across groups and both groups were slower on the incongruent trials. In the following section the cognitive and memory correlates of a typical selective attention response will be explored.

## SELECTIVE ATTENTION IN VISUAL AND AUDITORY MODALITIES IN ASD AND TD

The results from the two experiments showed that the patterns of responses to incongruity in visual and auditory domains did not distinguish ASD and TD groups. This finding failed to support Adams & Jarrold (2012) who showed that children with ASD were more strongly affected by incongruity than TD controls. However, ASD is heterogeneous at the cognitive level, and in the following section, intelligence, and memory mechanisms associated with preserved congruency/incongruency responses will be explored.

Although children with ASD responded to the congruency manipulation in visual and auditory stimuli, in a similar manner to TD participants, they were less accurate overall on the auditory task and slower overall on the visual task. The cognitive correlates of speed and accuracy on the two experiments will also be explored in the following section.

### Exploring the cognitive and memory correlates of selective attention in ASD and TD

Two types of correlations were carried out on the data, the first was on total accuracy and RT scores as a measure of overall task performance which were each correlated separately with each of the background variables and the second was on congruency factor scores as a more fine-grained measure of selective attention which was separately correlated with each of the background variables. Congruency factor scores were calculated by subtracting scores on congruent trials from scores on incongruent trials for both accuracy and RT.

Note: *p<0.01, **p<0.05 (two-tailed)

**Table 4-5.** Summary of background measures correlated separately with the total AR and total RT for the ASD and TD group on the visual flanker task

| **Group** | **ASD** | | **TD** | |
|---|---|---|---|---|
| Background variable | Total AR | Total RT | Total AR | Total RT |
| Matrix reasoning | *r* = .248 NS | *r* = .058 NS | *r* = - .268 NS | *r* = .411 NS |
| Block design | *r* = .442 NS | *r* = - .295 NS | *r* = .050 NS | *r* = .130 NS |
| Dot locations immediate | ***r* = .659 *p* = .010*** | *r* = - .193 NS | *r* = .386 NS | *r* = .279 NS |
| Family pictures immediate | *r* = .362 NS | ***r* = - .602 *p* = 023*** | *r* = - .086 NS | *r* = .184 NS |
| Stories immediate | *r* = .346 NS | *r* = - .122 NS | *r* = .094 NS | *r* = .474 NS |
| Sequences | *r* = .202 NS | *r* = - .278 NS | *r* = - .152 NS | *r* = - .042 NS |
| Numbers forward | *r* = .277 NS | *r* = - .240 NS | *r* = .250 NS | *r* = - .226 NS |
| Numbers backward | *r* = .430 NS | *r* = - .247 NS | *r* = .141 NS | *r* = - .215 NS |
| Chronological age | *r* = - .313 NS | *r* = - .104 NS | *r* = - .232 NS | *r* = - .183 NS |

As table 4-5 shows, no correlations for either total AR or total RT were significant for the TD group. On this experiment the ASD group were as accurate as the TD group and total AR significantly correlated with the immediate recall Dot locations task from the CMS (Cohen 1997). Whilst the comparison of scores on the Dot locations task (reported in chapter 3) did not show a significant difference between ASD and TD groups, these was considerable variation in scores within the ASD group (n=17). Two participants scored in the impaired range, 6 participants scored in the average range and seven participants scored in the high average, superior and very superior ranges.

Participants with ASD showed increased RT compared with TD controls, and the highly significant negative correlation between immediate recall of Family pictures and total RT shows that participants with the worse Family picture recall, achieved the slowest reaction times on the experimental task. On this subtest out of a total of 17 participants in the ASD group; one participant scored in the impaired range, three participants scored in the average range, two participants scored in the high average range and 11 participants scored between the superior and very superior ranges.

Note: *p<0.01, **p<0.05 (two-tailed)

**Table 4-6.** Summary of background measures correlated separately with total AR and total RT for the ASD and TD group on the auditory flanker task

| **Group** | **ASD** | | **TD** | |
|---|---|---|---|---|
| Background variable | Total AR | Total RT | Total AR | Total RT |
| Matrix reasoning | *r* = -.063 NS | *r* = .104 NS | *r* = .485 NS | *r* = .101 NS |
| Block design | ***r = .740 p = .002**** | *r* = .233 NS | *r* = .390 NS | *r* = - .040 NS |
| Dot locations immediate | *r* = - .031 NS | *r* = - .002 NS | *r* = - .072 NS | *r* = - .226 NS |
| Family pictures immediate | ***r = .557 p = .039**** | *r* = - .328 NS | *r* = .205 NS | *r* = - .293 NS |
| Stories immediate | *r* = .340 NS | *r* = - .025 NS | *r* = .143 NS | *r* = .104 NS |
| Sequences | *r* = .415 NS | *r* = - .139 NS | *r* = .092 NS | *r* = .067 NS |
| Numbers forward | *r* = .278 NS | *r* = - .415 NS | *r* = .111 NS | *r* = .051 NS |
| Numbers backward | ***r = .651 p = .012**** | *r* = .079 NS | *r* = .277 NS | *r* = - .051 NS |
| Chronological age | *r* = - .090 NS | *r* = - .277 NS | *r* = .377 NS | *r* = - .098 NS |

As table 4-6 shows, no correlations were significant for the TD group. Participants with ASD were less accurate than controls on the auditory task and accuracy scores were significantly and positively correlated with Block Design, Numbers backward and Family pictures. On the Block Design subtest out of a total of 17 participants in the ASD group; two participants scored in the low average range, ten participants scored in the average range and five participants scored between the high average to superior range. On the Numbers backward subtest, ten participants scored in the impaired range, one participant scored in the low average range, three participants scored in the average range and three participants scored between the high average and superior ranges.

RTs did not differ over ASD and TD groups and none of the background measures significantly correlated with RT scores for either group.

Note: *p<0.01, **p<0.05 (two-tailed)

**Table 4-7.** Summary of background measures correlated separately with the total AR and total RT congruency effect for the ASD and TD group on the visual flanker task

| **Group** | **ASD** | | **TD** | |
|---|---|---|---|---|
| Background variable | AR | RT | AR | RT |
| Matrix reasoning | *r* = .160 NS | *r* = .173 NS | *r* = - .239 NS | *r* = .066 NS |
| Block design | *r* = .373 NS | *r* = .396 NS | *r* = -. 027 NS | *r* = .410 NS |
| Dot locations immediate | ***r* = .933 *p* = *.000***** | *r* = .511 NS | *r* = .093 NS | *r* = .453 NS |
| Family pictures immediate | *r* = .365 NS | *r* = .125 NS | *r* = -. 018 NS | *r* = .136 NS |
| Stories immediate | *r* = .368 NS | *r* = .100 NS | r = .219 NS | r = .429 NS |
| Sequences | *r* = .078 NS | *r* = .412 NS | *r* = .002 NS | *r* = - .035 NS |
| Numbers forward | *r* = .075 NS | *r* = .243 NS | *r* = .244 NS | *r* = .088 NS |
| Numbers backward | *r* = .365 NS | *r* = .310 NS | *r* = - .018 NS | *r* = - .024 NS |
| Chronological age | *r* = - .402 NS | *r* = .137 NS | *r* = - .238 NS | *r* = - .271 NS |

As table 4-7 shows, no correlations were significant for the TD group. The ASD group showed a similar congruency to TD controls and the highly significant correlation with dot locations, suggests that an intact congruency effect during visual processing relies on intact abilities on this task.

Note: *p<0.01, **p<0.05 (two-tailed)

**Table 4-8.** Summary of background measures correlated separately with the total AR and total RT congruency effect for the ASD and TD group on the auditory flanker task

| **Group** | **ASD** | | **TD** | |
|---|---|---|---|---|
| Background variable | AR | RT | AR | RT |
| Matrix reasoning | *r* = .380 NS | *r* = - .053 NS | *r* = .379 NS | *r* = .095 NS |
| Block design | *r* = - .056 NS | *r* = .292 NS | *r* = .201 NS | *r* = - .053 NS |
| Dot locations immediate | *r* = .409 NS | *r* = - .111 NS | *r* = .105 NS | *r* = - .108 NS |
| Family pictures immediate | *r* = - .200 NS | *r* = .439 NS | *r* = .120 NS | *r* = .006 NS |
| Stories immediate | *r* = - .403 NS | ***r* = .550 *p* = *.042***** | *r* = - .008 NS | *r* = .086 NS |
| Sequences | *r* = - .098 NS | *r* = .494 NS | *r* = - .059 NS | *r* = .024 NS |
| Numbers forward | *r* = .018 NS | *r* = .234 NS | *r* = .026 NS | *r* = - .198 NS |
| Numbers backward | *r* = - .400 NS | ***r* = .724 *p* = *.003***** | *r* = - .133 NS | *r* = - .176 NS |
| Chronological age | *r* = .080 NS | *r* = - .302 NS | *r* = .417 NS | *r* = .113 NS |

As table 4-8 shows, no correlations were significant for the TD group. The ASD group showed a similar congruency response to TD participants and accuracy scores did not correlate with any of the background variables. The RT congruency measure significantly correlated with stories immediate and the Backward digit span task. The implications of these correlations will be considered in the discussion of this chapter.

## IS SELECTIVE ATTENTION DOMAIN GENERAL?

Research into selective attention suggests that individuals with ASD have an increased perceptual capacity across both auditory and visual domains (Remington et al. 2009; 2012; Remington and Fairnie, 2017). Whilst experiments 1 and 2 did not test perceptual capacity, they tested selective attention across visual and auditory domains in the same participants. Correlations carried out on total accuracy and RT scores for the visual (experiment 1) and auditory (experiment 2) tasks were non-significant for the ASD group (accuracy $r$ = .340: RT $r$ = .292) or the TD group (accuracy $r$ = .152: RT $r$ = .383).

Correlations carried out on congruency scores for the two experiments were not significant for the ASD group (accuracy $r$ = .239: RT $r$ = - .187) or the TD group (accuracy $r$ = - .218: RT $r$ = - .332). These correlations suggest that speed and accuracy in selective attention is not domain general in ASD and TD.

## DISCUSSION

The aim of the studies described in this chapter was to test selective attention and its cognitive correlates in visual and auditory modalities in ASD and TD controls. Motivated by studies carried out by Adams & Jarrold (2012), it was predicted that participants with ASD would show a reduced incongruency effect on the visual flanker task. Although results from Remington & Fairnie (2017) suggested that auditory selective attention was unimpaired under low perceptual load in ASD, some of the participants who completed the task described in this chapter, performed poorly on tasks measuring auditory short-term memory and unimpaired performance on the auditory task was not predicted for the ASD group.

The results only partially supported the two hypotheses. In experiment one, groups did not differ on accuracy scores, but RTs were significantly greater in the ASD group. However, the group by condition interaction was not significant and both groups showed a similar pattern of accuracy and RT response rate in response to incongruity. In experiment two, accuracy scores were significantly lower in the ASD group than the TD group, although they did not differ on RT response rates. Again, interaction effects were not significant and a similar pattern in response to incongruity was observed across groups.

The first set of correlation analyses aimed to evaluate and assess 'residual normality' (Thomas & Karmiloff-Smith, 2002) where similar results across typical and atypically developing groups can hide differences in the underlying cognitive processes involved in task performance. The analysis of IQ data described in chapter three showed how equivalent full scale IQ scores across groups masked different sub-test profiles. The second set of congruency correlations were carried out to see which background measures were associated with a 'typical' pattern of visual and auditory selective attention within the groups. The first set of correlations carried out on the experimental data looked at which background variables were associated with overall performance on the two tasks. On the visual flanker task accuracy scores did not differ across groups and for the ASD group accuracy scores significantly correlated with immediate Dot locations test scores. The ASD group were significantly slower than the TD group on the visual flanker task and for the ASD group RT scores were negatively correlated with the Family pictures subtest scores. On the auditory flanker task, the ASD group were significantly less accurate than TD participants, and the correlations showed that accuracy scores significantly correlated with visual (Block Design and Family pictures), auditory and memory (Numbers backward) skills.

The second set of correlations, carried out on the visual accuracy data, showed that ASD participants with high scores on the immediate Dot locations task showed the highest levels of congruency. Inspection of the data from the immediate recall Dot locations task (figure 3-13, chapter 3) showed that whilst TD scores on this subtest were mostly in the average ranges, ASD scores were exceptionally widely distributed with some individuals performing in the impaired range. This may suggest that the ASD sample tested by Adams & Jarrold (2012) included a larger proportion of individuals with poor visual-spatial short-term memory skills than the sample tested here. The congruency correlations carried out on the auditory task showed that RTs were significantly correlated with immediate recall of Stories and Numbers backward for the ASD group. Potential explanations for these correlations will be fully explored in the final discussion chapter.

Whilst the major theoretical models of ASD, described in chapter 1, differ in detail they all suggest that hierarchical processing is atypical (WCC; Happé, 1999; EPF, Mottron & Burack 2001) and a central premise of these theories is that ASD is characterised by a local processing bias. Whilst experiments one and two do not directly test local and global processing, they do test attention, and this is relevant to questions about whether perception is locally oriented in ASD. The results revealed a strong congruency effect, in both visual and auditory modalities in the ASD group. The results also showed that levels of memory skills and/or impairments (visual and auditory) influence selective attention. Finally, the results showed that selective attention in visual and auditory modalities is relatively independent for both TD and ASD participants. The WCC theory predicts enhanced local processing and in flanker tasks the incongruency effect will be most apparent when an individual is attending to the stimuli in a global way. Therefore, the aim of the study described in the following chapter is to determine whether the participants who showed a typical congruency effect will show a local information processing bias.

# CHAPTER 5: LOCAL - GLOBAL PROCESSING IN AUTISM SPECTRUM DISORDER


## ABSTRACT

Theoretical models of ASD have proposed that this condition is characterised by a local processing bias, and global impairments have been identified in experimental studies in this group. The experiment described in this chapter utilised a Navon paradigm to test these theoretical models. The results failed to show a local bias in the ASD group but the group difference in responses to congruency manipulations did significantly differ. The ASD group scored significantly lower on the incongruent trials and were more susceptible to interference from global and local incongruent stimuli relative to the TD control group. Correlations were carried out to look at within group associations between congruency processing scores with variables measuring memory and cognition. None of the correlations reached significance for either the ASD or TD group. However, when the congruency score from the current experiment was correlated with the congruency score from the visual flanker experiment, no significance results were reported in the ASD group though a positively significant correlation was reported for the TD group between visual flanker congruency and G Cg score.


## INTRODUCTION

The visual flanker experiment described in the previous chapter investigated selective visual attention under low level perceptual load in individuals with ASD and TD controls. Based on previous research (Adams & Jarrold, 2012) participants with ASD were predicted to show a reduced incongruency effect on the visual flanker task. However, the group by condition interaction was not significant and both groups showed a similar pattern of accuracy and RT in response to incongruity.

In order to determine whether the similarity in the pattern of performance across ASD and TD groups reflected a reliance on similar cognitive mechanisms, correlations were carried out between the performance scores in the experiment (total accuracy and RT data) as the first variable, and the background cognitive test scores as the second variable, for the two groups separately. Whilst none of these correlations were significant for the TD group, a different pattern was seen for the ASD group. For this group total accuracy scores correlated significantly and positively with the immediate Dot locations task and the total RT scores correlated significantly and negatively with immediate recall of Family pictures. When responses to congruency manipulations (incongruent minus congruent AR/RT) were correlated with background variables, a significant correlation with immediate recall Dot locations task was observed. Within the ASD group scores on visual and visual spatial memory, showed considerable variation and the correlation analysis showed that strengths and weaknesses in these skills influenced performance on the visual flanker task. In line with these findings, the cognitive correlates of local/global biases in TD and ASD participants will be investigated in this chapter.

The idea of a local information processing bias in ASD has been a fundamental tenet of theoretical models of this disorder. In her early book on autism, Frith (1989) discussed the impairments characteristic of this condition and put forward ideas about a global processing impairment. One interesting idea to emerge in this book was that people with autism frequently show strengths on tasks that require superior local processing ability, and this was expanded in a paper written by Happé in 1999. Key studies, taken as evidence for a local processing bias, were those carried out by Shah & Frith in 1983 and 1993. In the first of these studies 20 children with ASD, 20 children with intellectual impairment and 20 TD controls completed the Children's Embedded Figures Test (CEFT) (Witkin et al., 1971). The results showed that the group of children with ASD performed at a significantly higher level on the CEFT than TD and intellectually impaired controls. In support of this finding, Shah & Frith (1993) carried out a further study testing 20 individuals with a diagnosis of ASD, 12 individuals with intellectual impairment and 33 TD controls, aged between 16 and 25 years, on variations of the Block design subtest, originally invented by Kohs (1923). Subjects were each shown 2-D patterns and were verbally instructed to manually reproduce the design as quickly as they could using patterned blocks. In the study, the designs were either "whole" or segmented, rotated or unrotated, with the absence or presence of obliques. It was reported by Shah and Frith (1993) that only the segmentation factor revealed a significant group difference: individuals with ASD scored higher than the TD controls when presented with unsegmented designs. Shah & Frith (1993) concluded that segmentation of the designs facilitated performance in TD, whilst a local bias enabled participants with ASD to segment the designs without the need for any additional cues. The results from these two studies were taken as evidence for the WCC model of information processing in ASD.

Happé (1999) conducted a study to explore coherence at a perceptual level in ASD. In the study participants with ASD, aged between 8 and 16 years were instructed to make judgements about visual illusions. Happé (1999) hypothesized that if individuals with ASD are predisposed towards fragmented perception and focus on the segments which need to be evaluated, without assimilating them into the surrounding information that drives the illusion, they will be affected less by the illusion than typical controls. The results from this experiment showed that participants in the ASD group made more accurate judgements about the illusions than the comparison groups and this confirmed Happé's hypothesis.

In an attempt to replicate this study, Ropar & Mitchell (2001) studied coherence in groups of children with ASD (n=30), MLD (n=20) and TD controls (37). They administered the BD, the Embedded Figures test (EFT), a visual illusion task as well as the Rey Complex Figures test to examine perceptual organisational and visual memory abilities. They reported that on the BD task; the ASD group scored significantly higher than verbally matched (MLD) controls, and at similar levels to the TD group, suggesting preserved rather than enhanced block design performance in ASD. A similar pattern of results was obtained from the EFT, suggesting spared, but not superior visuospatial ability in autism. On the Rey Complex Figure test, all groups achieved a significantly higher score on copy than recall conditions and on the Rey Recognition task no significant differences were reported between groups. One particularly important finding to emerge in this study was that scores on the EFT and BD tests did not correlate. Whilst the studies by Shah and Frith (1983, 1993) were taken as evidence for a local bias, Roper and Mitchell's findings suggested that performance on these visuospatial tasks relies on different mechanisms.

Plaisted et al. (1999) used the Navon stimuli (Navon, 1977), in divided and selective attention tasks, to investigate hierarchical visual processing in 6- to 16-year-old children with ASD and TD. In the divided attention task, participants were instructed to press one of two buttons if the letter 'A' was present or absent on each trial. Participants were not cued whether to attend at the local or global level on each trial during this version of the Navon test. This task consisted of six different stimuli, a large A made up of small As, a large X made up of small Xs, a large A made up of small Hs, a large X made up of small ks, a large H made up of small

As and a large K made up of small Xs. The target could appear at either the local or global level. In the selective attention task, the stimuli were different, and the children were instructed to identify either the small or the large letter by pressing either H or S on the keyboard. Participants were cued beforehand whether to attend at the local or global level on each trial during this version of the Navon test. This task consisted of eight different stimuli, a large H made up of small Hs, a large S made up of small Ss, a large H made up of small Ss, a large S made up of small Hs, a large X made up of small Hs, a large X made up of small Ss, a large H made up of small Xs and a large S made up of small Xs. Plaisted et al. (1999) reported from their findings, that in the divided attention task where attention was not cued to the local or global levels, ASD participants made more errors on global incongruent trials. On the selective attention version of the task where attention was cued to either a local or global level, both groups responded faster when the target letter appeared at the global level and the ASD group made a greater number of errors than the TD group on the local and global incongruent trials. However, the presence of a global interference effect was also reported from the error data for both groups, participants accuracy in their responses are being inhibited by local incongruent information.

Rhinehart et al. (2000) investigated global interference effects and a global bias in individuals with HFA and Asperger's disorder (AD) compared with TD controls. They assessed 12 participants with HFA, 12 participants with AD and two groups of 12 TD controls matched on age and FSIQ. The study comprised two conditions: local and global, with three varieties of stimulus type: congruent, incongruent, and neutral. On the local task, participants were explicitly instructed to press the right button when the smaller numbers were 1s and the left button when the smaller numbers were 2s. On the global task, participants were explicitly instructed to press the right button when the large number was 1 and the left button if the larger number was a 2. When the local condition was combined with the congruent stimulus type, the local stimuli (small figure 1s or 2s) matched the global configuration (a large figure 1 or 2). When the local condition was combined with the incongruent stimulus type, the local stimuli (small figure 1s) mismatched the global configuration of a large 1 or a large 2. For the neutral configuration, the global stimuli did not pertain to either response (e.g., a large 3 or 4 composed of smaller 1s). When the global condition was combined with the congruent stimulus type, the global stimuli (large figure 1 or 2) matched the local configuration (small figure 1s or 2s). When the global condition was combined with the incongruent stimulus type, the global stimuli (large figure 1 or 2) mismatched the small configuration (small figure

1s or 2s). Finally, for the neutral configuration, the global stimulus did not pertain to either response (e.g., a large 2 or 1 composed of smaller 4s). The results from the study showed that both the HFA and the TD group responded significantly quicker to local congruent than local incongruent configurations and there was no significant difference in error rates between these groups. Moreover, the autism group were faster at responding to global than to local stimuli. The main group difference to arise in the study was that both HFA and AD groups experienced significant difficulties on global incongruent trials involving interference at the local level. These results did not provide strong support for the WCC theory, and the authors discussed their results in the context of fronto-striatal abnormalities, linked with problems of inhibitory controls in individuals with ASD (Langen et al., 2012)

Iarocci et al. (2006) investigated the extent that explicit demands influence perceptual biases in 12 children with ASD and 12 TD controls. In the first experiment participants completed a visual search task which assessed global-local processing in control, local hard and global hard conditions. Each display set of dots was made up of 4 dots out of which 2 were black and 2 were white. The white dots were the target items and were referred to as the 'sleepy' ones by the experimenter. The dots were arranged in a local condition where the spatial distance was very short and in the global condition the dots were separated by a greater spatial distance. The target items were any dots which were not arranged in a vertical alignment and instead were tilted in orientation. The target pattern could appear at either the local level, global level, or at both levels (dual level). Participants were required to distinguish a target item with a tilted orientation in either the dots within a pair (local), the dots between pairs (global), or a tilted in orientation at both levels (dual). The target appeared alongside 1, 7, or 17 other vertically arranged dots. Before starting the experiment, participants were each shown drawings of all the experimental conditions and were asked to identify the 'sleepy' ones. During the experiment, participants were instructed to focus on the centre of the screen. They were told that only one of the items would appear on either the left or right side of their screen and were asked to respond as soon as they saw the 'sleepy' item. In the second experiment, participants were initially presented with a big or small square or a diamond for identification. Participants were told that they would see a square or a diamond in every display set of items and were asked to respond to these by pressing one of two separate keys (either small or big). The diamond at the global level was made up of small circles at the local level. The circle at the global level was made up of diamonds at the local level. The square at the global level was made up of small circles at the local level. The circle at the global level was made up of squares at the local level.

The experiment included three conditions with the target appearing at either the global or local level. In the global bias condition, the target was presented at the global level 70% of the time and at the local level 30% of the time. In the neutral condition the target was equally likely to appear at both the local and global levels. In the local bias condition, the target appeared at the local level 70% of the time and at the global level 30% of the time. The results from the first experiment showed that both the ASD and TD group showed similar patterns of performance whilst searching for a target at the local and global level, they did not find evidence for enhanced local processing or a global deficit in the ASD group. In the second experiment, the ASD group were quicker responding to global than local targets and showed relatively equal levels of susceptibility to the biasing manipulations in the experiment but favoured global targets.

Following on from this study, Plaisted et al. (2006) used a simplified version of a paradigm originally developed by Kimchi (1998) to test perceptual processing in participants with HFA (n=22) and TD (n=22) aged between 7 and 12 years. The stimuli were hierarchical patterns, in which large squares or diamonds (global level) were made up of small squares or diamonds (local level). The visual angle of the small elements was 0.2º and the visual angle of the large elements was 0.7º. The global visual angle of the 16 small element stimuli was 3.3º, and 5.8º for the 16 large element stimuli. The global visual angle of the 4 small element stimuli was 1.3º and 3.3º for the 4 large element stimuli. On each trial participants were shown a sample stimulus and after that they were shown a pair of choice stimuli that varied from one another in global configuration and in local element shape.

Each response was recorded as either local or global choice. A response was recorded as local if the participant chose a choice stimulus with the same local features, a response was recorded as global if the participant chose a choice stimulus which was similar in configuration to the sample stimuli. For example, the sample stimuli could consist of a square made up of 4 square elements which could be followed by a first choice of a square configuration made up of diamond elements or a second choice which may consist of a diamond configuration made up of square elements etc. Consequently, on each trial, the sample stimulus matched one of the choice stimuli at the local level and the other choice stimulus matched at the global level. Participants were instructed that they would be shown a single stimulus immediately followed by two choice stimuli and were instructed to indicate, using a button press, which one of the two choice stimuli were identical to the initially presented single stimulus.

Each participant completed 192 trials out of which each block was made up of 64 trials with eight possible combinations of stimulus. The trials were randomly assigned, and half were presented for 50ms and the other half of the trials on each block were presented for 800ms. Plaisted et al. (2006) found no group differences in response to perceptual discrimination of the local and global stimuli: a local bias was not reported in the HFA group. Participants were more predisposed to making local choices for elements containing fewer large element stimuli and more global choices for elements containing a greater number of smaller element stimuli.

Although local and global processing in ASD has been tested using different paradigms, a significant number of studies have used Navon type tasks (Navon, 1977). Whilst these studies have largely failed to demonstrate impairments in accurately identifying local and global stimuli in congruent trials, several have described highly atypical responses on incongruent trials. These findings, and the results from their own experimental study led Wang et al. (2007) to conclude that ‘a local bias, with local-to global interference is a key and characteristic feature of autistic visual cognition and a strong candidate for the endophenotype of autism’. However, this claim has been challenged by more recent work in the area.

Hayward et al. (2012) used a similar paradigm to that employed by Iarocci et al. (2006) to test young adults with ASD (n=12) and a TD (n=12) control group matched on IQ and CA. Participants completed both selective and divided attention tasks. In the selective attention task, there were four experimental conditions, congruent, incongruent, neutral-local, and neutral-global. The congruent stimuli consisted of a large diamond made of small diamond and a large square made up of small squares. The incongruent stimuli consisted of a large diamond made up of small squares and a large square made up of small diamonds. The neutral-global stimuli were a large diamond made up of small circles and a large square made up of small circles. The neutral-local were a large circle made up of small diamonds and a large circle made up of small squares. In this experiment participants completed a block of 120 trials with specific explicit instruction to “attend-to-global” and ignore the local shapes followed by a second block of 120 trials, in which they were instructed to "attend-to-local" and ignore the local shapes.

On the divided attention experiment, participants were instructed to attend to both the local and global levels at the same time. This experiment included only the neutral-local and neutral-global conditions used in experiment 1. Hayward et al. (2012) reported that the experimental groups performed similarly across both experiments. Both groups were slower on the incongruent trials and were faster at responding to global than local targets. On the divided attention task, both groups were faster when responding to "attend-to-global" targets. On the basis of these findings the authors concluded that ASD is not characterised by atypical global processing or difficulties in flexibly shifting attention across tasks. Experiment 3 presented in this chapter will further investigate local and global processing and responses to congruency in hierarchical stimuli in participants with ASD.

## AIMS AND HYPOTHESES

The aim of the study is to extend work on local/global processing and the effects of incongruity on these processes in ASD. In experiment one, presented in chapter four, participants with ASD showed a similar pattern of response to incongruity manipulations as TD controls and these same individuals will complete the current, more cognitively demanding task. The hypothesis for the study states that the participants with ASD will be less accurate and/or slower in responding to global incongruent stimuli. The rationale for the hypothesis draws on previous findings showing increased local-to global interference on incongruent trials (Wang et al., 2007).

## METHODS

### Participants

From the initial group of 34 participants described in chapter 2, 14 ASD participants (13 males and 1 female) and 14 TD controls (13 males and 1 female) were able to complete all the trials satisfactorily and their data was included in the analysis.

Independent samples t-tests were conducted to ensure that the ASD and TD group were still adequately matched for chronological age (CA) and FSIQ. These showed that the groups did not differ significantly on CA ( $t$ = .469, df = 26, $p$ = .643 ) or FSIQ ( $t$ = - .589, df = 26, $p$ = .561 ).

All fourteen TD participants who completed experiments 1 and 2 also completed experiment 3 and twelve participants from the ASD group who completed experiments 1 and 2 also completed experiment 3.

### Materials and procedure

The experiment was created using E-prime software version 1 (Schneider et al., 2002) and was conducted on a laptop. Task instructions were displayed on the computer screen. Each participant was presented with 120 global-salient conditioned trials within 2 blocks, one local block condition and one global block condition. Within each of the 2 blocks, there were 60 trials, out of which 30 were compatible trials and 30 were incompatible trials. Consequently, there were 4 conditions which were global compatible, global incompatible, local compatible, local incompatible. Participants were verbally instructed. In the global compatible condition, the participant had to attend at the global level (this was either a large square or a large cross), the local features of this element were congruent to the global. In the local compatible condition, the participant had to attend at the local level (this was made up of either small crosses or small squares), and the global features of this element were congruent to the local. In the global incompatible condition, the participant had to attend at the global level (this was either a large square or a large cross), the local features of this element were incongruent to the global (large square made up of small crosses, large cross made up small squares). In the local incompatible condition, the participant had to attend at the local level (either small squares or small crosses), the global features of this element were incongruent to the local (small crosses making up a large square or small squares making up a large cross). These stimuli are shown in figure 5-1 below.

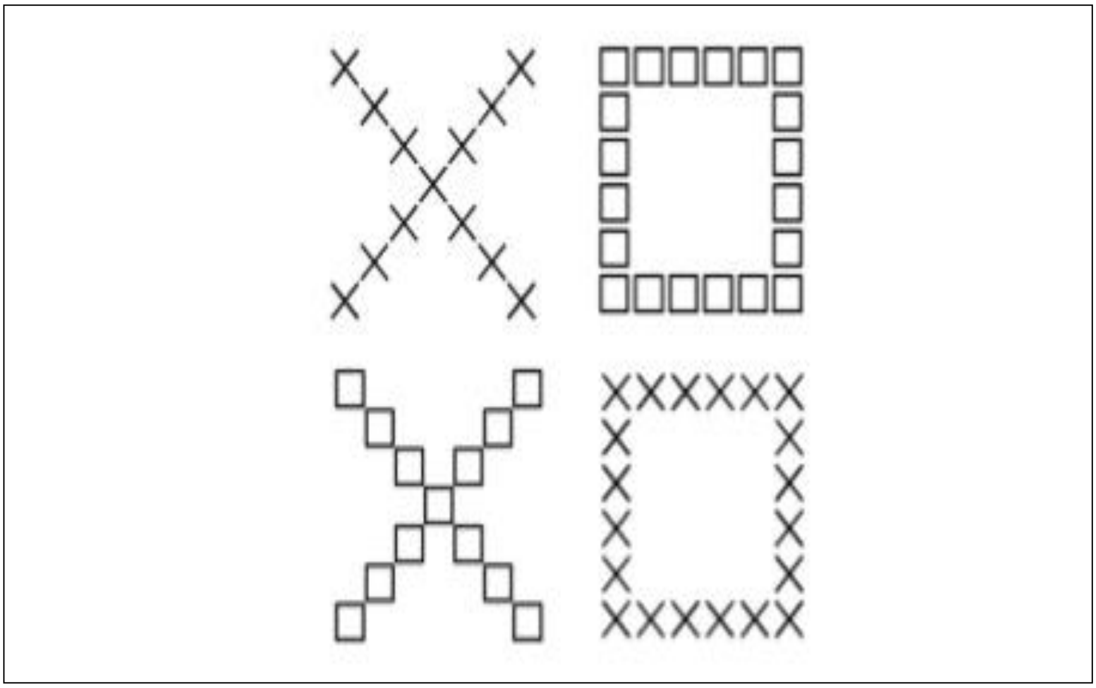


**Figure 5-1.** Shows the congruent (top left/top right) and incongruent (bottom left/bottom right) visual stimuli used in the current Navon study (Caparos et al., 2013)

All responses were collated using a computer keyboard, participants pressed the number 4 (LEFT button) on the keyboard to represent a SQUARE and the number 5 (RIGHT button) on the keyboard to represent a CROSS at both the global and local levels, these buttons remained the same.

A blank screen appeared for 1000ms, instructions were shown on the screen and the participant was instructed to read them. The instructions read ‘a large figure made of small elements will be shown on every trial (for example, a large square made up of small crosses). Your task is to decide whether the LARGE figure is a square or a cross. Ignore the small elements. Press the LEFT button if the large figure is a square and the RIGHT button if the large figure is a cross. Press a button to continue to a couple of examples.' Participants were then given a 200ms break, 2 practise trials were then presented on the screen. After pressing the right or left button (depending on whether the large figure is a cross) there was a 200ms break. Participants were then instructed to 'press a button if you are ready'. All the subjects were counterbalanced, with half receiving the local block first and the other half receiving the global block first. Participants were presented with 30 global trials - after completing, participants were instructed on the screen to take a short break and to press SPACE to continue. 30 more global trials were presented. Instructions then appeared on the screen stating 'take a break. Press a button to continue to the second part of the experiment when you are ready. Carefully READ the new instructions.'

The new instructions were shown on the screen 'A large figure made of small elements will be shown on every trial (for example, a large square made up of small crosses) Your task is to decide whether the SMALL elements are squares or crosses. Ignore the large figure. Press the LEFT button if the small elements are SQUARES and the RIGHT button if the small elements are crosses. Participants were instructed to press a button to continue to a couple of examples. Participants were then shown 2 more practise trials. After pressing the right or left button (depending on whether the large figure is a cross or square). Participants were given a 200ms break and were shown 'press a button if you are ready'. Participants presented with 30 local trials, after completing these participants asked to take a short break, press SPACE to continue and they were then presented with 30 more local trials. The experiment ended with 'end of experiment' being shown on the screen. Accuracy feedback was not given.

## RESULTS

Means and standard deviations for the ASD and TD accuracy rate scores are shown in table 5-1 and a visual representation in graph form can be found below in figure 5-2.

**Table 5-1.** Means and standard deviations for the ASD and TD accuracy rate scores

| | **Local congruent AR Mean SD Range** | **Local incongruent AR Mean SD Range** | **Global congruent AR Mean SD Range** | **Global incongruent AR Mean SD Range** |
|---|---|---|---|---|
| TD | 28.29 (2.97) | 27.21 (2.61) | 29.21 (1.25) | 28.07 (2.30) |
| | 19 - 30 | 22 - 30 | 26 - 30 | 21 - 30 |
| ASD | 26.50 (4.93) | 19.64 (10.74) | 27.36 (3.27) | 22.00 (8.94) |
| | 13 - 30 | 1 - 30 | 20 - 30 | 4 - 30 |

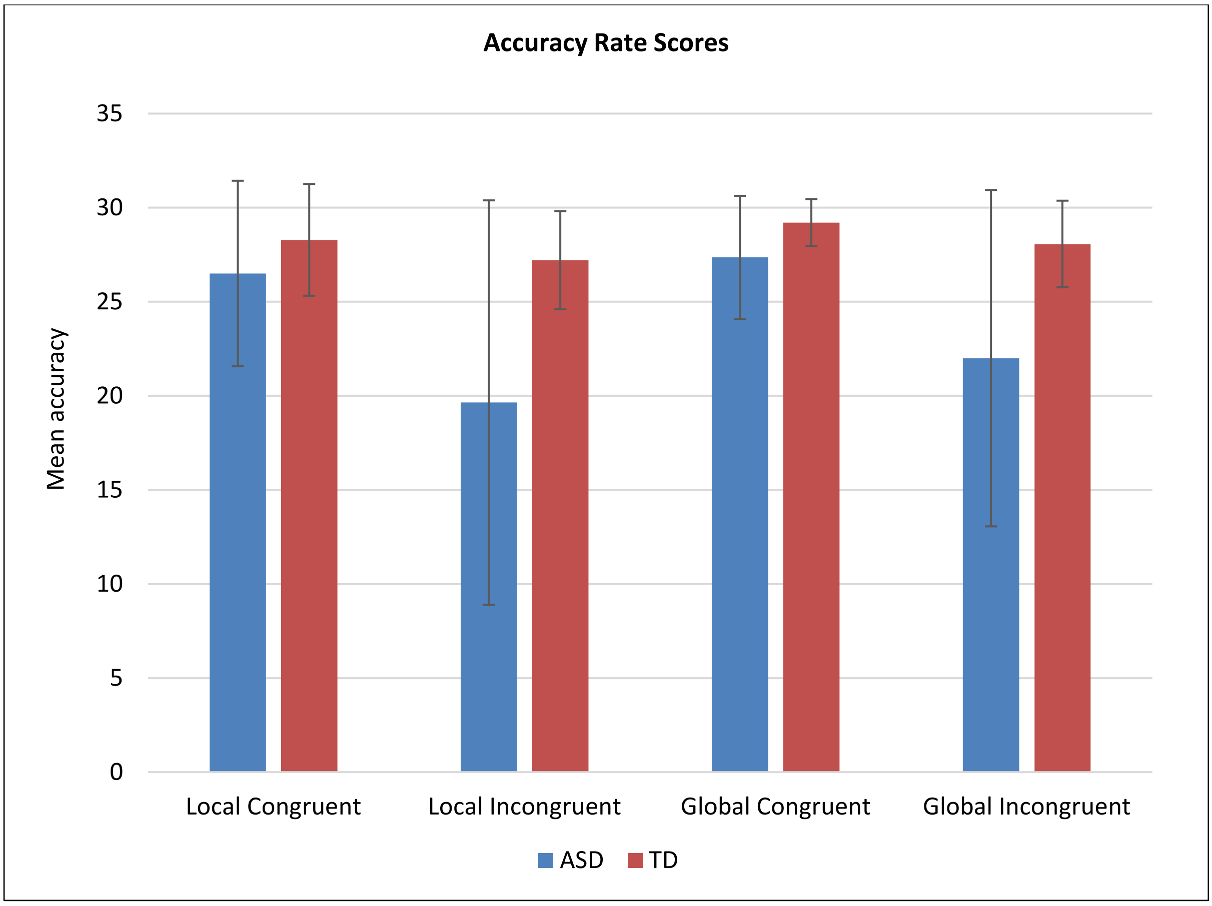



**Figure 5-2.** Graph showing the mean AR scores with SD error bars for the ASD and TD group

Analysis of variance was carried out on the accuracy (AR). Stimulus type (local/global) and congruency (congruent/incongruent) were the within subjects' variables and group (ASD/TD) was the between subjects variable.

The results revealed a significant main effect of group ($F$ (1 ,26) = 10.14, $p$ = .004), with lower AR scores in the ASD group. The main effect of stimulus type (local/global) was not significant ($F$ (1 ,26) = 1.612, $p$ = .215). The main effect of congruency was significant ($F$ (1 ,26) = 16.257, $p$ = .000) with lower AR scores on the incongruent trials. The stimulus type by congruency ($F$ (1 ,26) = .141, $p$ = .710) and stimulus type by group interactions were not significant ($F$ (1 ,26) = .132, $p$ = .720). The group by congruency interaction was significant ($F$ (1 ,26) = 7.809, $p$ = .010). As can be seen from figure 5-2, the ASD group showed a greater decrease in accuracy scores on the incongruent conditions than the TD group. The three-way congruency, by stimuli by group interaction was not significant ($F$ (1 ,26) = .171, $p$ = .683), so ASD participants showed a similar decline in scores whether distractors were local or global.

Means and standard deviations for the ASD and TD reaction times are shown in table 5-2 below.

**Table 5- 2**. Means and standard deviations for the reaction times (RTs) for both ASD and TD groups

| | **Local congruent RT Mean SD Range** | **Local incongruent RT Mean SD Range** | **Global congruent RT Mean SD Range** | **Global incongruent RT Mean SD Range** |
|---|---|---|---|---|
| TD | 279.56 (176.65) | 314.38 (183.83) | 260.05 (280.00) | 292.41 (189.01) |
| | 116.40 - 516.54 | 162.57 - 747.83 | 115.60 - 650.40 | 159.57 - 585.57 |
| ASD | 493.06 (257.62) | 591.47 (378.54) | 525.81 (279.84) | 582.82 (325.92) |
| | 151.90 - 932.20 | 130.60 - 1391.40 | 162.97 - 997.33 | 107.27 - 1141.73 |

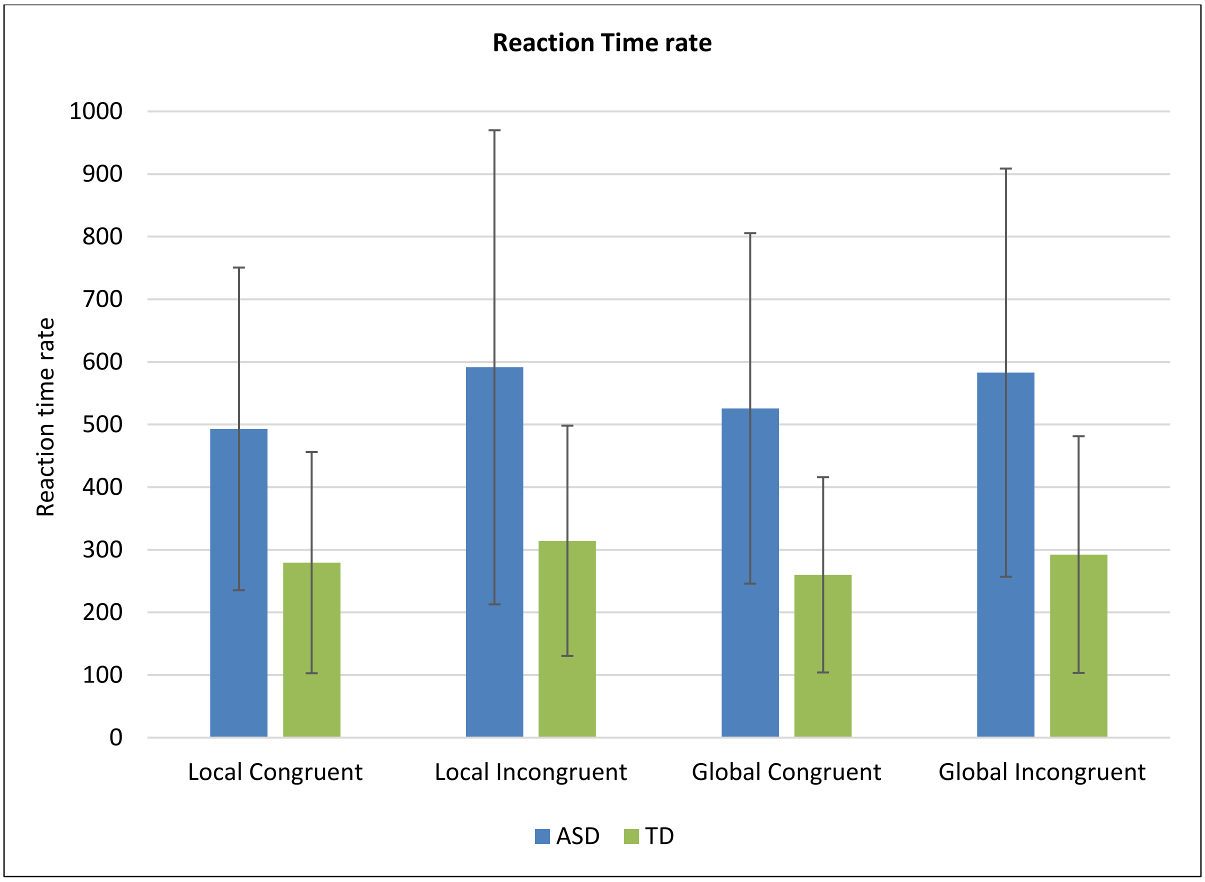



**Figure 5-3.** Graph showing the mean RT rate with SD error bars for the ASD and TD group

Analysis of variance was carried out on the RT. Stimulus type (local/global) and congruency (congruent/incongruent) were the within subjects variables and group (ASD/TD) was the between subjects variable.

The main effect of group was significant ($F$ (1 ,26) = 9.413, $p$ = .005), with higher RT scores in the ASD group. The main effect of stimulus type (local/global) was not significant ($F$ (1 ,26) = .015, $p$ = .902). The main effect of congruency was significant ($F$ (1 ,26) = 6.976, $p$ = .014) with greater RTs on the incongruent trials. The stimulus type by congruency ($F$ (1 ,26) = .371, $p$ = .548) and stimulus type by group interactions ($F$ (1 ,25) = .219, $p$ = .644) were not significant. The group by congruency interaction was not significant ($F$ (1 ,26) = 1.096, $p$ = .305), and the three-way congruency by stimuli by group interaction was not significant ($F$ (1 ,25) = .292, $p$ = .594).

## BRIEF SUMMARY OF RESULTS FROM EXPERIMENT THREE

The analysis of the accuracy data from the congruent trials did not reveal a local bias or an impairment in global processing in the ASD group. Although RT scores were significantly higher in the ASD group, the group by condition and group by congruency interactions were not significant and this suggested that slower responses were general, rather than differing over experimental conditions. In contrast to the pattern of performance on congruent trials, incongruent trials sharply differentiated ASD and TD groups. Whilst accuracy scores showed a very small decline on incongruent trials for the TD group, the decline was far steeper in the ASD group, and variance of scores was very wide in this group. So, whilst the lowest TD AR scores on incongruent trials were 22 (local) and 21 (global) (max = 30), the lowest ASD group scores on these conditions were 1 (local) and 4 (global). Some participants in the ASD group achieved a ceiling score of 30 on the incongruent trials, suggesting considerable individual differences in responses to incongruity within ASD samples. Taken together these results suggest that some, but not all children with ASD find it very difficult to ignore distractor stimuli, even when attention is explicitly cued to targets, in complex hierarchical stimuli. In the following section congruency responses will be correlated with cognitive and memory background tests.

**EXPLORING THE ATTENTIONAL COGNITIVE AND MEMORY CORRELATES OF CONGRUENCY PROCESSING IN ASD AND TD**

Congruency accuracy scores were calculated by subtracting the incongruent accuracy scores from the congruent accuracy scores for both the local (LCs) and global (GCs) conditions, this score shows how susceptible individuals are to interference from a local or global level.

These are shown in table 5-3 below.

**Table 5- 3.** Shows the mean congruency AR for ASD and TD group on the local and global condition and for mean total incongruency score

| | **ASD** | **TD** |
|---|---|---|
| | **Mean SD** | **Mean SD** |
| Local congruent – Local incongruent | 6.86 (10.06) | 1.07 (3.81) |
| Global congruent - Global incongruent | 5.36 (8.41) | 1.14 (1.79) |
| Total congruency scores | 12.22 (12.48) | 2.21 (4.85) |

**Table 5-4.** Shows the correlations of the congruency conditions with the background variables

| **Group** | **ASD** | | | **TD** | | |
|---|---|---|---|---|---|---|
| Background variable | L Cg | G Cg | T Cg | L Cg | G Cg | T Cg |
| Matrix reasoning | r = .219 | r = .025 | r = .194 | r = - .515 | r = .164 | r = - .358 |
| Block design | r = .254 | r = .228 | r = .359 | r = - .366 | r = .231 | r = - .213 |
| Dot locations immediate | r = - .011 | r = - .027 | r = - .027 | r = - .184 | r = .130 | r = - .102 |
| Family pictures immediate | r = .058 | r = .277 | r = .233 | r = .122 | r = .364 | r = .234 |
| Stories immediate | r = - .197 | r = - .063 | r = - .201 | r = - .249 | r = .008 | r = - .200 |
| Sequences | r = .103 | r = - .042 | r = .055 | r = - .192 | r = .031 | r = - .144 |
| Numbers forward | r = - .378 | r = - .219 | r = - .452 | r = - .020 | r = - .208 | r = - .093 |
| Numbers backward | r = .272 | r = .024 | r = .235 | r = - .083 | r = .047 | r = - .050 |
| Chronological age | r = .240 | r = .019 | r = .206 | r = .072 | r = - .206 | r = - .017 |

As table 5-4 shows, none of the correlations reached significance for either the ASD or TD group.

In the visual flanker task, described in chapter four, the ASD group performed as well as the TD control group and showed a very similar pattern of responses to congruency manipulations. However, on experiment three, described in this chapter, the ASD groups' responses to congruency manipulations was markedly different to that of TD controls.

The congruency factor for accuracy score (congruent – incongruent) from the visual flanker for experiment one was correlated with the L Cg and G Cg factors and are shown in table 5-5 below.

**Table 5-5.** Shows the correlations of the local and global congruency variables with the visual flanker congruency variable

| **Group** | **ASD** | | **TD** | |
|---|---|---|---|---|
| | L Cg | G Cg | L Cg | G Cg |
| Visual flanker congruency score | r = .122 | r = - .156 | r = .257 | **r = .663 p = .010**** |

As can be seen from table 5-5, none of the correlations were significant for the ASD group and this suggests that the two variables were measuring different processing mechanisms. However, there was a highly significantly positive correlation between the visual flanker congruency score and G Cg for the TD group.

## DISCUSSION

The results from experiment three only partially supported the experimental hypothesis. Based on previous research suggesting that global processing is particularly vulnerable to interference from local information in ASD (Wang et al., 2007) it was hypothesised that accuracy and reaction time scores would be lower than those of controls in the incongruent global condition. The accuracy data showed a significant fall in scores on both local and global incongruent conditions for the ASD group, and although RT scores were lower in the ASD group than the control group, they did not differ over experimental conditions.

Early studies into hierarchical processing in ASD were motivated by theoretical accounts describing global impairments and enhanced local professing in this group (Frith, 1989; Happé, 1999). Although a range of tests have been used in these studies, (Shah & Frith 1983; 1993, Happé, 1999; Ropar & Mitchell, 2001) a significant number of researchers have investigated hierarchical processing in ASD using adaptations of the test originally developed by Navon 1977). Here test stimuli are typically a large shape, letter, or digit (global level), comprised of smaller shapes, letters, or digits, (local level) that are the same (congruent) or different (incongruent) from the large version. Navon (1977) proposed that factors such a stimulus complexity, saliency and recognisability could significantly affect hierarchical processing and Rhinehart et al. (2000) suggested that methodological differences across studies may partially explain conflicting findings in studies of ASD. However, the results from experiment 3 suggest that heterogeneity in cognitive profiles within ASD populations, are also likely to contribute to the confusion in the literature.

In the study by Hayward et al. (2012), using a Navon-type paradigm with young adults, participants with ASD and TD showed very similar patterns of performance on both selective and divided attention tasks and in the current experiment some individuals with ASD scored at ceiling on both types of incongruent trials. Like the participants in Hayward et al's study, these participants did not appear to be distracted by competing global or local information. Whilst it is difficult to draw conclusions on the basis of studies testing different groups (adults/children) using different methods (selective and divided attention), the results from experiment 3 nevertheless suggest that typical perceptual responses to incongruity are characteristic in some individuals with ASD.

Experiment three tested selective attention only, and this highlighted what appears to be profound attentional difficulties in some individuals in the ASD group. Despite being implicitly instructed to attend to the global or local levels of the stimulus, accuracy scores fell below chance level on incongruent trials for some individuals. The correlational analysis attempted to identify factors associated with an increased vulnerability to distracting stimuli during hierarchical processing. However, none of the correlations reached significance. The negative correlation been congruency scores and the numbers forward subtest, showed a moderate to large effect size suggesting that participants with higher auditory short term-memory scores were less susceptible to distracting stimuli. The positive correlation between congruency scores and the block design test showed a medium to large effect size, suggesting that participants with higher scores on the block design test were most susceptible to distracting stimuli. Wang et al., (2007) interpreted their result showing lowest performance on incongruent global trials as evidence for strengths in local processing. However, in experiment three, both local and global processing were vulnerable on incongruent trials in the ASD group, and correlations carried out between block design and local congruency (local congruent-local incongruent) and block design and global congruency (global congruent-global incongruent) showed small effect sizes. In an attempt to explain seemingly typical responses to the congruency manipulations in the selective attention task, presented in chapter three, and findings showing increased vulnerability to congruency manipulations in the current study, further correlations were carried out. For the TD group responses to incongruency on the selective attention task and interference from the local to the global level on experiment three were significantly correlated. However, none of these correlations were significant for the ASD group. This therefore suggests that attention and cognitive mechanisms, responsible for increased vulnerability to distraction were not measured in the study. Rhinehart and colleagues (2000) implicated the potential involvement of fronto-striatal abnormalities in ASD in these difficulties and an increased vulnerability to distraction with be further discussed in chapter seven.

In summary, the results from experiment three did not provide evidence for a local bias in ASD but did reveal a group level increase in vulnerability to distraction when stimuli were relatively complex. Experiment 4, presented in the following chapter, will further investigate higher-order perceptual processing in a visual averaging task.

# CHAPTER 6: PERCEPTUAL AVERAGING IN AUTISM SPECTRUM DISORDER

## ABSTRACT

Perceptual averaging describes the process by which statistical summaries of visual information are formed and presented. Theoretical accounts of ASD suggest an increased reliance on local information and this suggests that perceptual averaging will be weaker in this group than in TD. In this experiment, the shape and number of items in the visual arrays were systematically manipulated and participants were instructed to adjust the size of a single target circle so that it corresponded with the mean of the set of circles which they had just viewed. The results from the study revealed similar patterns of performance across conditions for both ASD and TD groups. Correlations showed that for the ASD group perceptual averaging was not significantly associated with memory or cognitive variables, or with an increased vulnerability to incongruent competing stimuli during local and global processing. However, for the TD group, significantly negative correlation between L Cg and mean total perceptual averaging scores suggesting high levels of perceptual averaging accuracy were seen in individuals who were less vulnerable to global interference.

### PERCEPTUAL AVERAGING IN TYPICAL DEVELOPMENT

Experiment three described in the previous chapter investigated local-global processing using a Navon task in individuals with ASD and a TD control group. The hypothesis for the study stated that participants with ASD would be less accurate and/or slower in responding to global incongruent stimuli. The rationale for the hypothesis was drawn from previous findings showing increased local-to global interference on incongruent trials (Wang et al., 2007). However, the results from experiment 3 failed to reveal a local or global bias in the ASD group, and increased interference on incongruent trials was observed on both local and global conditions. Whilst the analysis of the group data revealed difficulties screening out competing incongruent information in the ASD group, inspection of individual data revealed considerable variability, with some individuals performing as well as TD participants on incongruent trials. Experiment four described in this chapter does not involve competing information, but rather investigates the extent to which grouping processes are influenced by increases in perceptual load.

Typically developing human beings are known to possess the ability to perceptually average items within their visual field in order to form statistical summary representations (SSRs) (Pollard, 1984). Albrecht & Scholl (2010) gave a practical example of the process of visual averaging. In an orchard full of apple trees, the choice of tree for harvesting will result from the picker's statistical summary of the size and ripeness of the apples on the tree they select.

Weiss & Anderson (1969) conducted one of the very first studies investigating perceptual averaging of different line lengths in terms of SSRs in the typical population. Eight TD controls took part in this study, in the first experiment they were shown either six (or three) lengths in each sequence and had to estimate at the end of each sequence the average length of the lines. The length of the lines ranged between 14cm up to 26cm and were displayed on the screen for 4 seconds with a 2 second interstimulus interval break. In the second experiment, participants estimated the average length after the onset of each line. The results from the two experiments revealed a recency effect: lines which were presented nearer the end of each sequence and more recently had a significant impact and influence on the participants' estimations of average line length.

One of the most widely cited studies investigating the extraction of size in terms of SSRs was carried out by Ariely (2001). In the study, two new experimental paradigms, investigating both mean-discrimination as well as member-identification were carried out. Two participants completed three experiments; the first two experiments assessed a persons' understanding about the sizes of individual spots in a set (member-identification) and the third experiment calculated sensitivity levels to the mean size of a set (mean-discrimination). The member-identification experiment employed two different methodological techniques; yes/no and two-alternative forced choice (2AFC). In the yes/no task, participants were presented with a set of spots on their screen during the first interval, on the second interval they were presented with a single spot and had to respond with either yes/no if the single spot was a member of the set of spots which they had been presented with in the first interval. In the 2AFC task, participants were presented with a set of spots on the screen during the first interval and during the second interval they were presented with two spots. Participants had to identify which of the two spots was a member of the set of spots that had been presented with in the first interval. Out of the two spots which were displayed in the second interval, one was part of the set displayed in the first interval and the other was either the next in descending or ascending size in range from the spots shown in the first set. For the mean-discrimination experiment the same stimuli was used as to that previously used in the yes/no experiment for the member-identification. In the first interval, participants were presented with a set of spots, on the second interval participants were shown a single test spot and were asked whether it was larger or smaller than the mean size of the set presented in the first interval. Ariely (2001) reported from the findings of this study that participants were less accurate at judging the size of individual items in the member identification task whereas in the mean discrimination task, participants could calculate the mean size of the group more accurately. These results suggest that when individuals are provided with a set of four or more items that are alike, their visual systems generate representations of the set and bypasses individual items in the set.

The findings of this study were replicated by Chong & Treisman (2003) in a series of three experiments. The first experiment included two conditions. In the first, simultaneous presentation condition, 12 circles made up of 4 different sizes and 12 circles of the same size or a single circle of the same size was displayed for 200ms at the same time in the right and left sides of the visual field. In the successive presentation condition, the circles on the left side of the visual field appeared for 100ms and the circles on the right side of the visual field appeared for 100ms either 11ms or 2 seconds later. Participants were instructed to respond by selecting which side of the visual field had the larger mean size or which side of the visual field displayed the larger sized circles. In the second experiment, Chong & Triesman (2003) analysed how different exposure durations of 50ms, 100ms and 1 second would affect participants' judgments about the mean size (heterogeneous) and same size (homogeneous) arrays of a single pair of circles. In the third experiment, they assessed comparisons of mean size across different variations of sizes, to see how thresholds for the mean size would be affected. They reported from the findings of the first two experiments that participants were most accurate when judging the mean size of a heterogenous group of circles and single circles. There was little effect on mean judgments of either the delay with successive rather than simultaneous presentation (over a range of 0–2 s) or exposure duration (over a range of

50–1000 ms). During the more advanced conditions, trials with short exposure times and with larger delays and the same sized circles yielded better performance than the sets of different sized circles or the single item displays. Thus, the redundant presentation of multiple identical circles appears to help participants when the conditions impose extra demands either on processing speed or on memory. Furthermore, the levels of accuracy increased as the exposure duration increased for the single item displays compared to the heterogenous display set. They reported from findings of their third experiment that participants were averaging accurately and precisely when instructed to put forward mean size judgements of the circles. Therefore, the findings of these studies can be taken as evidence that TD individuals promptly form an SSR of the size of the individual items in the set and do so do without being heavily reliant upon focussed attention (Ariely, 2001; Chong & Triesman, 2003).

As an extension to the previous findings which have suggested that individuals are able to accurately predict the mean size of a set of similar items (Ariely, 2001; Chong & Triesman, 2005), De Fockert & Marchant (2008) conducted a study in which a group of young adults completed two averaging tasks. The authors predicted that 'subset averaging' would lead to an anomaly or inaccuracy in observation when predicting the mean size of the subset when the smallest or the largest set member would be part of the selected subset. In the first experiment, participants were presented with 9 different sized circles and were required to estimate the average size of the whole set. However, on each trial, the participants attention was directed towards a particular target circle which was the same as smallest or the largest in size out of the whole set of circles. Following this, participants were presented with two test circles on their screen, one of the circles had the same mean size as those set presented in the previous interval whereas the other circle was either smaller or larger than the mean size of the set. Participants had to decide which circle out of the two on their screen represented the mean size of the set. The second experiment was similar to the first experiment apart from the way in which the target circle was defined. Whereas in the first experiment, participants were explicitly instructed to identify the smallest or the largest circle in a display set, in the second experiment, the target circle was presented in different brightness levels from the rest of the set. Participants were required to find the circle which had a different level of brightness to the rest of the set members. On half of the trials the smallest circle was the target whereas in the other half of the trials the target was the largest circle. Participants were not provided with explicit instruction during the second experiment. On the basis of their study, De Fockert & Marchant (2008) reported that explicit or implicit instructions did not have any impact on participants' choice. When attention was directed to a smaller circle, their prediction of the set size was always smaller and when their focus of attention was directed towards a larger circle, their estimation was always larger. Thus, estimating the mean size of a set was sensitive to and significantly influenced by focus of attention.

As an extension to their original study, Marchant et al. (2013) conducted a further study in which participants attended to a set of 4, 8 or 16 regular or irregular sized circles and were instructed to estimate the mean size of the whole set by altering the size of a single circle which appeared immediately on their screen after the set of circles. They reported from the findings of their study that the levels of accuracy in mean size judgements decreased as the number of heterogenous circles in a display set increased. The mean size judgement for homogenous arrays consisting of 2 circles were similar in levels of accuracy up to a set size of 16 circles.

## PERCEPTUAL AVERAGING IN ASD

Early studies exploring visual perception in ASD have reported that they are quicker at identifying local targets when shown in a global stimulus such as the embedded figures task (Shah & Frith, 1983; Jolliffe & Baron-Cohen, 1997), perform at superior levels on visual search tasks (Plaisted et al., 1998; O'Riordan et al., 2001), and when required to disassociate multifaceted objects into constitutional fragments (Shah & Frith, 1993; Happé, 1999; Ehlers et al., 1997). These studies have been taken as evidence for a local bias detailed in WCC (Happé, 1999), or enhanced perceptual processing detailed in EPF (Mottron et al., 2006) models of perception in ASD. Moreover, some evidence from studies of visual perception suggests that individuals with ASD are more susceptible to interference from local distractors in visual arrays than TD controls (e.g., Plaisted et al., 1999; Wang et al., 2007). In experiment 3, reported in chapter 5, participants with ASD did not show a local bias but did appear to be more susceptible to local and global distractors than TD participants. Whilst this finding did not provide unequivocal support for WCC or EPF models, it does suggest that aspects of visual perception are atypical in ASD. The experiment described in this chapter, will test whether or not atypical visual perception results in impoverished perceptual averaging in ASD. To date, perceptual averaging has not been extensively studied in children and adolescents with ASD.

One study carried out by Corbett et al. (2016) investigated perceptual averaging in groups of adults with ASD and TD using simplified versions of discrimination and adaptation tasks. In the first task, 'mean versus member', assessed the participants ability to accurately differentiate which of the two test circles presented on their screen represented the mean size of the previous set of irregular sized circles (mean task) and which of the two test circles was an actual member of the previous set (member task). In their second experiment 'adaptation of mean size', participants observed two sets of test circles with different mean sizes and were instructed to decide which of the two test circles (left or right) was larger. Participants had not been explicitly informed that on the majority of the trials the two set circles were the same size. The results from the first experiment showed that the ASD participants were more accurate when deciding which of the two test circles represented the mean size of the previous set than which of the test circles was an actual member of the previous set. On the second experiment the ASD participants' perception of the size of the individual test circles was influenced by mean size adaptation. This suggests that participants were able to implicitly decide on the mean size of set of circles without being verbally instructed to do this. The results from the study failed to reveal significant differences between ASD and TD groups and the authors concluded that perceptual averaging is intact in adults with ASD. The aim of experiment 4 is to extend these findings in a study of perceptual averaging in children and adolescents with ASD.

## HYPOTHESIS

Theoretical models of ASD such as the WCC (Happé, 1999) propose increased attention to detail. Visual averaging reflects the tendency to perceptually average information about groups of stimuli within a contextualising environment, and Corbett et al. (2016) showed unimpaired visual averaging in a group of adults with ASD.

Given Corbett's findings and the absence of a local bias in the ASD group in experiment 3, it is hypothesised that participants with ASD will not show marked impairments on the task. The relationship between a local processing bias and visual averaging, and the effects of increased susceptibility to distractors revealed in ASD in experiment 3 will also be investigated in this study.

## METHODS

### Participants

From the initial group of 34 participants described in chapter 2, only 14 ASD participants (13 males and 1 female) and 14 TD controls (13 males and 1 female) were able to complete all the trials satisfactorily and their data was included in the analysis. Independent samples t-tests were conducted to ensure that the ASD and TD group were still adequately matched. These showed that the groups did not differ significantly on CA ( $t$ = -1.706, df = 26, $p$ = .100) or FSIQ ( $t$ = 1.698, df = 26, $p$ = .102 ).

### Materials and procedure

The experiment was taken from Marchant et al. (2013) and was originally developed using E-Prime software (Schneider et al., 2002) and was presented on a laptop computer. Participants were shown a set of circles on the computer screen for which they had to estimate the mean size of the set by adjusting the size of a single circle. The set sizes contained either 4, 8 or 16 circles which were made up of either two set sizes (regular circles) or all different set sizes (irregular circles), these are shown in table 6-1. The six array types were formed by crossing the set size (small array: 4 circle, large array: 8 circles, extra-large array: 16 circles) and heterogeneity (regular set = 2 distinct sizes, irregular sets = all circle sizes unique).

There were two blocks of 54 trials, each comprising of 18 randomised trials for each combination of circle and group size.

In the experiment, participants were seated 70cm away from the laptop screen. Each experimental trial began with presentation of a central fixation cross (500ms) after which the set of circles appeared for 1000ms. The circles varied in size by 0.1° to the next circle closest in visual angle. To stop participants from basing their judgment on the absolute size of the set of circles, two different mean sizes of 1.4º and 1.5º were presented in each display set of circles.

After the fixation cross and 1000ms of stimulus exposure, a small circle appeared at the centre of the screen. Participants were instructed to adjust the size of the single target circle so that it corresponded with the mean of the set of circles which they had just seen. They were instructed to use the letters on the keyboard ("k" to increase the diameter by 1 pixel, "m" to decrease it, and "z" to lock in the final value and proceed to the next trial). The starting size of the circle was either greater or smaller than the largest or smallest of the circles in any of the sets (i.e., beyond the 16-member irregular set range). The precise starting size of the single target circle was altered by 0.4° at each trial to stop participants from knowing the number of buttons presses that they would need to make to estimate the mean size of the set.

Participants were told that accuracy was crucial and that they could alter the size of the target circle as much as they needed to generate an accurate estimate. Before the experiment started, participants were given a practice trial in which they practised the mean estimation task until they fully understood the procedure. Each participant was then instructed to begin the experiment. No accuracy feedback was given.

Figure 6-1 below shows a representation of the heterogenous/irregular (left) and homogenous/regular (right) sized circles presented for set size 16.

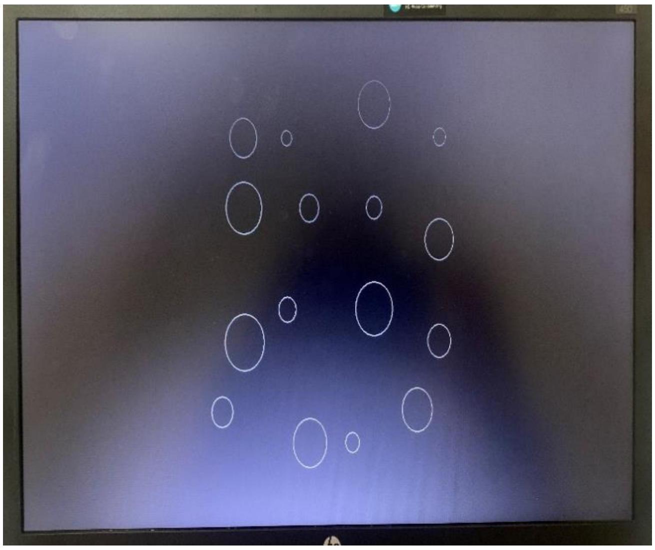
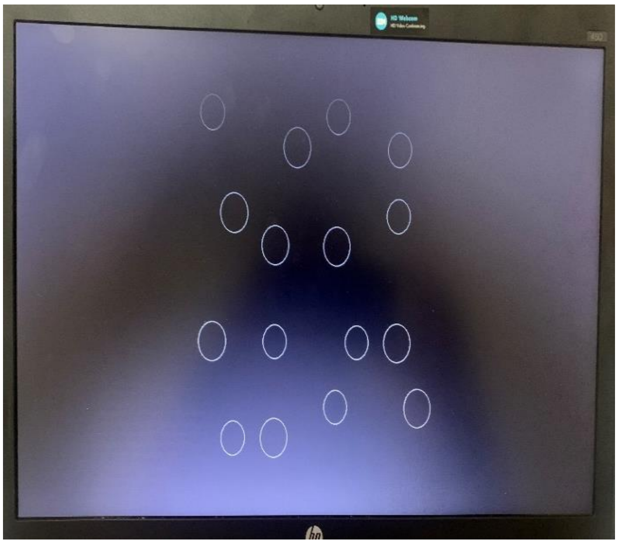
 

**Figure 6-1.** A representation of the circles presented for homogenous/heterogenous set size 16

**Table 6-1.** Table of circle sizes (degrees of visual angle), experiment included arrays with a mean of 1.5° for which all sizes were increased by 0.1°

| Set size | Set type | Member sizes |
|---|---|---|
| 4 | Irregular size circles | 1.2, 1.3, 1.5, 1.6 |
| 4 | Regular size circles | 1.3, 1.3, 1.5, 1.5 |
| 8 | Irregular size circles | 1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.7, 1.8 |
| 8 | Regular size circles | 1.3, 1.3, 1.3, 1.3, 1.5, 1.5, 1.5, 1.5 |
| 16 | Irregular size circles | 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2 |
| 16 | Regular size circles | 1.3, 1.3, 1.3, 1.3, 1.3, 1.3, 1.3, 1.3, 1.5, 1.5, 1.5, 1.5, 1.5, 1.5, 1.5, 1.5 |

## RESULTS

Means and standard deviations for participants with ASD and TD for the six blocks of trials are shown in table 6-2 below. The more accurate the individuals were, the smaller the difference (visual angle) between the observer average size estimated and the actual arithmetic mean size as a function of set size. The higher the mean, the less accurate the individuals were. Therefore, the closer they are to 0, the more accurate they are at estimating the average mean size of the given set.

Note: Accuracy rate is defined as the mean absolute difference (visual angle) between the arithmetic mean size of the set and the observer's final mean estimate. The dependant variable is absolute error in pixels.

**Table 6-2.** Accuracy rate for both ASD and TD group on all set sized circles

| **Stimulus Type** | **Mean SD Range**<br>**ASD** | **Mean SD Range**<br>**TD** |
|---|---|---|
| Regular size circles | | |
| 4 circles | 6.72 (3.56) 2.54 - 15.30 | 5.51 (1.71) 3.22 - 8.00 |
| 8 circles | 7.04 (3.60) 2.81 - 17.41 | 5.87 (1.64) 2.93 - 8.81 |
| 16 circles | 6.44 (3.73) 2.67 - 16.60 | 5.55 (1.91) 3.21 - 11.53 |
| Irregular size circles | | |
| 4 circles | 7.04 (3.13) 3.16 - 16.12 | 5.84 (1.76) 2.45 - 8.55 |
| 8 circles | 8.10 (2.92) 3.63 - 15.06 | 7.72 (2.14) 6.00 - 11.62 |
| 16 circles | 11.12 (3.31) 5.67 - 16.47 | 10.94 (4.21) 4.31 - 19.53 |

The graph below figure 6-2 shows the results for both groups for all set sizes (4, 8 and 16) and for both set types (homogenous/heterogenous).

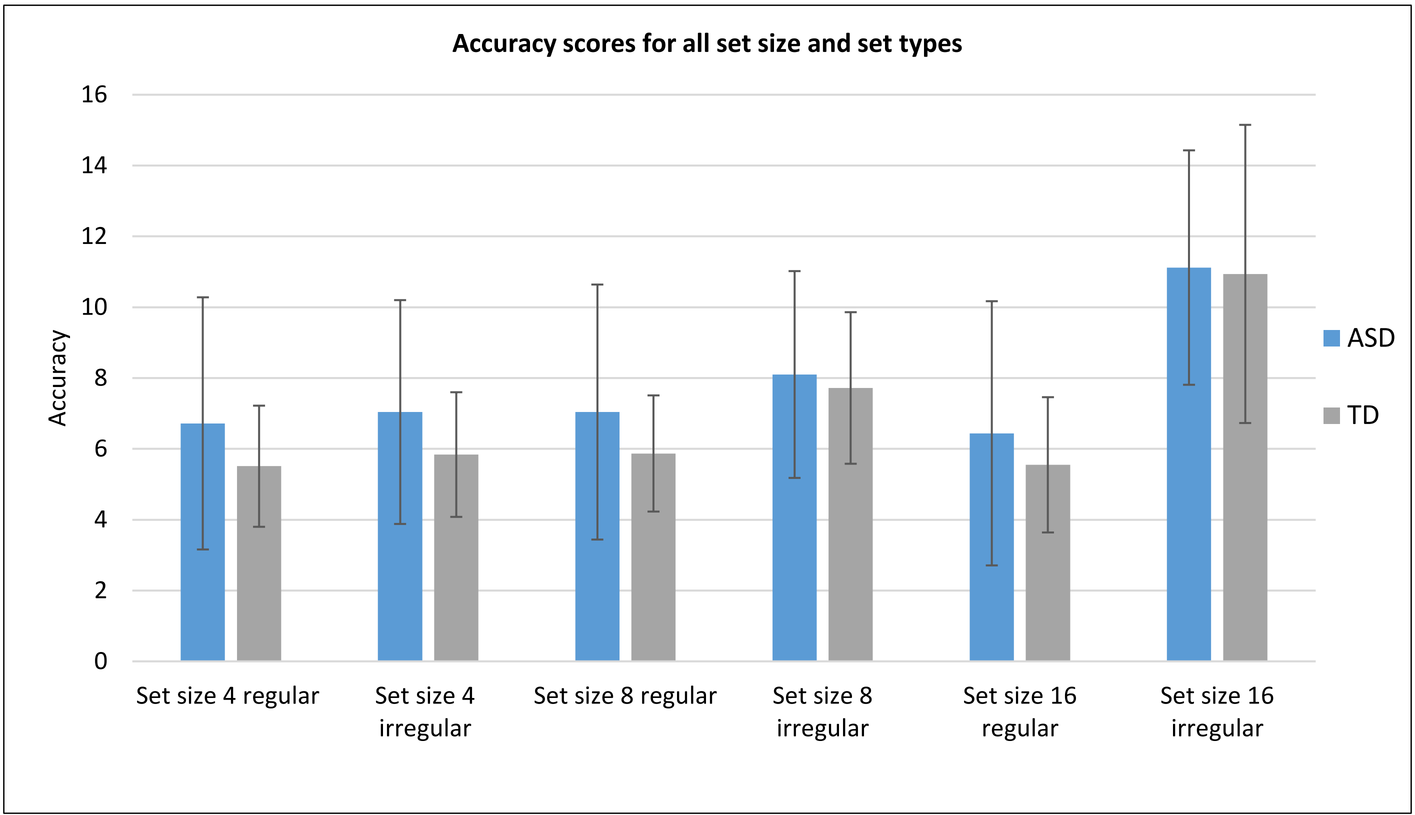



**Figure 6-2.** Bar charts with error lines showing results for ASD and TD for all set types and set sizes

The data were analysed using repeated measures ANOVA. The between subjects' factor was group (ASD/TD) and the within group factors were set type (regular/irregular size circles) and set size (4, 8 or 16 circles).

The results showed no significant main effect of group ($F$ (1,52) = .795, $p$=.381). The main effect of stimulus set type was statistically significant ($F$ (1,52) = 57.26, $p$ = .000) with higher levels of inaccuracy in conditions when circles were irregular sizes. The main effect of stimulus set size was also highly statistically significant ($F$ (2,52) = 22.668, $p$ < .001), with greater levels of inaccuracy as the set sizes of the circles increased. The interaction between set type and set size was statistically significant $F$ (2,52) = 33.58, $p$ = .000. and is shown in figure 6-3 below.

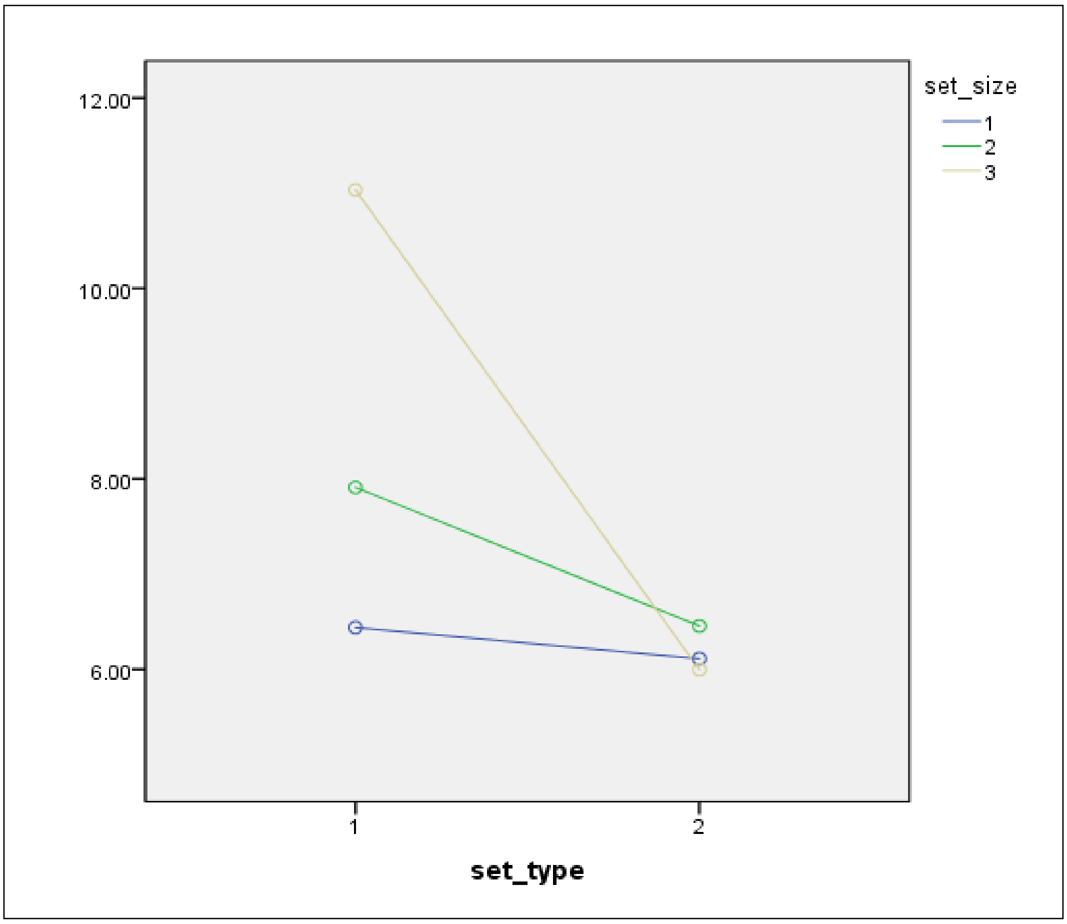



**Figure 6-3.** Plot showing interaction between set type and set size

Figure 6-3 suggests that for regular sets, set size has little or no effect on accuracy, but for irregular sets, set size shows an increasing negative effect on accuracy.

The interaction between set type (homogenous or heterogenous circles) and group was not significant ($F$ (1,52) = .707, $p$ = .408). The interaction between set size and group was not significant ($F$ (2,52) = .522, $p$ = .596). The three-way interaction between set size, set type and group was not significant ($F$ (2,52 = .256, $p$ = .775).

## BRIEF SUMMARY OF RESULTS FROM EXPERIMENT FOUR

The findings revealed that the group of children with ASD responded to the complex manipulations in the study in the same way as the TD group. This finding provides support for Corbett et al. (2016) who reported that perceptual averaging was intact in a group of adults with ASD.

## EXPLORING THE COGNITIVE AND MEMORY CORRELATES OF HIERARCHICAL AND CONGRUENCY PROCESSING IN ASD AND TD

Although the pattern of performance was very similar for the ASD and TD groups, figure 6-2 showed a wider spread of scores in the ASD than in the TD group. In order to determine which background variables were associated with averaging performance, mean total averaging scores across all the conditions of the experiment were summed and correlated with background data for the ASD and TD groups. These correlations are shown in table 6-3. It should be noted that a score of zero indicates perfect averaging performance, and scores increase in line with increases in inaccuracy.

To further establish whether averaging showed developmental increases chronological age (CA) was also correlated with the mean total perceptual averaging scores for the two groups.

Note: *p<0.01, **p<0.05 (two-tailed)

**Table 6-3.** Summary of correlations for background variables with the mean total perceptual averaging score for the ASD and TD group

| **Group** | **ASD** | **TD** |
|---|---|---|
| Background variable | Mean total perceptual averaging score | Mean total perceptual averaging score |
| Ravens Matrices | r = .260 | r = .162 |
| Block Design | r = .145 | r = .099 |
| Numbers forward | r = - .030 | r = .338 |
| Numbers backward | r = - .270 | r = .099 |
| Dot Locations immediate | r = .098 | r = .183 |
| Family Pictures immediate | r = .030 | r = - .169 |
| Stories immediate | r = - .443 | r = - .029 |
| Sequences | r = .100 | r = - .190 |
| Chronological age | r = - .262 | r = - .126 |

As table 6-3 shows, none of the correlations reached significance. For the ASD group the correlation between Stories immediate recall and averaging was negative and showed a medium to large effect size. This may suggest that memory for language advantaged ASD participants on the averaging task. Even though the correlations do not strongly implicate memory, verbal, or non-verbal intelligence in good averaging performance in the ASD group, the question about why they showed impaired performance on the incongruent trials in experiment 3 yet still showed intact performance on a visual averaging task merited further investigation. In chapter five, scores on incongruent trials were subtracted from scores on congruent trials to obtain a measure of interference for local and global conditions. These are shown in table 6-4 below.

**Table 6-4.** Local and Global congruency scores from experiment 3

| | ASD | TD |
|---|---|---|
| | **Mean SD** | **Mean SD** |
| Local congruent – Local incongruent | 6.86 (10.06) | 1.07 (3.81) |
| Global congruent - Global incongruent | 5.36 (8.41) | 1.14 (1.79) |
| Total congruency scores | 12.22 (12.48) | 2.21 (4.85) |

The congruency scores were correlated with the mean total perception averaging scores and are shown in table 6-5.

Note: *p<0.01, **p<0.05 (two-tailed)

**Table 6-5.** Summary of correlations with variables from experiment 3 and experiment 4 with CA for the ASD and TD group

| **Group** | **ASD** | **TD** |
|---|---|---|
| Background variable | Mean total perceptual averaging score | Mean total perceptual averaging score |
| Block design | r = .145 | r = .099 |
| L Cg | r = - .082 | **r = - .575* p = .031*** |
| G Cg | r = .075 | r = - .228 |

As table 6-5 shows, none of the correlations between experiment three and the averaging score from experiment four reached significance for the ASD group. For the TD group, there was a significantly negative correlation between L Cg and mean total perceptual averaging scores. Lower mean perceptual averaging scores indicate higher levels of accuracy whilst higher L Cg scores indicate decreased vulnerability to interference from incongruent global stimuli. This negative correlation therefore suggests that within the TD group, high levels of perceptual averaging accuracy were seen in individuals who were least vulnerable to global interference.

# DISCUSSION

The aim of experiment 4 was to investigate perceptual averaging in ASD, and TD controls matched for age and intelligence. Cognitive models of ASD propose a local bias, with increased processing of details. Such a characteristic could place constraints on an individual's ability to form statistical representations of visual information during perceptual averaging. However, the results from experiment 3 did not reveal a local processing bias in ASD and a study by Corbett et al., (2016) showed that visual averaging is intact in adults with ASD. The hypothesis for experiment 4 was that ASD and TD groups would not differ on the visual averaging task. The results revealed similar levels and patterns of performance across the ASD and TD groups and this supported the hypothesis.

The paradigm used in the current study was developed by Marchant et al., (2013) who tested a group of adult TD controls. In the experiment, participants were explicitly instructed that on each trial they would be shown a set of circles from which they would have to estimate the mean size of the set by adjusting the size of a single circle by pressing the letter 'k' to make the circle larger and the letter 'm' to make it smaller which appeared directly after the set of circles. This experiment involved assessing and analysing each and every circle in the visuospatial array (comprised of either 4, 8 or 16 regular or irregular sized circles) in order to calculate the average size of the set without visual access to the full array. The importance of encoding the task instructions at the beginning of the experiment and maintaining them during task performance is unlikely to pose problems for TD adults, but may influence performance in children and adolescents, whose verbal and verbal memory skills are still developing. The analysis of the background data in chapter three showed that the ASD participants scored lower on attention concentration (numbers and sequences from the attention/concentration index of the CMS; Cohen, 1997) and verbal working memory skills (immediate recall of Stories from the verbal immediate index of the CMS; Cohen, 1997) and significantly higher on immediate recall of Family pictures from the visual immediate index and fluid intelligence (matrices subtest) than TD controls, despite being matched on FSIQ, and this may have influenced task performance, albeit in subtle ways.

In experiment 4 the pattern of performance did not differ across ASD and TD groups. Increases in set size and alterations to the components within the sets elicited the same pattern of responses. The correlations carried out on the ASD and TD group provided insights into the cognitive mechanisms recruited during averaging in children and adolescents. While the correlations did not reach significance for the ASD group, the correlation between visual averaging and verbal working memory showed a medium to large effect size. Although visual averaging tasks, developed for use with adults, test perception and cognition, verbal memory skills may influence task performance in adolescents with ASD.

A question that was explored in this chapter concerned the extent that increased vulnerability to competing incongruent stimuli, reported in chapter five in the ASD group, influence perceptual averaging performance. Whilst reduced vulnerability to competition from global stimuli, on local processing trials, was associated with good averaging for TD participants, this was not the case for the ASD. The pattern of performance across visual perceptual tasks in the ASD group will be further discussed in chapter seven.

# CHAPTER 7: GENERAL DISCUSSION

## ABSTRACT

The overarching aim of the assessment and studies presented in this thesis was to investigate perception and cognition within the context of heterogeneity in ASD. In this chapter, the results from the experimental chapters will be considered in the context of the assessments described in chapter two, predictions based on theoretical models of ASD and previous research in the field. Limitations in the work presented in the thesis and recommendations for future research will be further explored and discussed.

The first aim tested in the thesis was to examine subtest variability in intelligence and memory using standardised measures such as the WASI-II (Wechsler, 2011) and the CMS (Cohen, 1997) in groups of adolescents with ASD and TD matched for CA and full-scale IQ (FSIQ). This method of matching has been widely used in experimental studies comparing participants with ASD and is believed to be methodologically stringent in controlling for differences in developmental level and intellectual ability. Chapter two included a description of the participants and the tests of intelligence and memory used in the study. The WASI-II (Wechsler, 2011) comprises four tasks, which measure non-verbal intelligence (Block Design and Raven's Matrix reasoning), and verbal ability (Vocabulary and Similarities). The Children's Memory Scale (CMS; Cohen, 1997) is an extensive test that yields verbal, visual and an attention/concentration index. The verbal and visual indexes are further subdivided and assess either immediate or delayed memory. Although the CMS (Cohen, 1997) was administered with all participants and showed that ASD and TD groups did not differ on total memory scores, the data analysis only included memory index scores that were of direct relevance to the research questions addressed in the thesis. These indexes included Verbal Immediate, Verbal Delayed, and Visual Immediate recall and the Attention/Concentration index. An important finding to emerge in chapter three, was that ASD/TD group matching, on the basis of full-scale memory and/or IQ scores, may fail to rule out potentially important differences in perceptual and/or cognitive profiles in ASD and TD.

The analysis of the WASI-II (Wechsler, 2011) showed that groups did not significantly differ on FSIQ, PIQ or VIQ scores. However, the ASD group scored significantly higher on the matrix reasoning subtest, and this suggested that non-verbal intelligence was higher in this group. Whilst FSIQ in TD typically reflects similar verbal and non-verbal subtest scores, higher non-verbal scores may compensate for lower verbal scores in ASD groups.

Dawson et al. (2007) and Soulières et al. (2011) have discussed superior matrix reasoning performance in ASD and Asperger Syndrome (AS) and suggested that non-verbal intelligence underpins cognitive strengths to a greater extent in ASD than in TD. An important finding to emerge from the analysis of the IQ data was that the majority of participants with ASD failed to show peak performance on the Block Design (BD) subtest. In an early analysis of studies using the Wechsler tests to measure intelligence in ASD, Happé, (1994) reported peak performance on this subtest and this was taken as evidence for a local bias in ASD. However, findings from the current study were consistent with those from a more recent large-scale (SNAP) study carried out by Charman et al. (2011) who reported 'no peak' in BD subtest scores for the ASD group. Charman and colleagues highlighted high levels of heterogeneity and co-morbidities in the ASD sample, and the difference between these findings and those reported by Happé (1994) may reflect changes in diagnostic criteria for ASD during this timeframe.

At the group level, the analysis of the CMS (Cohen, 1997) data revealed no significant differences between groups on the Verbal Delayed and Visual Immediate indexes. The ASD group scored significantly lower compared to the TD group on the Verbal Immediate and the Attention/Concentration indexes. It should be noted that the three subtests making up the Verbal Immediate index varied on levels of semantic complexity, with performance levels falling in line with increases in language complexity for the ASD group. At the individual subtest level, the ASD group scored significantly lower compared to the TD group on the immediate recall of Stories subtest from the Verbal Immediate index, though two of the ASD participants were able to score within the superior and very superior ranges. No significant differences were reported between groups on the less complex Word pairs and a Word lists subtest. On the word pairs subtest, scores were in the average range for the ASD group and only two participants scored in the impaired range.

The results from the Visual Immediate index subtest were surprising, given previous research and theoretical models proposing superior visual discrimination in ASD. The Dot locations subtest measures visuospatial working memory and revealed exceptionally variable performance in the ASD group. For example, within the ASD group, two participants scored in the extremely low range, six participants scored in the average range and nine participants scored in the high average, superior and very superior ranges. Within the TD group, four participants scored within the low average and average ranges, six participants scored in the high average range and seven participants scored in the superior range. Although the group mean score was significantly higher for the ASD group than the TD group on the Family pictures subtest, a similar wide range of scores was observed. Whilst one participant scored in the impaired range, and many scored in the average ranges, more than half of the participants scored in the superior and very superior ranges. No significant differences were reported between groups on the immediate recall of Faces subtest. In the ASD group, five participants scored within the impaired and borderline ranges, two participants scored in the low average range and seven participants scored within the average and high average ranges. For the TD group, five participants scored within the impaired and borderline ranges, two participants scored in the low average range, and ten participants scored within the average and high average ranges.

The between group comparisons, revealed the most marked difference on the Attention/Concentration index and subtest scores were significantly lower in the ASD group than the TD group. At the individual subtest level, no differences were reported between groups on the Picture locations subtest. However, there was a highly significant between group difference on the Numbers subtest, with lower scores in the ASD group. This subtest further subdivides into forward and backward digit span tests and the ASD group appeared to experience most difficulty on the backward digit span task. On the forward digit span, the group difference approached significance, and scores were widely distributed for the ASD group relative to the TD controls. In the ASD group, seven participants scored within the borderline and impaired ranges, nine participants scored in the average and high average ranges and one participant scored in the superior range. Whereas for the TD group, two participants scored within the impaired and borderline ranges, eleven participants scored between the low average, average, and high ranges and four participants scored within the superior and very superior ranges. On the backward digit span test, the ASD group scores were significantly lower than TD group scores. For the ASD group, ten participants scored in the impaired range, one participant scored in the low average range, four participants scored in the average and high average ranges. Despite generally poorer scores in the ASD group it was interesting to see that two participants scored in the superior range. In contrast for the TD group, twelve participants scored in the low average and average ranges, two participants scored in the high average range and three participants scored in the superior range. On the Sequences subtest, the ASD group scored significantly lower than the TD group. In the ASD group, five participants scored in the impaired and borderline ranges, eight participants scored in the low average and average ranges, two participants scored in the high average range and two participants scored in the superior range. Whereas for the TD group, fifteen participants scored in the average and high average ranges and two participants scored in the superior range. Background testing, using the WASI-II (Wechsler, 2011) and the CMS (Cohen, 1997) revealed considerable heterogeneity at the cognitive level in the ASD group. This finding has implications for theoretical accounts of ASD and these will be further discussed.

The second aim of the study was to examine attention in visual and auditory modalities and determine whether patterns of performance generalised across domains. The extent to which performance on tests of attention is influenced by intelligence and memory was also investigated. Experiment one used a visual flanker task to investigate processing of congruent and incongruent stimuli in groups with ASD and TD. Several studies have reported atypical performance on tasks of visual attention in ASD (Eskes et al., 1990; Rinehart el al., 2000). Adams & Jarrold (2012) showed that children with ASD and TD were more susceptible to interference when stimuli were incongruent than when they were congruent. The results from experiment one replicated Adams & Jarrold's (2012) findings: participants with ASD and TD were less accurate on incongruent than on congruent trials and whilst total reaction times (RT) were slower in the ASD group, their advantage on congruent trials remained.

Experiment two investigated auditory attention using an auditory flanker task to investigate auditory processing of congruent and incongruent stimuli. Participants were required to ignore the male voice and attend to the female voice only. Sequences of letters were played through the headphones and participants had to listen out for the female voice saying either G or T and ignore the Xs. Remington & Fairnie (2017) carried out an experimental study of auditory discrimination in ASD and reported that skills were intact when cognitive load was low. The results from the CMS (Cohen, 1997) were somewhat consistent with this in that they showed a decrease in auditory memory for more complex stimuli. However, behavioural, and neural abnormalities in processing low-level auditory information have also been widely reported in ASD (O'Connor, 2012). It was therefore hypothesized that individuals with ASD would perform at a significantly lower level than TD participants on a test of auditory selective attention. The results supported the experimental hypothesis and total accuracy scores were significantly lower in the ASD compared with the TD group. However, both groups scored higher on congruent than on incongruent trials, so the pattern of performance did not differ across the groups in the experiment. The correlations carried out on the data from experiments one and two were not significant for either group. This result has implications for domain general theories of perception and cognition in ASD and will be further discussed.

The third aim of the study was to test models of ASD that predict a local processing bias in ASD (Shah & Frith, 1993; Happé, 1999; Mottron et al., 2001, 2006; Baron-Cohen et al., 2009). Since Frith's (1989) account of cognition in autism, this idea has been a cornerstone of theorising about cognitive processing in ASD. Experiment three built on previous work by Wang et al. (2007), who showed stronger local-to global interference when judging incongruent stimuli and attributed this to a local processing bias in the ASD group. The experiment utilised a local-global paradigm in which participants were presented with 120 global-salient conditioned trials within 2 blocks, one local block condition and one global block condition. Within each of the 2 blocks, there were 60 trials, out of which 30 were compatible trials and 30 were incompatible trials. The experiment was made up of 4 conditions which were global compatible, global incompatible, local compatible, local incompatible. In the global compatible condition, participants had to attend at the global level (this was either a large square or a large cross), the local features of this element were congruent to the global. In the local compatible condition, the participant had to attend at the local level (this was made up of either small crosses or small squares), and the global features of this element were congruent to the local. In the global incompatible condition, the participant had to attend at the global level (this was either a large square or a large cross), the local features of this element were incongruent to the global (large square made up of small crosses, large cross made up small squares). In the local incompatible condition, the participant had to attend at the local level (either small squares or small crosses), the global features of this element were incongruent to the local (small crosses making up a large square or small squares making up a large cross).

In accordance with theoretical accounts of a local bias in ASD the hypothesis stated that these participants would be less accurate and/or slower in responding to global incongruent stimuli. The results from experiment three did reveal a group difference but did not support the experimental hypothesis. For the ASD group, incongruence resulted in decreased accuracy on both local and global trials, and this could not be explained by a local processing bias. The analysis of the RT data also failed to reveal a local bias in the ASD group. Total RT scores were significantly higher in the ASD group, but the group by condition and group by congruency interactions were not significant. Thus, a congruence-incongruence by group interaction, but no effect of locality vs globality was found. This suggests that distractibility rather than a global processing impairment characterises cognitive processing in ASD. However, scores were very widely distributed in the ASD group and some of these participants scored at ceiling on incongruent trials.

The fourth aim of the study was to investigate perceptual averaging in adolescents with ASD and TD. The paradigm used in experiment four utilised a mean estimation task previously used by Marchant et al. (2013) in adult TD controls. Participants were presented with a group of either 4, 8 or 16 heterogeneous or homogeneous circles on their screen; after the presentation of the set of circles, participants were presented with a single circle, and were instructed to adjust the size of the single target circle so that it corresponded with the mean of the set of circles which they had just seen. Perceptual averaging had not been previously tested in children or adolescents with ASD although Corbett et al. (2016) showed that perceptual averaging was unimpaired in adults with ASD. Given these results, and the lack of evidence for a local bias in experiment three, the hypothesis stated that ASD and TD groups would not differ on a test of visual averaging. The results supported the hypothesis and extended findings by Corbett et al. (2016) to adolescents. The pattern of performance was surprisingly similar across ASD and TD groups. Accuracy scores across set types and set sizes were very similar, and the distribution of total scores showed a smaller difference across groups than the other three experiments. Corbett et al. (2016) had concluded that visual grouping, active during averaging, is intact in adults with ASD. The results from experiment four, considered in the context of the results from the visual flanker task (experiment two), suggest that grouping is intact in ASD when distractor conditions are not included in the paradigm. However, as previously discussed, this interpretation does not generalise to all individuals with ASD, as some participants in the flanker task did not show reduced accuracy, compared with controls, on the distractor conditions.

Although the results from the four experiments presented in the thesis did not provide support for a local bias in information processing in ASD, some interesting differences did emerge from the experimental studies. For example, group differences in reaction times emerged in experiments one (visual flanker) and three (local-global) but not in experiment two (auditory flanker). This is consistent with a recent study by Baisch et al. (2017) who compared simple and choice reaction times in children with ASD and TD, and reported variability across tasks, slower reaction times and greater standard deviations in the ASD group. Whilst slower RTs in experiments one and three could reflect motor manual difficulties in ASD (Travers et al., 2017), the same participants complete all four experimental studies, and it is difficult to understanding why RTs were not slower in the ASD group on experiment two. A difference in accuracy emerged in experiment two but could not be linked with the experimental manipulations in the study. The only group difference in response to the experimental manipulations was seen in experiment three, where participants with ASD were more susceptible to incongruity than TD participants. However, even in this study, some participants with ASD obtained very high scores on incongruent trials. Across the series of experiments, standard deviations were generally far larger in the ASD group than in the TD group, and this motivated the correlations carried out in the experimental chapters.

## EXPLORING HETEROGENEITY IN ASD AND TD USING COGNITIVE AND MEMORY CORRELATES

The aim of the background testing described in chapter three, was to identify group differences in intelligence and memory and to investigate variability in these different measures within the ASD group. As the literature review in this thesis highlights, the results from experimental studies of ASD often produce very mixed findings. Whilst this may reflect methodological factors such as the use of different paradigms or testing of different age groups, the results from chapter three showed considerable heterogeneity in perceptual, cognitive and memory skills within the ASD sample. At the group level the ASD group scored higher than the TD group on the Matrix reasoning and memory for Family pictures subtests, and lower than the TD group on tests probing memory for complex language, visual spatial memory, and digit span tests, and the potential impact of these strengths and weaknesses on the experimental studies will be discussed in the following section.

## EXPLORING THE POTENTIAL ASSOCIATIONS BETWEEN COGNITIVE AND MEMORY STRENGTHS AND IMPAIRMENTS ON EXPERIMENTAL PERFORMANCE IN ASD

The Matrix reasoning (MR) subtest, like the more extensive Raven's Progressive Matrices task (Raven, 2003), is believed to measure abstract reasoning and fluid intelligence, recruiting spatial perception, abstract reasoning, concentration, and attention. Although total MR scores were higher in the ASD group than in the TD group, these skills were not strongly associated with good performance on the experimental tasks. The correlation between MR and averaging performance (experiment four) showed a small to moderate effect size and this suggests that strengths in spatial perception, attention and concentration may be advantageous during perceptual averaging. More surprisingly, the correlation between congruency accuracy scores on the auditory flanker task and the MR subtests was positive and showed a medium to large effect size. This congruency accuracy variable measured sensitivity to congruency across experimental conditions and appeared to be higher in individuals with higher fluid intelligence.

More difficult to explain was the highly significant correlation between the block design subtest and accuracy scores on the auditory flanker task. One potential explanation is that the block design test measures spatial visualisation and well as spatial ability, and the spatial component may be involved in organising auditory patterns as well as visual ones. The correlation between scores on the family pictures subtest and the auditory flanker test were highly significant for the ASD group but not the control group. This task tests memory for complex visual information presented at different locations, and the ASD group showed strengths on this task. Auditory difficulties are very common in ASD (O'Connor, 2012) and total accuracy scores on the auditory flanker task were lower in the ASD group than the TD group. However, there was considerable variance on the task and the correlations suggested that participants with less marked impairments on visual tasks where the stimuli were relatively complex and included a large spatial component, were less impaired on the auditory flanker task.

Participants with ASD did not perform well on the test measuring immediate memory for spatial arrays of dots (immediate dot location subtest) but this did not appear to influence performance on the auditory flanker test. Poor performance on the immediate Dot locations task is difficult to explain. As participants were required to recreate the presented visual spatial information manually, motor difficulties, common in ASD (Licari et al., 2020) but not tested in the study could have influenced performance. However, the BD task also involved manual manipulation, and the ASD group performed as well as the TD group on this task. Levels of immediate Dot locations task performance were strongly associated with accuracy performance on the visual flanker task and the correlation between this test and the congruency variable was exceptionally high. This might suggest that the cognitive demands of the visual flanker and Dot locations were very similar. On the visual flanker task, perceptual load increased in line with the addition of the distractors, whereas on the dot locations task, perceptual load increased as participants were required to remember the visuospatial locations of increasing numbers of counters on an increasingly larger grid. Consideration of the task demands of the visual and auditory flanker tasks helps explain why the accuracy and RT scores did not correlate across the tasks.

The analysis of the digit span tests from the CMS (Cohen, 1997) revealed a significant group difference, and auditory short term memory difficulties were characteristic in many participants in the ASD group. The group difference was most marked on the backward digit span, which relies more heavily on auditory working memory (Kercood et al., 2014). For the ASD group, the correlation between the numbers backward subtest and visual flanker accuracy and RT scores showed a moderate effect size. However, the correlations between the numbers backward and the auditory flanker accuracy and RT scores were highly significant, and this implicated working memory impairments in poor auditory perception in ASD.

Language abilities are exceptionally variable in the ASD population (Kjelgaard & Tager-Flusberg, 2001) and whilst VIQ scores from the WASI-II (Wechsler, 2011) did not differ across ASD and TD groups, it should be noted that the WASI-II (Wechsler, 2011) does not test complex language skills. The ASD group scored lower than the TD group on the immediate recall of stories and when scores from this subtest were correlated with congruency scores from the visual and auditory flanker tasks, they showed moderate effect sizes. The ability to immediately recall stories significantly correlated with RT congruency scores in the auditory flanker tasks suggesting that poor recall of complex verbal information is associated with slower identification of congruency in auditory information. The implication of these correlations, for our understanding of the cognitive phenotype, merits further study.

Perception and cognitive processing have been studied extensively in ASD, and the designs of the different paradigms presented in this thesis are very similar to those used in published studies investigating cognitive theories of ASD. However, rather than testing cognitive models of ASD, the main aim of the work presented in this thesis was to study heterogeneity in cognitive phenotypes in ASD and evaluate the impact of this on tests of perception and cognition in this group. Although the results from the flanker tasks did reveal group differences in accuracy and RTs, the patterns of performance across the different conditions of the four experiments showed more similarities than differences between ASD and TD groups. The studies did not provide strong evidence for a marked difference in cognitive architecture in ASD. However, it is important to consider the characteristics of the individuals who participated in the studies presented in the thesis. Like the majority of participants in studies testing theoretical models of cognition in ASD, these individuals were intellectually high functioning, achieving full scale IQ scores in the normal range. Yet even within this sample, there was considerable heterogeneity in profiles of skills across the different IQ and memory measures administered. For intellectually lower functioning individuals, heterogeneity in skill profiles may be significantly more marked. Uneven profiles of skills potentially impact on learning styles, and an increased understanding of cognitive heterogeneity in ASD will be important for the ongoing development of educational approaches.

## LIMITATIONS IN THE STUDY

The most notable limitation in the thesis is the relatively small group size. Although group sizes were equivalent to those reported in many published studies, larger groups would have enabled a more detailed exploration of associations between cognitive skills and performance on the experimental tasks. Although some significant correlations did emerge in the analyses, consideration of associations between experimental and background tests often relied on descriptions of effect sizes. With sufficiently large samples, and an expanded battery of background tests, regression analysis could be used, for example, to explain factors predicting increased susceptibility to interference during perceptual processing.

The original design of the study included more background testing than is presented in the thesis. For example, one of the tests initially sent to parents was the Sensory Profile assessment (Dunn, 1999) and information from this test may have provided information on auditory and visual sensitivities that may in turn have influenced performance on visual and auditory flanker tasks. Additional data from tests measuring executive functioning, sensory-motor skills and symptom severity would have provided valuable information about the individual participants' strengths and weaknesses and the level of variability across skills within the ASD group. However, such testing is extremely time consuming and cannot always be accommodated within the school setting. The very low rate of return for parental questionnaires is likely to reflect additional pressures faced by those caring for children with special needs. Understanding heterogeneity within ASD has important educational implications and should be studied within a multi-lab setting. This would allow researchers to identify large data sets that would increase the possibility of identifying cognitive subgroups within the spectrum. This approach would also enable researchers to study developmental changes in cognitive profiles throughout the childhood years in ASD. Changes in conceptualisations of ASD in DSM-5 and ICD-11 have resulted in higher prevalence rates and increased heterogeneity within samples of individuals with ASD and this presents new challenges for researchers working in the field.

In conclusion, the studies described in this thesis investigated atypical perceptual and cognitive processing described in theoretical models of ASD. The findings failed to support current theoretical models and moreover showed that the cognitive profile of ASD is considerably more heterogeneous then is widely believed.

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Goldsmiths
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# APPENDICES

**APPENDIX A:** Information letter

## INFORMATION LETTER

Dear Parent/Guardian,

My name is Sonya Makhmood and I am a first year Psychology doctoral student at Goldsmiths University of London, working under the supervision of Professor Pamela Heaton. I am carrying out research looking into the cognitive strengths in children with Autism Spectrum disorders (ASD) and am writing to ask if you would be happy for your child to participate in my studies.

The areas that are of interest to me concern the children's focus of attention and cognition. I will test this using computer tests and paper and pen tests of memory, attention, and non-verbal intelligence. These tests have all been previously used with children and adolescents and I would hope that the children at your school would enjoy completing them. Testing would take approximately two hours and I would aim to book appointments that are most convenient for the child, parents, and his/her teachers. I would be testing children between the ages of 9 - 14.

The study has been approved by the Ethics committee at Goldsmiths University of London and meets all guidelines for testing children and vulnerable populations detailed by the British Psychological Society. This includes the child's right to withdraw from the study and their right to absolute privacy. Data files will not include any information that would violate each child's right to anonymity.

I would be very happy to provide the school as well as the parents with full feedback on test scores and would also send you any publications that results from the research.

I would be very happy and willing to provide further information regarding my CV, my studies, and ethics as well as giving you further information as to how I will be carrying out and conducting the experiments.

I would also be very happy to meet in person.

If you could please contact me on psp02sm@gold.ac.uk

I look forward to hearing from you.

Yours faithfully,

Sonya Makhmood

Goldsmiths
UNIVERSITY OF LONDON

## **APPENDIX B:** Consent form

### CONSENT FORM

Dear Parent/Guardian,

My name is Sonya Makhmood and I am a first year psychology doctoral student at Goldsmiths University of London, working under the supervision of Professor Pamela Heaton. I am carrying out research looking into 'perception, cognition and heterogeneity in Autism Spectrum Disorders' and am writing to ask if you would be willing to allow your child to participate in my studies.

The areas that are of interest to me concern the children's focus of attention, perception, and memory abilities. I will test this using computerized experimental paradigms and paper and pen tests of memory, language, and non-verbal intelligence. These tests have all been previously used with children and adolescents and I would hope that your child will enjoy completing them. Testing would take approximately two hours and I would aim to book appointments that are most convenient for your child and his/her teachers. The study has been approved by the Ethics committee at Goldsmiths College and meets all guidelines for testing children and vulnerable populations detailed by the British Psychological Society. This includes the child's right to withdraw from the study and their right to absolute privacy. So, data files will not include any information that would violate your child's right to anonymity. I would be very happy to provide you will full feedback on your child's test scores and will also send you any publications that result from the research.

If you would like more information about the aims of my study, or the way I will be carrying it out, please do not hesitate to contact me on the e-mail address detailed below. If you would be happy for your child to participate in my studies, please fill in the section below and return this form to your child's school.

Yours faithfully,

Sonya Makhmood Email contact: psp02sm@gold.ac.uk

I am the parent/ guardian of ________________________________ and agree that s/he may participate in the research studies carried out by Sonya Makhmood and detailed in this letter.

Name ………………………………………………… Date ……….

Yours faithfully,

Sonya Makhmood

Goldsmiths
UNIVERSITY OF LONDON

**APPENDIX C:** Debriefing form

## DEBRIEFING FORM

Dear Parent/Guardian,

Thank you for giving permission and for taking part in my PhD research on 'Perception, cognition and heterogeneity in Autism Spectrum Disorders' (ASD).

The purpose of my study was to explore profiles of cognitive and memory skills in children and adolescents with ASD and TD matched for full scale IQ and chronological age. Variability will be further assessed, and the potential impact of cognitive and memory strengths and weaknesses in relation to the experimental paradigms will be further explored. The results of the studies are yet to be statistically analysed, but a copy of the findings will be made available, and I will also send you any publications that result from the research.

If you have any further questions regarding the research, please feel dree to email me or my supervisor Professor Pamela Heaton whose email address I have also provided below.

Sonya Makhmood: psp02sm@gold.ac.uk
Professor Pamela Heaton: p.heaton@gold.ac.uk

Once again, many thanks for your participation in the study.

Yours faithfully,

Sonya Makhmood

**APPENDIX D:** Visual flanker experimental stimuli

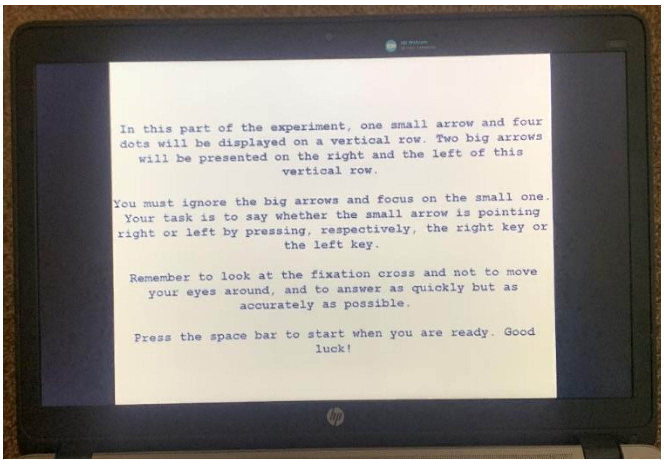


Figure representation of task instructions

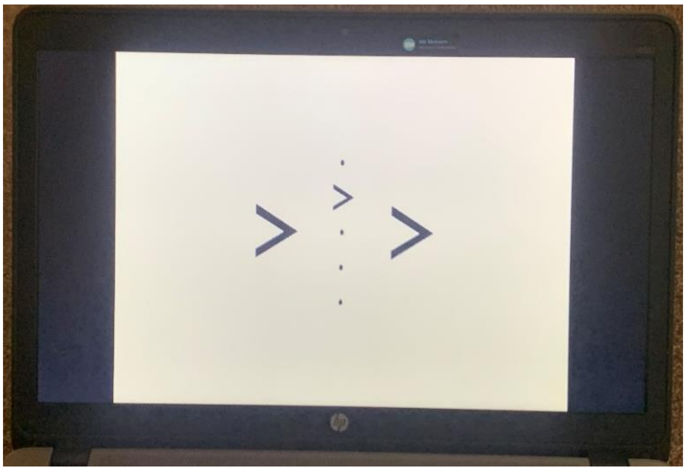

Figure representation of a congruent trial

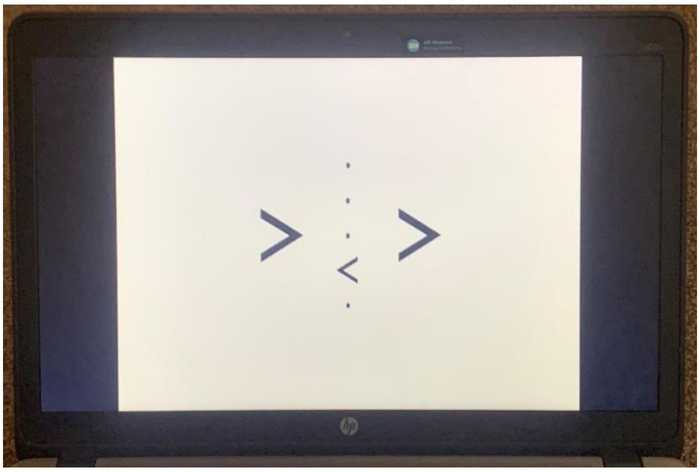

Figure representation of an incongruent trial

**APPENDIX E:** Auditory flanker experimental stimuli

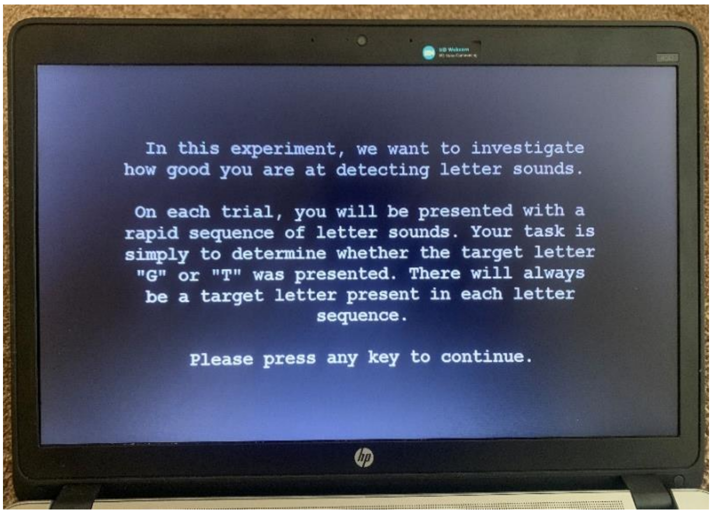


Figure representation of introductory instructions

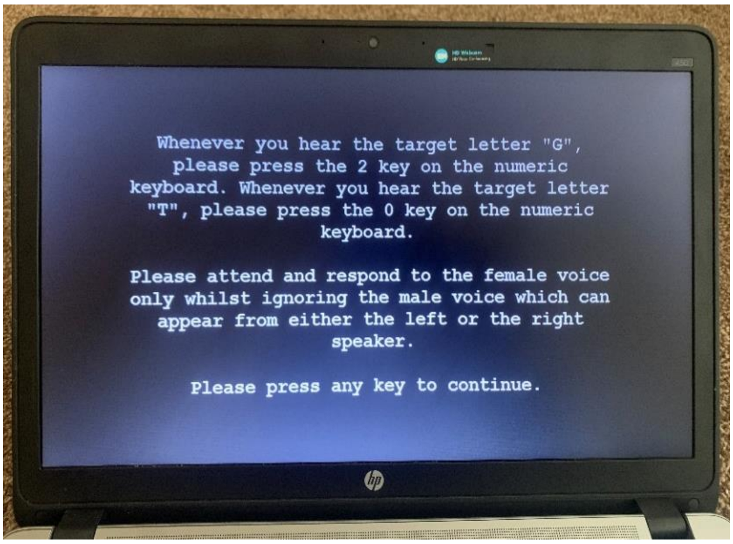


Figure representation of task instructions

**APPENDIX F:** Local/global experimental stimuli

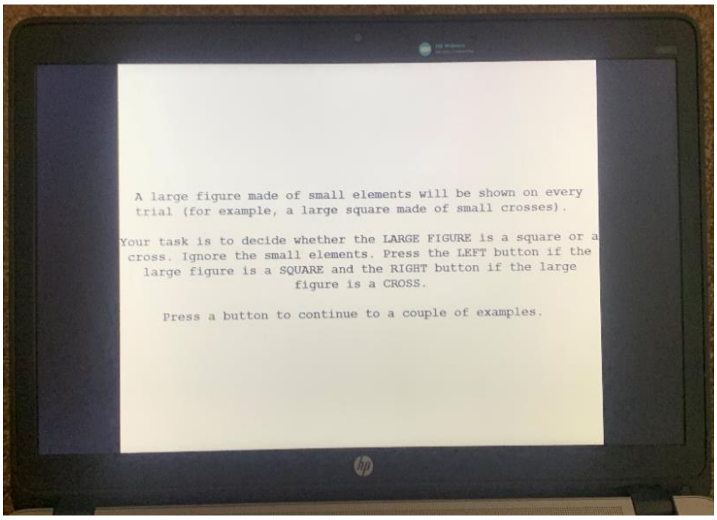


Figure representation of task instructions for global condition

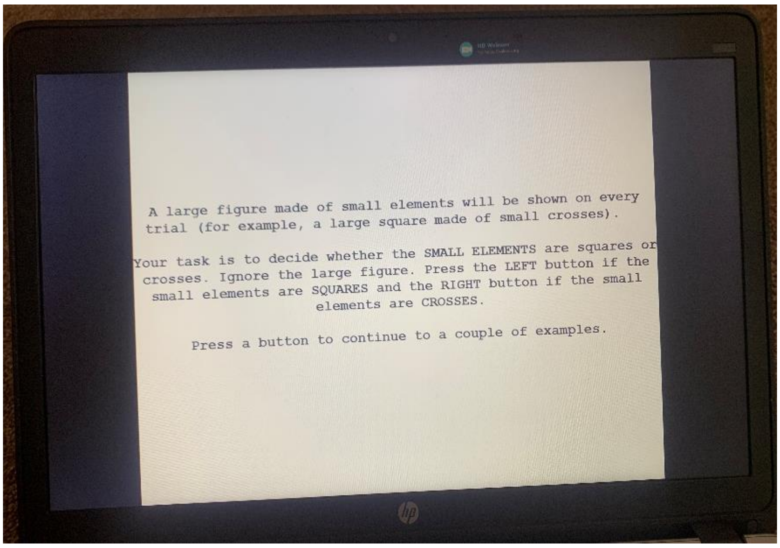


Figure representation of task instructions for local condition

Figure representation of local/global congruent trials

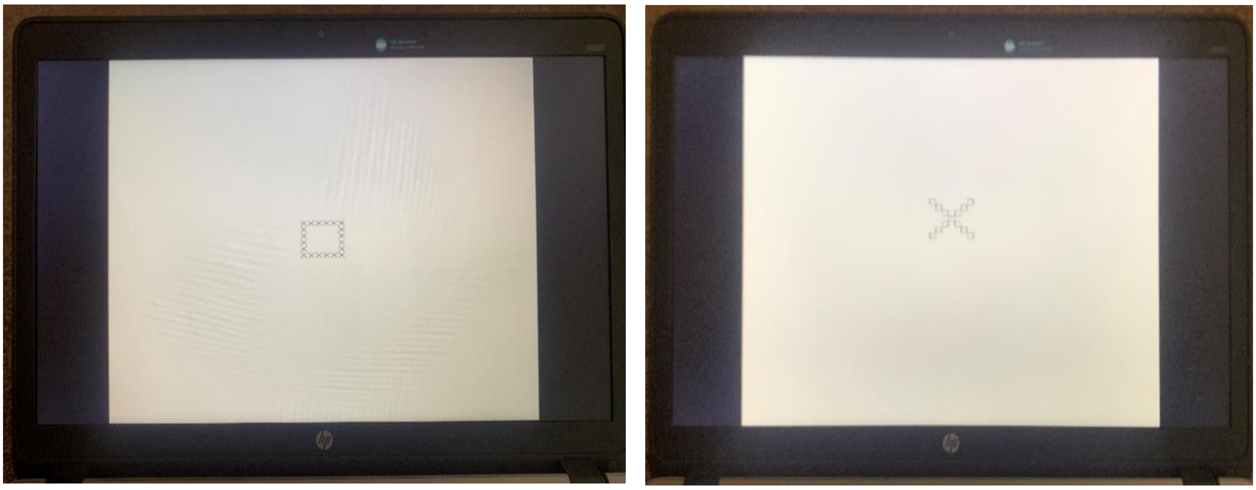

Figure representation of local/global incongruent trials

**APPENDIX G:** Visual averaging experimental stimuli

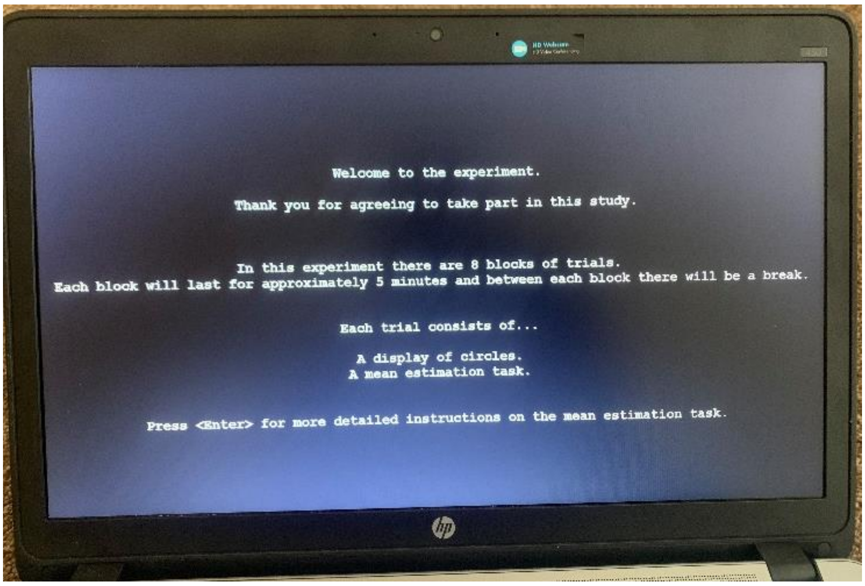


Figure representation of introductory instructions

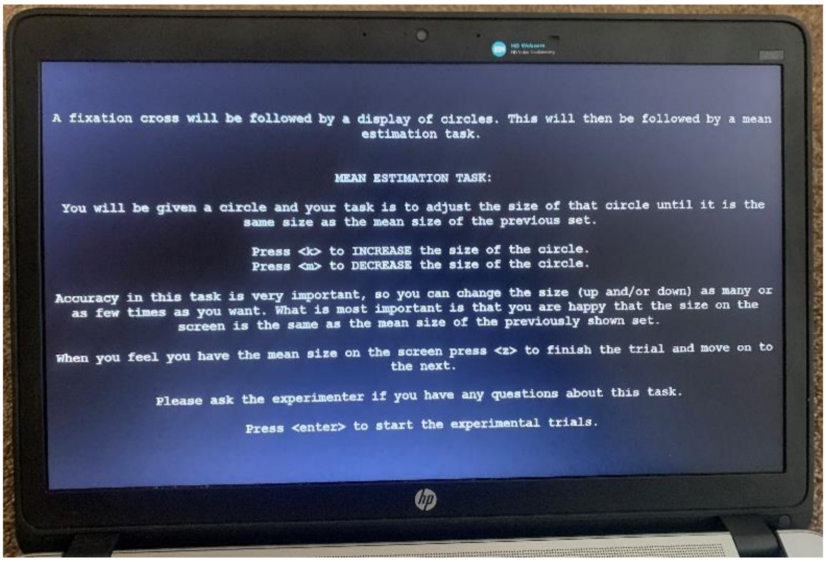


Figure representation of task instructions

Figure representation of set size 4 homogeneous/heterogenous circles

Figure representation of set size 8 homogeneous/heterogenous circles

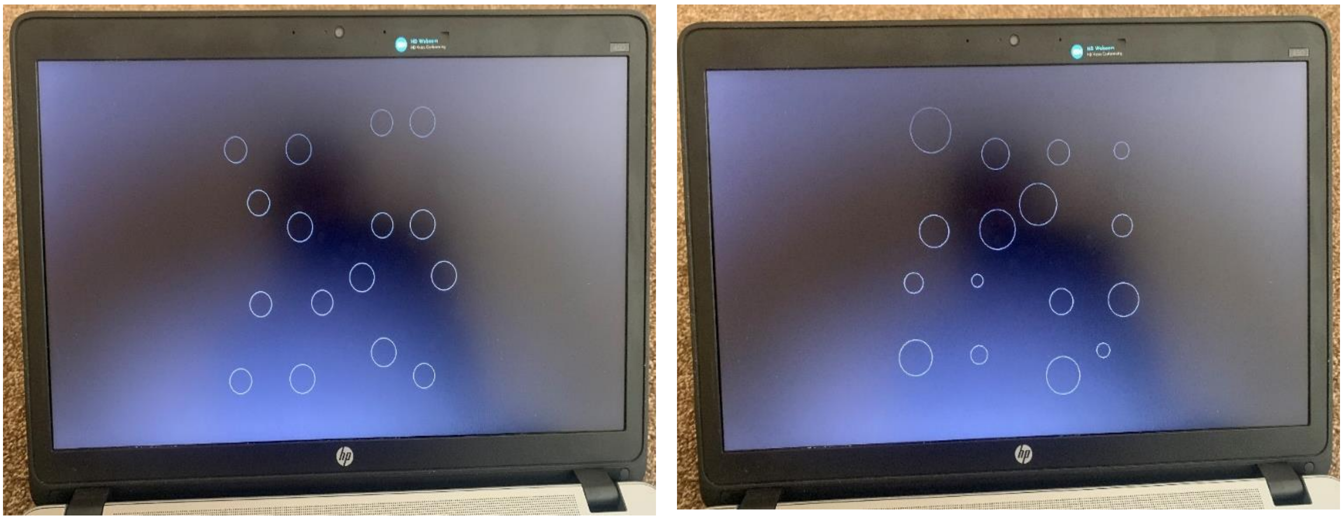

Figure representation of set size 16 homogeneous/heterogenous circles