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**The Role of Declarative Memory in the Acquisition of Conceptual  
Semantic Knowledge in Autism Spectrum Disorder**

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**September 2016**

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## **Abstract**

Based on Ullman's (2004) hypothesis that declarative memory impairment will contribute to language impairment, this thesis presents two experiments that test familiarity and recollection in children with Autism Spectrum Disorder (ASD) and Intellectual Disability (ID). Four experimental groups comprised children and adolescents with ASD with language impairment (ALI); ASD without language impairment (ALN), intellectually disabled children without ASD (ID) and typically developing children (TD). Children were tested on two forced choice recognition tests of familiarity and recollection and a shape recognition and cued action-recall test. The relation between familiarity and conceptual semantic knowledge was investigated whilst controlling for visuo-perceptual abilities and fluid intelligence. Findings confirmed an association between familiarity and conceptual semantic knowledge in the ASD population as well as the use of visuo-perceptual skills to enhance familiarity. The broader role of declarative memory in language is addressed in ASD. Implications for future methods of testing in ASD populations are considered, as are implications of declarative memory anomalies in both ASD and ID populations in educational settings.

# **Chapter One**

## **An Introduction**

### **The Autism Spectrum**

Autism spectrum disorder (ASD) is a neuro-developmental disorder that is present from early childhood. It has been more recently defined by the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM-5, APA, 2013) as a single 'spectrum' disorder that includes disorders that were previously considered separate — autism, Asperger's syndrome, childhood disintegrative disorder and pervasive developmental disorder not otherwise specified (PDD-NOS).

For a current diagnosis, as stated in the DSM-5 (2013), there needs to be evidence of both impairments in social communication and interaction (SCI) as well as restricted and repetitive behaviours (RRB's). Within the SCI domain, deficits must exist across all three sub-categories pertaining to social-emotional reciprocity; non-verbal communication behaviours and in developing and maintaining relationships. Within the domain of restricted, repetitive behaviours, two out of four sub-categories must be met. These include: stereotyped or repetitive speech, motor movements or use of objects; excessive adherence to routines, ritualised patterns of verbal or non-verbal behaviour or excessive resistance to change; highly restricted, fixated interests that are abnormal in intensity or focus; and hyper or hypo-reactivity and/or unusual interest to sensory input. Other determining diagnostic factors must

include the presence of these symptoms from early childhood as well as everyday functioning being limited and/or impaired by the symptoms.

In addition to the diagnostic determinants, the DSM-5 introduces two 'dimensional' features, which are 'severity levels' and the presence or absence of 'specifiers'. Severity levels must be established from three levels ranging from "requiring support" to "requiring very substantial support" for each of the SCI and RRB criteria. The specifiers then require identification as to whether the criteria are accompanied by intellectual and/or language impairment; as well as any known medical or genetic condition or environmental factor, and catatonia.

The first major change from the DSM-IV to DSM-5 is the 'new' term Autistic Spectrum Disorder (ASD). This change reflects a scientific consensus that the four previously identified categories: Asperger's disorder, autistic disorder, childhood disintegrative disorder and pervasive developmental disorder not otherwise specified, are not clearly discriminable, and are more appropriately considered to constitute a single condition (Grzadzinski, Huerta & Lord, 2013; Wing, Gould & Gillberg, 2011). This establishes ASD as more of a dimensional, spectrum disorder rather than defining it in terms of subtypes. The second major change is within the diagnostic criteria where the original 'triad' of core impairments has been collapsed into two (SCI and RRB's) by combining the two domains of impaired social interaction and impaired communication. If no RRB's are present, a new classification defined as 'Social Communication Disorder' can now be diagnosed.

## The Causes of ASD: Cognitive Theories of ASD

Causes of ASD largely remain unknown although it is well established that they are anchored in abnormal neurobiology. Many genes and brain structures have been implicated in the etiology of ASD but as yet, no biological marker for the disorder has been identified. In the absence of such markers, psychological explanations of the disorder have proven useful for guiding interventions and treatment.

There are several challenges when trying to look at what might 'cause' ASD. First there is the more generic problem of establishing what actually constitutes a 'cause' at both theoretical and empirical levels and then how 'unidirectional' a cause may be. For instance, it is difficult at times to establish whether a certain cognitive 'style' (as opposed to a deficit or relative skill), such as enhanced field independence (the ability to separate details from the surrounding context), is a cause or an effect (Happé, 1999). It is also possible that a factor like enhanced field independence has a cyclical effect on other cognitive skills, which further complicates the possibility of trying to single out and separate causes from effects. In addition, the fact that ASD is a *developmental* disorder and causes and effects are likely to change and develop over time makes it much harder to identify a clear-cut cause.

Second, given the nature of ASD's heterogeneity, research has attempted to look for individual causal factors to explain this heterogeneity. However, by looking for a single cause, or even multiple causes in ASD (which is more likely) the focus of the researcher is redirected towards looking for unifying factors at either (neuro)biological and/or cognitive levels, not forgetting environmental possibilities too. As ASD is defined by such heterogeneity it is difficult to establish unifying theories that withstand further research and it

is questionable how useful a unifying theory can be if it cannot accurately and convincingly explain ASD. However, there are four main cognitive theories that continue to be accepted, cited and studied.

The first theory states that ASD is the result of an impaired ability to understand that other people have their own beliefs and thoughts, which is called 'theory of mind' (ToM) (Baron-Cohen, Leslie & Frith, 1985). This impairment has been latterly rendered untenable by multiple studies that have demonstrated that many individuals with ASD do have the ability to imagine the minds of other people (Waterhouse, 2013). Rather it has been shown that performance on ToM tests depend more on cognitive and language abilities than on ToM (van Buijsen, van Buijsen, Hendriks, Ketelaars & Verhoeven, 2011). This theory, to a point, can explain some of the social and communicative difficulties present in ASD. If a child is not able to understand what others are thinking, feeling and believing, it is likely that children (and adults) with ASD will behave in ways that may be perceived by others as divergent from social norms. This is because to behave 'appropriately' in a social context requires a certain level of understanding of others including social cues, facial expressions, and nuances in spoken language, body language and many more. These types of behaviour are often the most striking to a 'non-expert' in ASD but cognitive behaviour in ASD is characterised by many more anomalies in attention, memory and language which may not be immediately obvious to the 'non-expert' observer. There are also some specific limitations to the ToM theory of ASD if measured by tests of false belief. The most obvious limitation is that there are some children, normally those with good verbal skills, who are able to pass tests of false belief.. These children appear to use a different set of skills to solve ToM tasks and 'hack out' solutions rather than utilise any form of mentalising ability (Happé, 1994). Therefore, it is

difficult to operationalize ToM into specific components that can be reliably tested between TD and ASD populations.

In contrast to the ToM hypothesis there is an alternative theory that relates to social motivational ability. Hobson (1993) argues that the primary deficit in ASD is not a difficulty in understanding that other people have their own minds but rather that it is a basic impairment in the biological capacity to engage in social interaction. He suggested that if children with ASD struggle with interaction with others from very early on they would then have fewer opportunities to develop an understanding that other people have minds.

However, one salient factor that the two theories above do not address is that children with ASD find it difficult to draw together different pieces of information to create a meaningful construction of what is perceived (like field dependence mentioned above). This has been re-conceptualised as 'weak central coherence' (WCC) and constitutes another main theory of a cognitive cause of ASD (Frith, 1989; Happé & Frith, 2006). Weak central coherence manifests as an attention to parts or details of, for example a picture, rather than the whole. It may follow that if children with ASD have a fragmented experience of the world, then their behaviour is likely to be fairly meaningless in terms of it containing unintegrated actions that may seem more random or impulsive. In addition, if their actions are responses to fragmented and discrete perceptions then their behaviour may result in being repetitive and restricted.

Children with ASD often have very good visuo-spatial skills and are skilled at finding embedded shapes within a whole picture. During such a task as the Children's Embedded Features Test (Karp & Konstadt, 1963) the embedded shapes do not represent a particular object. Weak central coherence means that children with ASD do not attend to the overall

picture but rather they are drawn to the individual lines and shapes that make up the picture. This results in an ability to locate embedded shapes. The point of this theory is that these abilities are not just confined to looking at pictures but rather that they influence the whole cognitive system. For example, memories from a birthday tea party may be of the pattern on a tea cup rather than an overall memory of whose birthday party it was and whether it was enjoyable or not. Also, at the attentional and perceptual levels, how stimuli are processed may have much to do with weak central coherence. Whether or not this particular aspect of their cognitive behaviour is conceptualised as a strength or a weakness is interesting. Mottron and Burack (2001) have conceptualised this particular cognitive style as an 'enhanced perceptual functioning' ability whilst Plaisted (2001) contends that this 'style' is more to do with enhanced discriminability and reduced generalisation simultaneously.

Another explanation stems from a more generalised deficit of executive function which has been considered as a major cause of ASD (Ozonoff, Pennington & Rogers, 1991). Executive functioning enables us to plan how to achieve a particular goal and relies mainly on the prefrontal cortex. The process of planning (and decision making) requires that immediate attention to a task is put on hold and replaced by another task that has been decided to be more important. If a child with ASD lacks executive control, then their attention may be easily captured by other objects or actions and they may be unable to shift from this. The executive dysfunction theory as an explanation of ASD is a useful one because it manages to account for the broad array of anomalies and difficulties in ASD including both SCI and RRB's. If a child is 'locked' into a basic activity or focused on a particular part of an object then they may find it difficult to plan a way of moving onto something else and shifting their attention. Therefore the behaviour is repeated over and over again.



However, the executive dysfunction account has one major disadvantage and that is that it is not confined to ASD. Deficits in executive functioning can also be found in children who have damage to their frontal lobes (Pennington & Ozonoff, 1996) and although some behavioural similarities will exist these children do not have ASD. Therefore a deficit in executive functioning cannot alone explain the nature of ASD.

A more recent paper came from Pellicano and Burr (2012) who suggested that autistic perception can be explained via Bayesian modelling. Bayesian decision theory states that our perceptions are influenced by a combination of incoming sensory information and prior knowledge about the world. In ASD, this functions in a way that prior beliefs, which generate top-down predictions are compromised which leads to an over reliance on bottom-up sensory evidence. In ASD, the authors propose that these Bayesian priors are attenuated and therefore result in the anomalous perceptual experience evident in ASD, which in turn will influence their whole learning experience. If individuals with ASD are less biased by their prior experiences, then the authors infer that they may see the world more accurately – “as it really is” (Pellicano & Burr, 2012).

This is an interesting account, however, it has been suggested by other researchers that the lack of central coherence typical in ASD could also be attributable to attenuated ‘hyperpriors’ (which refer to the parameters of estimation by prior beliefs) which is not a failure of ‘prediction’, but rather an inability to process top-down predictions during the perceptual synthesis (Friston, Lawson & Frith, 2013). This would mean that there is a failure of beliefs (relating to precision estimation) about beliefs (relating to predictions), which stem from a failure of metacognition which is a complex form of higher order thinking involving awareness of one’s own thinking.

## **The Role of Language in ASD**

The defining features of ASD have always included impaired communication (APA, 2000; WHO, 1992). The role of language impairments in this context, however, has evolved. More specifically structural language impairment was deemed central to autism as defined in the DSM-III (APA, 1987) . However, since Wing's influential writings on Asperger's syndrome (Wing, 1979; 1981a; 1981b) the presence of language abnormalities in autism have not always been considered requisite. She described children clearly who had problems with social interaction and communication as well as behavioural inflexibility, but who did not have significant language impairments. In addition they did not possess relatively lower IQ's, indeed some were above average as well as having precociously large vocabularies. Wing suggested that these individuals should be described as having 'Asperger's syndrome', after the German paediatrician who first described individuals with autistic features but no language or intellectual impairments (Asperger, 1944). Asperger Syndrome was ultimately recognised in the DSM-IV (1994) but in the interim, the DSM-III ® (APA, 1987) reflected these cases by acknowledging that autism can also affect individuals who have no language or learning difficulties. But, at this time, instead of recognising Asperger's syndrome as a form of autism, the emphasis on structural language impairment as a diagnostic criterion reduced whilst the focus on impaired communication increased. Now, however, the DSM-5 recognises language impairment by appointing it as a 'specifier' thus whilst the emphasis on structural language impairment as a diagnostic criterion has reduced over time, the focus has remained on wider social communication impairments including aspects of language pragmatics but primarily also non-verbal behaviours.

Interestingly there is a huge amount of research into impaired social communication in autism, mainly focussing on individuals with normal language at the higher functioning end of the spectrum –referred to in this thesis as the ‘Autistic Language Normal’ (ALN) group. By contrast, there is relatively little recent research into the structural language impairments that most commonly occur in individuals at the lower-functioning end of the spectrum referred to here as the ‘Autistic Language Impaired’ (ALI) group. In addition to the lack of emphasis in research on structural language impairments (LI) in autism, intellectual disability (ID) is also relatively under researched. Yet in around 55% of cases, autism co-occurs with intellectual disability (Charman, Pickles, Simonoff, Chandler, Loucas & Baird, 2010; Elsabbagh, Divan, Koh, Kim, Kauchali, Marcin, Montiel-Nava, Patel, Paula, Wang, Yasamy & Fombonne, 2012). Moreover, LI and ID most often occur together in ALI. There are many more individuals with ALI than ALN with most ALI’s enduring a challenging ‘trio of difficulties’ comprising autistic features, intellectual disability and language impairments (Loucas, Charman, Pickles, Simonoff, Chandler, Meldrum, Baird, 2008; Boucher, 2012; Kjelgaard & Tager-Flusberg, 2001) . This ‘trio’ causes severe lifelong difficulties for individuals with ALI themselves and additionally for their families, carers and educators resulting in substantial governmental costs (Järbrink & Knapp, 2001).

Currently, the outlook for support for adults with ASD, especially those with ALI, is gloomy. A report from the National Autistic Society (Redman, Downie, Rennison & Batten, 2012) asked 323 adults with autism what their experiences of employments and benefits was like using a quantitative questionnaire both online and by post. 71% of these individuals had Aspergers or high functioning autism and the percentage of male and female participants was 74% and 26% respectively. Findings showed that in England nearly two-thirds did not have enough support to meet their needs with at least one in three experiencing severe mental

health difficulties. 51% of adults with autism in the UK have spent time with neither a job, nor access to benefits, 10% of those having been in this position for a decade or more. 61% of those out of work say they want to work and 79% of those on Incapacity Benefit say they want to work (Redman, Downie, Rennison, & Batten, 2009; Rosenblatt, 2008; Wilkins, 2012). There is therefore a strong need for research into LI in ALI such as would contribute to improvements in intervention which would, in turn, positively impact on the futures for individuals themselves, their families, and associated costs. The principal aim of this research is therefore to investigate causes of structural language impairments in ALI. The most common characteristics of structural language in people with ALI will be described in the next chapter. Theories as to the causes of LI in ALI will also be presented and discussed.

## **The Aims of this Thesis**

Following Boucher et al. (2008a), the work reported in this thesis will test the hypothesis that possible causes of LI in ALI are a combination of impaired declarative memory and impaired mindreading ability, whilst fully accepting that other factors such as hearing impairment, comorbid SLI and low nonverbal intelligence may also contribute in individual cases. The first part of the hypothesis is based on Ullman's (2004) argument that declarative memory is necessary for the acquisition of words and word meanings (semantics), whereas procedural memory is necessary for the acquisition of the rules of phonology and grammar. Declarative memory is thought to depend on two distinct but mutually supportive processes, namely recollection and familiarity (Jacoby, 1991; Yonelinas, 2002; Aggleton & Brown, 2006). Recollection is particularly important for episodic memory i.e. memory for personally experienced events, whereas familiarity is particularly important for semantic memory i.e.

memory factual information including words and their meanings. The typical language profile that emerges from group studies of individuals with ALI, as described in the next chapter, is consistent with a declarative memory deficit according to Ullman's theory. Moreover, evidence on memory in ALI indicates a combined impairment of recollection and familiarity. Evidence for this claim will be provided in Chapter Three. Briefly, impaired free recall of events demonstrates impaired recollection and episodic memory (Boucher, 1981; Boucher & Lewis, 1989; Millward et al., 2000) and impaired recognition of numerous kinds of materials including words and pictures (Boucher & Warrington, 1976; Summers & Craik, 1994; Barth et al., 1995; Boucher et al., 2008b) demonstrates impaired familiarity such is essential for semantic memory and for language acquisition. Notably, studies of memory in individuals with ALN reveal milder impairments in declarative memory but with difficulties pertaining selectively to recollection and episodic memory whilst familiarity is spared. Performance on recognition tests is unimpaired indicating intact familiarity and semantic memory (Bowler & Gaigg, 2008), consistent with normal language ability. A preliminary test of the declarative memory explanation of LI in ALI showed that, as predicted, recognition was impaired in ALI (relative to ability-matched typically developing children), and correlated with conceptual knowledge and vocabulary (Boucher et al., 2008b). Although, recognition was also impaired in participants with intellectual disability without autism (ID), there was no correlation with language ability.

The second part of the above hypothesis is based on the argument that 'theory of mind' (the ability to attribute mental states to others) and social engagement are important for early language acquisition (Bloom, 2000; Ahktar & Tomasello, 2000). It also raises the question of what causes LI in individuals with ID. The secondary aim of this research is, therefore, to assess causes of LI in idiopathic ID, looking in particular at the possible effects of low

nonverbal ability. It is recognised that auditory processing impairments, comorbid SLI and sensory or neuromuscular impairments may all contribute to language impairments (Robinson, 1991). These additional factors will form part of the exclusion criteria for participants in attempts to isolate the other factors of interest (memory, theory of mind and non-verbal ability). Language impairment in individuals with idiopathic ID is, like LI in ALI, of practical importance but little researched. Yet recent government reports show that children with intellectual disabilities without autism have profound impairments in language (Dockrell et al., 2012a; Dockrell et al., 2012b). These two reports state that in comparison to children with autism they are relatively more impaired in structural language and whilst phonological skills remain intact there is evidence that their expressive and receptive language skills are further compromised compared to children with ASD's.

There is evidence that non-verbal ability plays a significant role in lexical semantic impairments and this will be investigated in this research. This is the case in both individuals with ALI and ID (Rapin, 1996) but how specific components of NVIQ interact and affect language is still uncertain as well as to what extent. Furthermore, these interactions may be different in ALI and ID. This research should thus contribute to an understanding of the problems these ID children face and to improved therapy and education in their case, as well as contributing both theoretically and practically to an understanding of ALI.

## **Structure of this Thesis**

Chapter Two will review past and present evidence for structural language anomalies in ALN and ALI. It will then attempt to outline some of the possible causes of language impairments

in ASD. As this is the focus of this thesis, Chapter Three is dedicated to memory in ASD. First, memory systems and processes will be outlined followed by a review of declarative memory literature in ASD. General methods comprising all the baseline tests used in this research will be described in Chapters Four and Five and Chapters Six and Seven will include the methods and results of Experiment 1 (Forced Choice Recognition study) and Experiment 2 (Shape Recognition – Action Recall study) respectively. Chapter Eight will then discuss these results along with the implications at theoretical, empirical and educational levels.

## Chapter 2

### Structural Language in ASD

#### Introduction

Early research up until the 1980's showed that 50-75% of individuals with a diagnosis of 'early childhood autism' never acquired functional verbal language skills (Bryson, Clark & Smith, 1988; Rapin, 1991). Today, that percentage is lower for two reasons. First, as noted in the previous chapter, diagnosis up to this point specified that there had to be a clinically significant language impairment. The classification of autism later expanded to include those with Asperger's syndrome (AS) or those with higher functioning forms of autism where language was not significantly affected. This expansion of the classification of ASD to include those with higher functioning forms of autism means that the proportion of those with little or no language is smaller today. Second, as ASD is often diagnosed from an early age, sometimes as young as two years old, early interventions have led an increasing number of children to acquire and develop some verbal skills (Koegel, 2000; Prizant, 1983). However, the actual number of these individuals with a language impairment (LI) has not reduced or changed. The majority of non-verbal individuals with ASD have severe or profound intellectual disability but there is also a small minority who have superior skills that are in advance of their language abilities (Boucher, 2011). It is difficult to estimate the percentage of non-verbal individuals because although 25%-30% is a broad estimate, a number of these will go on to develop minimal language if they have the relevant education or intervention (Wodky, Mathy and Kalb, 2013).



Socio-communicative and pragmatic language impairments, which in part define autism (APA, 2000) have been extensively researched and a review of this literature is beyond the scope of this thesis (for a recent review see Loukusa & Moilanen, 2009). The focus of this thesis is on the large proportion of individuals who have additional structural language difficulties at a clinically significant level. For this reason, only structural language will be investigated in this research, to address the current lack of research here particularly at the lower end of the spectrum.

## **Definitions within structural language**

Structural language refers to the system of items and rules stored in the brain comprising grammar, phonology and semantics. ‘Semantics’ refers to the ‘meaning’ in language (Crystal, 1987), not only vocabulary but also the analysis of sentence meaning which includes many aspects such as prosodic meaning (the way a sentence is said); pragmatic meaning, social and grammatical meaning. It also comprises the study of lexemes, which form the basis of semantic analysis. ‘Grammar’, comprising syntax and morphology, refers to the structure of words, phrases, clauses and sentences and ‘phonology’ is the systematic organisation of speech sounds (phonemes) into speech (phonotactics).

The boundary between semantics and grammar can sometimes become blurred particularly in morphology where connectives such as ‘if’ and ‘but’ belong under the category of grammar ‘grammar’ and alongside ‘semantics’ whereas other morphemes such as pronouns, irregular noun-plural and verb forms fit better under the category ‘semantics’. Also, with sentences that are used in a habitual manner such as “come to think of it” and “think nothing of it” it is

argued that people memorise these types of expressions as part of the process of building up fluent and connected speech. However, these ‘lexicalised sentence stems’ are not necessarily as ‘fixed’ in their structure as conventional idioms and their meaning can be predicted quite accurately from their constituent lexemes (unlike “it’s raining cats and dogs”). This results in an area of usage that is midway between grammar (productive sentence types) and semantics (properties of particular lexical items) (Crystal, 1987). This is particularly relevant, in this instance, to those with ASD, who in spite of possessing a range of semantic impairments are able to use their rote memory skills to remember certain phrases regardless of their meaning. It may then appear that their semantic skills are more highly developed than they actually are.

## **Features of structural language in ASD**

Structural language in ASD is a complex area and there are many factors to address simultaneously and this is difficult. First, it is important to consider the broad scope of impairment across the spectrum: why do some individuals not display any degree of impairment, in fact some show superior skills in specific domains such as rote learning, whilst others at the opposite end might never manage any spoken language? And mid-spectrum there is huge diversity where it is not obvious if language is simply delayed or more complexly deviant (Boucher, 2012).

Second, this extreme diversity continues between individuals where there does not appear to be any particular ‘pattern’ or ‘consistency’ of specific language skills or impairments that cluster together at any point along the spectrum. Therefore two individuals, for example, with either a similar IQ and/or similar autistic symptomology may display a widely different

profile of language abilities. Nevertheless there is an overall ‘typical’ language profile that does emerge when large groups with ASD are assessed but only beyond pre-school age and into adulthood (Boucher, 2012). There is still heterogeneity between individuals but this simultaneous profile demonstrating an overall developmental trajectory consists of impaired comprehension and semantics; whilst phonology and syntax are less affected. This will be discussed below.

## **Etiological factors of structural language in ASD**

For research and interventions into LI in ASD to be effective it is important to understand the possible causes that underpin the diversity of impairments. It is understood that there is no single genetic cause of overall autistic symptomology (Happé , 2006) and this would likely follow for language impairments more specifically. ASD, by definition, requires a broad subset of behaviours to occur together however there is no likely mechanism that would be able to cause this co-occurrence (Happé , 2006; Boucher, 2011; Holt & Monaco, 2011; Szatmari, 2011). Most theories that unify ASD as having a single cause fail at being sufficiently autism-specific because the unifying feature is never only unique to ASD but is also present in cases such as intellectual disability, Alzheimer’s disorder or other disorders (Waterhouse, 2013).

There are already many proposed and understood causes of structural language impairment in ASD and the most ‘unambiguous’ is hearing loss (Rosenhall, Nordin, Sandstrom & Ahlsen, 1999). There is a significant amount of research that demonstrates how an impairment of theory of mind is associated with poor early language skills (Astington & Baird, 2005). There

is also evidence suggesting that the language impairment in autism could be due to *co-morbid SLI* (Tager-Flusberg, 2006; Churchill, 1972). Therefore, if the language impairment is not ‘inherent’ to autism, what exactly is it and how does research account for this? In addition, it is necessary to investigate the relationship between *nonverbal IQ* and structural language impairment as well as addressing existing theories of *visuo-spatial abilities* as a possible contributing factor also. These are all possible causes that will be addressed later in this chapter.

## **Features of the literature on structural language in ASD**

There are several theoretical and empirical factors that need attention when reviewing literature on ASD and language in particular. First, it is important for the purposes of this current research to establish terminology that is helpful, rather than restrictive or absolute, in defining the differing abilities along the spectrum. The studies that are reviewed in this section will either be categorised within ASD as including participants who are ‘language impaired’ (ALI) or ‘language normal’ (ALN). It must be stated that language abilities lie on a continuum in ASD and this boundary is artificial. However, one of the main objectives of this research is to investigate the apparent differing characteristics and explanations of both higher and lower language abilities. More specifically, in this chapter, mean language and verbal abilities in ALI groups refer to standard verbal test scores below 75 and ALN groups above 85. This will extend more strictly into the empirical work within this current research and will be discussed at greater length below. It must also be noted that scores across studies using different measures are not going to equate precisely but it does allow for broader comparisons between ALN and ALI.

Second, a significant proportion of recent studies include mixed ability groups, which is where verbal ability is not differentiated. It is therefore difficult to identify any similarities or differences of structural language anomalies between those with good or poorer verbal ability. However, prior to the late 1980's, all studies of autism would have been with 'language-impaired' (LI) individuals due to the diagnostic criteria at that time so this, in some respects, is more helpful. These early studies provide an invaluable window to structural language in lower functioning autism and are not complicated by mixed ability groups (although ASD symptom severity and IQ may still be diverse). There is unfortunately little research that defines or separates groups with language impairment versus mixed and unselected groups with autism. This is regrettable as language profiles may be different and consequently the needs of these individuals with LI may be different as well as likely greater; and knowledge of this is vital if research is to effectively influence more targeted interventions. Since the diagnostic criteria changed to include individuals with more normal language it has been difficult to identify studies that are solely dedicated to ALI. There has also been much more of a research focus on ALN as well as a large body of studies that include mixed ability groups. At the lower end of the spectrum the needs of individuals are more complex due to their broader and more severe impairments of structural language. This needs to be singled out and investigated.

It is also important to note that from 6.0 – 7.0 years of age some key language impairments pertaining to phonology and syntax begin to resolve in individuals with ASD. So at pre-school age, children with ASD will have a broader range of language impairments than at school age and beyond and at times it is therefore necessary to separate out research at these age boundaries because the overall profile will be different.

As early studies only include participants with ALI, they are dealt with under the ALI heading. They will also be followed by later studies that single out groups with ASD with language impairment (ALI) as opposed to unselected or mixed ability groups.

## **Language Characteristics: Review of Research**

### *ALI – studies that use participants with ASD who have language impairment*

#### *Early studies and more recent ALI specific*

This section comprises research from the early phase prior to diagnosis including HFA/AS – thus all studies were ALI by definition; and later studies that state explicitly that their groups are ALI or similar.

#### *Phonology and syntax in ALI*

Most early studies of school-age children with ALI show that in phonology and syntax, language development is more narrow and delayed rather than deviant and they are grouped together here under the same heading for that reason. When tested on mean length of utterance (MLU) Volden and Lord (1991) found that children with ALI had a significantly shorter MLU than a TD group of younger children matched on receptive vocabulary, whilst the higher functioning groups did not differ. An earlier study that compared language-matched children with developmental delay (DD) without autism to an ALI group found that articulation was superior in the children with ALI (Boucher, 1976). However, in a different study, when ALI's were matched for non-verbal mental age (NVMA) with DD children their

performances were then broadly equated (Bartolucci, Pierce, Streiner & Eppel, 1976). This may indicate that ALI's generally have a disproportionately higher non-verbal ability (akin to fluid intelligence) as compared to their verbal ability (Lord & Paul, 1997; Siegel, Minshew & Goldstein, 1996). This has important implications for matching in experiments because their performance will appear relatively higher when matched on NVMA to a DD group. Matching strategies are absolutely crucial in the study of ASD and some researchers emphasise the need to consider empirical work within a 'mosaic' framework containing smaller but more precise findings rather than that of a 'melting pot' where there may be more grander, broader interpretations of findings that may be less precise (Burack, Iarocci, Flanagan & Bowler (2004). In research that investigates group differences it is therefore important to address the specific context of the comparison groups, the experimental task, the developmental level and the matching measures of the individual study rather than extrapolate this information to a more general understanding. Therefore, in this case, it is important to understand that relative performance on measures such as MLU may be partially determined by the matching measure.

Bartolucci et al., (1976) also reported a delay in phoneme acquisition in both 'verbal autistic' and 'mentally retarded' groups. However, there was a significant correlation between the frequency of phonological errors and overall language development in the 'verbal autistic' group which the authors interpret to be an indication of a global delay in language development, rather than deviant or delayed in certain areas. In addition, Pierce and Bartolucci (1977) found that compared to NVMA-matched in another study, DD children and young typically developing (TD) children, ALI's used a similar rule-governed grammatical system which suggests that syntactic development may be more delayed rather than deviant.

In a sentence comprehension study, ALI's performed similarly to TD's in preferring a word order strategy to a 'probable event' strategy (Tager-Flusberg, 1981) which suggests that syntactic abilities here are MA-appropriate (Boucher, 2012). They also displayed similar preferences in their strategies employed on the task. Also, in another study, despite the fact that ALI's were impaired relative to TD and DD children in comprehension of transitive and intransitive phrases, their response patterns resembled controls (Prior & Hall, 1979). Both of these studies point towards delayed development rather than deviant development in phonology and syntax because of the similarity of strategies and responses used by ALI's to control groups, even if relatively impaired in the latter study (Prior & Hall, 1979).

### *Morphology in ALI*

In morphology, early research points to both deviance and delay amongst ALI's in comprehension and use of personal pronouns, errors of verb tense marking, use of articles and conjunctions and use of closed class words, especially in the early stages of language acquisition (Bartolucci, Pierce & Streiner, 1980; Howlin, 1994; Tager-Flusberg et al., 1990; Waterhouse & Fein, 1982). There are few studies on morphological development in ALI but findings point to early acquired morphological rules being learnt as efficiently in ALI as in controls (Waterhouse & Fein, 1982). It has also been shown that children with ALI (n = 10) are more likely to omit obligatory morphemes than TD and DD controls matched on mental age (MA), which the researchers suggest may reflect a specific delay in morpheme production rather than a more general language delay (Bartolucci, Pierce & Streiner, 1980). In a study of ALI children (mean chronological age (CA) = 9 years) compared to a dysphasic (in today's terms Dysphasia is more akin to Specific Language Impairment, SLI) control group, Cantwell, Baker & Rutter (1978) found similar performance in the use of morphemes in spontaneous speech. The only differences were that the ALI group displayed more



echolalic and abnormal speech. These mixed results may be due to the types of control groups used and the variables on which they were matched. In the Waterhouse & Fein study (1982) a mixed group of developmentally disabled children formed the experimental group and were matched to three different control groups of TD children; one was matched for chronological age, one for MLU and one for performance on a perceptual test. Contrastingly, the Bartolucci et al., study (1980) matched groups of TD and DD children to an ALI experimental group on MA; and the Cantwell et al., study (1978) only used a control group with dysphasia/SLI. These apparently diverse results underscore the relevance of different types of control groups that can be used in developmental research (Eigsti et al., 2011). For instance, when ALI participants are compared to a group matched overall on MA, it may appear that the ALI children have delayed syntactic skills but these may not be apparent when compared to a language impaired DD group matched on IQ. In terms of understanding whether development is deviant or delayed, the role of control groups here is pivotal.

### *Semantics in ALI*

In contrast to findings of delayed rather than deviant phonological and syntactic development, as early as Kanner (1946) semantic development was consistently found to be deviant. The use of idiosyncratic and stereotyped language featured highly amongst ALI's and arguably was a defining difference between children with autism and those with SLI (Bartak, Rutter & Cox, 1995). ALI's tend to use an excess of echolalic, stereotypic and bizarre language and the majority of these utterances relate to a meaning or context that was at the origin of their initial learning (Fay & Schuler, 1980; Prizant & Duchan, 1981). In the case of the 'initial learning phase', Fay and Schuler (1980) state that individuals with autism are severely limited in their understanding of word meanings because they are so bound by this initial learning situation. What occurs in here is that a word or phrase will be learnt with

a single referent rather than a rich, generalisable network of meanings and associations that also adapt and update over time with repeated occurrences (Fay & Schuler, 1980). Thus language will be 'stalled' in terms of its depth and maturity at a young age because first associations are the only associations that are grappled and processed. This therefore sets up a very narrow and inflexible foundation for the building and use of context in language for an individual with ALI and it will likely become more and more narrow as they get older.

The processing of meanings has also been shown to be anomalous amongst ALI's as shown in studies that test sentence recall or recall of semantically related word lists. With TD and DD children, recall on semantically related words is higher than in non-related conditions because they can use meaning to aid recall. However in ALI this is not the case and their performance is not enhanced by semantic relations of to-be-remembered material (Fyffe & Prior, 1978; Hermelin & O'Connor, 1967). Moreover, ALI's are less able to use or rely on lexical or sentential meaning to facilitate verbal recall. What causes this particular impairment was argued to be a fundamental difficulty in the acquisition of conceptual knowledge (Fay & Schuler, 1980; Hermelin & O'Connor, 1970). However, Tager-Flusberg (1991) showed that ALI's can indeed use semantic cues to aid verbal recall but they do not use similar semantic clustering strategies in a spontaneous way as age and verbal IQ-matched developmentally delayed children. This finding was shown in a task that replicated Boucher and Warrington's (1976) study where children were presented with semantically related word sequences in which the words came from a number of categories and random semantically unrelated word strings.

Later studies looking at adolescents have found additional impairments in ALI with spoken word recognition using the gating paradigm (Loucas, Riches, Baird, Pickles, Simonoff,

Chandler & Charman, 2013). A gating task presents listeners with increasingly long fragments of a word (gate) and asks them to identify the word after each gate (Grosjean, 1980). In a study investigating both ALI and SLI, with all groups including TD matched on non-verbal IQ, adolescents with ALI needed additional speech input to identify low-frequency words which have low competitor density, i.e. fewer already formed lexical representations. The authors speculate that these differences could be due to less well-specified word form representations, which may affect spoken word recognition.

Contrastingly, an earlier study by some of the same authors testing for interpretation of compound nouns in adolescents found that both SLI and ALI groups performed similarly in that their difficulties extended to processes of word formation which may reflect difficulties in making analogies with stored lexical items (Riches, Loucas, Baird, Charman & Simonoff, 2012). The authors conclude that these results support the hypothesis of a phenotypic overlap between SLI and ALI and this will be discussed briefly in the section relating to causes of LI in ALI. But first, studies with mixed ability groups will be reviewed that do not differentiate between ALI and ALN.

### *ALI and mixed ability*

#### **Preschool age**

With the advent of advances in early diagnosis, research started to show that the notion of a language delay in ALI was an oversimplification and that indeed language patterns in children with autism were different to both TD and DD children. According to Rapin &

Dunn (2003) 63% of pre-school children with autism with language impairment (ALI) have impaired phonology and grammar whilst only 37% have problems with ‘semantic meaning’ (defined in this study by a diagnosis of a higher processing order involving receptive and expressive semantics). Wolk and Giesen (2000) confirm deviant and delayed phonological impairments in pre-school children as shown in their case studies of four siblings. Impaired grammar has also been found by Eigsti, Bennetto & Dadlani (2007) in a comprehensive study that investigated three key areas of structural language. These areas were measured using the Inventory of Productive Syntax (IPSyn; Scarborough, 1990); Mean Length of Utterance (MLU) as measured in morphemes; and Number of Different Word Roots (NDWR) to assess lexical-semantic knowledge. On the IPSyn, children with ASD were not only significantly impaired compared to age, language and non verbal IQ matched TD and DD children; but they also showed a different pattern of scores which again shows a deviant as well as delayed type of development. Children with ASD also had shorter MLU than both the TD and DD groups but by contrast they produced a similar number of word roots as the TD group and significantly more than the DD group. In addition they produced significantly more jargon than both control groups.

In a large-scale study, Charman, Drew, Baird & Baird (2003) found that pre-school children with ASD had delayed language onset and a slowed rate of development. More specifically, phrasal understanding achieved by TD children at age 1 year and 4 months was not reached (as a group) until age 4:0, and a non-verbal mental age of 3 years 6 months in ASD children. This same study as well as another large scale study by Luyster, Lopez & Lord (2007) also found that children with ASD understood more words and phrases than they used spontaneously, following the normal pattern. However, what was interesting in both of these studies is that the divergence between comprehension and production was much smaller in

the ASD group than in the TD group (Hudry et al., 2010). This may be due to children with ASD using words and phrases without accessing their full meaning (Charman et al., 2003).

It is interesting to note that up until the age of 6 years there is clear evidence that children with ASD have significantly delayed language development in the areas of phonology and grammar. This finding is contrary to the results of earlier studies carried out with the school-age children with ALI where phonology and grammar improve dramatically but semantic difficulties are retained. Rapin & Dunn (2003) suggest that this is due to a change in the profile of language impairments with age; which highlights the non-linear nature of the developmental language trajectory in ALI. They also speculate that the children in the groups previously mentioned may have had a higher non-verbal IQ than the children in their study but this was challenged with findings from Eigsti et al., (2007).

In a follow up study with the same children Rapin, Dunn, Allen, Stevens & Fein (2009) reassessed the pre-schoolers when they were 7 and then 9 years old. 11% of the group had clinically normal language and 73% had unimpaired articulation with mild or moderate impairments of higher order syntactic and semantic comprehension. This pattern conformed in general terms to the language profile that had been identified by the earlier studies of school age ALI's mentioned above. For the 26% of children remaining, the majority were globally impaired both linguistically and intellectually apart from a small subset who had unimpaired comprehension but severe articulatory impairments. These findings have contributed significantly to our understanding of language profiles in ASD and particularly to what extent certain aspects of language impairments may resolve with age, but interestingly not in all cases.

Geurts and Embrechts (2008) found similar results supporting Rapin et al., (2009) study whereby at preschool age the language profiles of children with ASD largely resembled those of children with SLI. This included expressive phonological and syntactical impairments; however by school age the language profiles in the two groups had diverged. This is mainly due to higher order processing and pragmatic language impairments that become more dominant in children with ASD as they get older whereas in SLI, pragmatic development is conserved yet grammar and syntax are still impaired. Similarly, Bennetto et al., (2008) showed that structural language impairments were more common in children with ASD when assessed at 7 years of age and that these impairments at this particular age are likely to predict continued impairments into adolescence.

Park et al., (2012) showed that young children in a mixed ability group (3-6 years) with autism demonstrate an uneven pattern of language development specifically in morphological and syntactic skills. Contrary to their hypothesis, only some skills (such as the use of verb phrases) were atypical, some were delayed due to overall developmental delay (the use of regular plurals, noun phrases, sentence structures, length of utterances as well as past tense and third person singular). Some skills were intact (the use of –ing, auxiliary verbs, contractible copula verbs and articles; questions and negation). These results differ quite substantially from those of a similar study conducted by Eigsti et al., (2007). Whilst Park et al., (2012) found that there were only impairments on a few of the measures, Eigsti et al., (2007) found a more consistent profile of impairments, which included a less developed use of noun and verb phrases, questions and negation and sentence structure when compared to both TD and DD children. Both studies used the Index of Productive Syntax (IPSyn, Moyle & Long, 2013) however, there were other methodological differences that could contribute to the discrepancy in findings, such as smaller sample sizes in the Park et al., (2012) study as

well as language samples that were collected from the ADOS rather than free-play sessions. In addition, unlike the Eigsti et al., (2007) study, the Park et al., study (2012) used a mixed ability group and the within-group variability was consistent with previous research that investigated heterogeneity within autistic populations (Jarrod, Boucher & Russell; 1997). Park et al., (2012) acknowledge that larger sample sizes are required to test within-group variability, which is critical to understanding the sub-groups of language skills present in autism.

### **School age and adult**

Having looked at the pattern of profiles in the earlier years, language at school age, as well as in adulthood, needs attention. Kjelgaard and Tager-Flusberg (2001) assessed language in a group of 89 children with autism between the ages of 4;0 and 14;0 years. They administered a wide battery of tests from the Clinical Evaluation of Language Fundamentals—Third Edition UK (CELF-3UK; Semel, Wiig, & Secord, 2000) and calculated participant scores against age appropriate norms. Given the wide range in both age and ability the results were heterogeneous. Yet when the scores were grouped into categories for normal language, language impaired (ALI) and borderline language, based on vocabulary comprehension, the pattern emerged that was noted in earlier studies with school-age children with ALI. Specifically, phonological impairments were absent in the normal and borderline groups and only mild in the ALI group. Expressive and receptive single word vocabularies were relatively more impaired than articulation in all three groups but most significantly in the ALI group. Only 44 out of the 89 children were able to complete all the tests and amongst them higher order receptive and expressive language was more impaired than single word vocabulary. The other half of the participants were unable to complete the tests which is

indicative of the low ability level of some of the participants. Productive syntax was least affected throughout the whole sample whereas receptive language was markedly more impaired than expressive language. In terms of age and previous patterns of language mentioned above, interestingly the scores from the children that did the preschool CELF were lower than standard scores from those that did the CELF-3 UK for ages 6 years and above (Semel et al., 2000). This is consistent with Rapin et al.,'s (2009) findings that suggest that structural language impairment in autism is relatively more pronounced in the early preschool years as the profile changes with age.

Syntactic abilities, specifically grammatical structures in spontaneous language, have been found to be relatively intact in school age children with ASD (Condouris, Meyer & Tager-Flusberg, 2003). Also, in ALI's from 6:0 years, use of syntax was unimpaired compared to TD children and superior to children with SLI (Shulman & Guberman, 2007). This marks a difference in language abilities and profiles between children with SLI and ASD and is further confirmed by studies also reporting superior performance of ALI's on tests of the comprehension of grammar (Botting & Conti-Ramsden, 2003) and the processing of syntactic complexity (Riches, Loucas, Baird, Charman and Simonoff, 2010).

Further differences between ASD and SLI are found in an interesting study by Loucas, Charman, Pickles, Simonoff, Chandler, Meldrum & Baird, (2008) that investigated whether the co-occurrence of ASD and language impairment is linked with differences of severity or pattern of autistic symptomatology or language profile. Findings indicated that on the Social Communication Questionnaire (SCQ; Rutter, Bailey & Lord, 2003), a ratings scale for ASD, ALI's did not exhibit more autistic symptoms than ALN's and that children with SLI were well below the threshold for the number of traits related to ASD. Interestingly, in ALI's the



combination of ASD and language impairment was linked with weaker functional communication and more severe receptive language difficulties than those found in SLI. Whilst receptive and expressive language were equally impaired in ALI, receptive language was stronger than expressive language in SLI. The authors conclude that the co-occurrence of ASD and LI is not associated with increased autistic symptomatology but rather with greater impairment in receptive language and functional communication.

Unlike syntax, difficulties with morphology are often present in children with ASD. Three studies have found similar results. Condouris et al., (2003), mentioned above, reported that in ALI's, the mean MLU as measured by morphemes was 2 standard deviations (SD) below age-related norms in spite of the fact that vocabulary comprehension was around normal in most participants. Also, in a follow-up study from the Tager-Flusberg et al., (2001) study mentioned above, three groups of children (ALI, ALN and borderline) were tested for production of verb tense endings.

The ALI group showed marked impairments and some morphological errors but the normal language and borderline language groups also showed error in use of irregular past tense verbs such as 'spoke' and 'ran' (Roberts, Rice and Tager-Flusberg, 2004). Botting and Conti-Ramsden (2003) also found deviant use of verb tense marking in school age children with ALI but the type of errors were not recorded as part of the study. These findings point jointly towards an impairment in the acquisition and use of certain types of morphemes, such as past tense endings.

Lexical-semantic ability has already been shown previously to throw up varying difficulties for children with ALI. In a word fluency task, children aged 4-9 with ALI were more likely to

choose unusual words like ‘aardvark’ over more prototypical items (Dunn, Gomes & Sebastian, 1996). Compared to their TD counterparts who instead chose more ‘predictable’ and ‘likely’ items this indicates a possible difference in semantic organisation (Eigsti et al., 2011). Moreover, in a word fluency task, it is more usual for participants to remember items in clusters of semantic meaning or informal categories. For example, if a participant remembers the word ‘sheep’, this will likely prompt them to remember other similar words of closer semantic meaning, such as other animals: ‘pig’, ‘cow’ and so on. Therefore, the use of unusual words such as ‘aardvark’ could derive from reduced reliance on semantic connections that could normally aid word fluency, as it does in TD populations.

In the study above by Condouris et al.; (2003) mean scores on a test of number of different word roots (NDWR) from a natural language sample were also 2 SD’s below age-related norms like MLU but this finding differs from a later study that found NDWR to be unimpaired in preschool children relative to a TD group and superior to a DD group (Eigsti et al., 2007). However, Condouris et al.’s study was with older children and this finding may be explained by the formulaic and repetitive nature of spontaneous language used and ‘learnt’ by adults with ALI (Perkins, Dobbison, Boucher, Bol & Bloom, 2006). The Perkins et al. study looked at natural language samples from seven young adults with ALI and noted that they show a repeated preference for certain lexical items, phrases and also grammatical structures which would limit the range and variety of words and word forms used. Referring back to Fay & Schuler’s (1980) point earlier of first learnt language words and structures, this further highlights the paucity of language ‘experience’ and context amongst ALI’s. In a more recent study, single sentence level semantic processing was found to be intact in a mixed ability group of children with ASD (mean verbal IQ = 77) when dative (a grammatical case indicating the indirect object of a verb) expressions used a prepositional phrase, such as ‘to’,

but when the dative action was expressed in the syntax they were relatively impaired (Stockbridge, Happé & White, 2014). Hence the group with autism here performed more poorly when the dative expression could be syntactically alternated than when it was restricted. The authors argue that this may be due to a weakness in central coherence and this is discussed further below.

### *ALN – studies that use participants with ASD who have normal language*

Structural language, as defined in the DSM-5 (APA, 2013), may appear to be ‘fairly normal’ in high functioning ASD (HFA), or ALN, but on closer examination this is not the case.

Within phonology, whilst Kjelgaard & Tager-Flusberg (2001) found that articulation was normal in ALN’s, Shriberg, Paul, McSweeney, Klin and Cohen (2001) found that a third of their participants with ALN had sub-phonemic articulatory distortions (e.g. with ‘r’ and ‘s’).

More recently, Cleland, Gibbon, Peppe, O’Hare and Rutherford (2010) reported that a higher 41% of their participants with ASD with normal language had several articulatory errors with 12% of the total group having impairments that were clinically significant.

Whilst Asperger described language used by his patients to be superior in breadth (Asperger, 1944/1991; translated in Frith, 1991), later studies found receptive and expressive vocabularies to be average (Kjelgaard & Tager-Flusberg, 2001) or in the low normal range (Howlin, 2003). Furthermore, higher order language processing is more impaired than vocabulary (Kjelgaard & Tager-Flusberg, 2001) with comprehension being more affected (Salaasti et al., 2008). The picture that begins to emerge from these findings is that performance on ‘simple’ tests may generally resemble controls but on more ‘complex’ tasks

impairments and anomalies start to appear. This is further confirmed in a study that tested performance on more 'simple' tests, such as the vocabulary subtest from the Weschler scales (Weschler, 1997,a,b); compared with more 'complex' tests of reading comprehension (Minschew, Goldstein & Siegel, 2006). Although it does not suggest that every individual with ALN has below average performance on complex language tasks, it nevertheless demonstrates that semantic and grammatical profiles in ALN do not follow the same pattern as TD individuals.

The precise nature of these differences is not obvious and requires exploration. The idiosyncratic nature of language use regularly observed in ALN's (Mayes & Calhoun, 2001; Volden & Lord, 1991) suggests differences in their semantic processing.

Volden & Lord (1991) looked at samples of natural language and found that real words were often used with incorrect meaning such as 'waves' for 'leaves'. In addition, Dunn, Gomes & Sebastian (1996) found an excess of low frequency responses in a category-cued word fluency test compared to groups with either SLI or TD. Also, naming speed for low frequency stimuli was shown to be superior in ALN but contrastingly impaired for high frequency stimuli (Walenski, Mostofsky, Gidley-Larson & Ullman, 2008). In addition, Kelley, Paul, Fein and Naigles (2006) found that children who no longer had diagnoses of ALN, despite showing intact receptive and expressive vocabularies, still showed immature lexical knowledge on a test of the understanding of verb-argument structures but performed normally on single word comprehension and naming tests. Verbal memory, also, is indicative of anomalous semantic processing. In particular, the use of semantic clustering is impaired (Bowler, Matthews & Gardiner, 1997). In another study, it was found that neurotypical individuals develop similar sequences in recall of words over repeated trials, but individuals with ALN developed idiosyncratic sequences (Bowler, Gaigg & Gardiner, 2008).

Results from tests of semantic knowledge in ALN may sometimes appear comparable to TD populations and therefore may be interpreted as ‘normal’. For example, use of category cues in single word recall has been shown to be unimpaired in ALN’s (Mottron, Morasse & Belleville, 2001; Whitehouse, Maybery & Durkin, 2007) but ‘normal’ performance on these tests does not necessarily indicate ‘normal’ semantic processing. Kelley et al., (2006) note that whilst vocabulary tests assess knowledge of the identification function of words they do not probe conceptual networks that underpin word meanings. Hence there are different levels of semantic processing some of which are shown not to be intact even in ALN. Dunn and Bates (2005) support this observation and note that individuals with autism do not seem able to extract and apply commonalities among category numbers. The fact that they are contrastingly able to comprehend basic concepts and word meanings can appear misleading to researchers if the varying levels of semantic processing are not investigated.

Grammatical impairments in ALN are less clear-cut and there is mixed evidence in both syntax and morphology. Kelley et al.,’s (2006) study found intact productive morphology and syntax alongside the subtle impairments of lexical-semantic knowledge and processing. Similarly, a more recent study by Diehl, Bennetto, Watson, Gunlogson and McDonough (2008) showed that use of syntax to disambiguate sentential meaning was not impaired in an ALN group who were matched to a control group for full scale IQ (FSIQ) and receptive language scores on the CELF. Contrastingly, Volden and Lord (1991) report that grammatical errors (unrelated to development) were significantly more common in school age children with ALN than in controls correlating also with MLU. In addition, Eigsti and Bennetto (2009) found a reduced sensitivity to grammatical errors in children with ALN but this

reduced sensitivity only occurred when errors were embedded in long sentences which may suggest that memory load is implicated here (Boucher, 2012).

Interestingly, a study by Tyson, Kelley, Fein, Orinstein, Troyb, Bartron, Eigsti, Naigles, Schultsz, Stevens, Helt & Rosenthal (2013) found support for language relying on verbal memory even in individuals who had an original diagnosis of ASD and were now considered 'optimal outcome' (OO) with no further diagnosis. Even if some individuals lose their ASD diagnosis, they found that subtle weaknesses in language may still persist. Although their OO group scored similarly to their TD group, unlike their higher functioning (HFA) group who performed relatively lower on multiple language measures, even when controlling for verbal IQ, the OO group still showed that their language demonstrated greater reliance on verbal memory.

A number of useful pointers regarding expressive language development in both ALI and ALN have come from a recent study by Tek, Mesite, Fein and Naigles (2014) who found that there are likely two distinct language profiles children with ASD. Tek et al., (2014) stress the importance of separating ALN and ALI in research due to the fact that these two distinct profiles suggest two distinct developmental trajectories within ASD. They found that children with low verbal skills, (ASD-LV; broadly similar to ALI) showed a flatter trajectory across most expressive language measures and that their impairments were more indicative of a global delay; whereas children with higher verbal skills (ASD-HV; similar to ALN) not only had far fewer impairments but that they were also more specific to acquisition of certain grammatical structures, such as wh-question complexity. The implications of these findings are that if there are phenotypic differences at this level, this may suggest genotypic differences that are useful for identifying genetically meaningful subgroups in autism. For

example, these subgroups may overlap with other developmental disorders such as SLI. However, one limitation of this study, by the authors' own admission, was that only expressive language was investigated and it would be extremely useful to know if such patterns were similar in language comprehension. Tek et al., (2014) also highlight a fundamental difficulty that is present within language research with children with ASD. Not only is it not useful to draw conclusions from mixed ability groups but also it is vital to recognise that because language acquisition is steeper at younger ages experimental groups need to equate verbal ages using a more narrow range to pinpoint this.

## **Possible Causes of Structural Language Impairment in ASD: Theories and Findings**

It has now been recognised that there is unlikely a single cause to ASD (Waterhouse, 2013; Boucher, 2011; Szatmari, 2011; Happé, 2006). Although the unifying factor of ASD is the co-occurrence of a specific set of separate behavioural and physical disorders, there are no serious attempts at proposing that one single mechanism either in the brain or less likely in the environment causes this range of symptoms (Waterhouse, 2013). Happé et al., (2006) have argued that each of the diagnostic criteria for ASD is separate but the question is why these features occur together at above chance rates. It remains a key question as to why this occurs and Boucher (2011) stresses the difficulty in explaining how such a co-occurrence of different symptoms in varying combinations could have created a single unified autism brain dysfunction. Therefore whilst it is unknown as to why or how any mechanism would cause the wide range of individual variation in ASD to form itself into a meaningful continuum, it is still essential to look at a range of valid causal factors.

There are several proposed causal factors that arguably contribute to an impairment in structural language in ASD, such as Theory of Mind impairment; co-morbid specific language impairment (SLI), low nonverbal IQ and declarative memory impairment. It is also recognised that any additional hearing impairment will affect language acquisition and despite its bearing this will not be discussed here. In addition to these possible causes it is also necessary to examine how these causes may contribute to the main anomalies in structural language impairment described earlier: that is how is it that structural language impairment in ASD is simultaneously delayed, deviant and heterogeneous across the spectrum? Any valid causal factors of LI in ASD must be able to account for these 3 key language anomalies, not necessarily all together.

### ***Specific Language Impairment***

Earlier research has suggested that comorbid SLI constitutes a possible explanation of LI in ASD (Churchill, 1972; Rutter, Bartak & Newman, 1971). This was later rejected by evidence from longitudinal studies (Bartak et al., 1975, 1977; Cantwell, Baker & Rutter, 1978). More recently there has been renewed interest and it has been proposed by Tager-Flusberg and colleagues that there is a partial overlap between SLI and ASD. They propose that among children with ASD there exists a subgroup who have both ASD and SLI whom they named '*ALI*' (note the italics), which is not to be confused with the terminology that is used consistently in this research referring to individuals with ASD and language impairment (ALI). Tager-Flusberg and colleagues have presented findings showing similar language profiles as well as structural brain abnormalities in both SLI and *ALI*. There are similarities at



a behavioural level where certain ‘marker behaviours’ that feature in SLI are also seen in *ALI*. For example, impaired non-word repetition and confirmation of errors in verb tense marking are usually associated with SLI. However they have also been found to be present in some cases of *ALI* (Kjelgaard & Tager-Flusberg, 2001; Roberts et al., 2004). In their follow-up study of Kjelgaard & Tager Flusberg’s original study, Roberts et al., (2004) found that their *ALI* group made fewer correct responses on a past tense verb marking task and on 3<sup>rd</sup> person singular tests. Roberts et al., (2004) interpreted this finding to be an indication of a significant similarity between *ALI* and SLI that would support the notion that co-morbid SLI is a main cause of LI in ASD. However, Williams, Botting and Boucher (2008) conducted a re-analysis of Roberts et al.,’s (2004) findings and proposed that the types of errors made by the children in the *ALI* group were qualitatively different from the errors that are typically made by children with SLI. One example of this was that echolalic responses by children with *ALI* were collectively classified as being ‘no response’. Echolalia is a key trait in ASD and not in SLI, and a more extensive analysis of participants’ responses is shown to be necessary. For a more detailed account, see Williams et al., (2008) but this one example alone highlights the point that there is evidence for separate types of language difficulties in SLI and ASD.

There is also a significant amount of research that has reported a subgroup of children with SLI who also have pragmatic impairments similar to those seen in ASD, sometimes with additional semantic impairments but with intact phonology and grammar (Bishop & Norbury, 2002; Botting & Conti-Ramsden, 1999; Rapin & Allen, 1983). Interestingly there is also a subgroup of individuals with ASD that demonstrates phonological impairments in the absence of any intellectual disability or impairment of comprehension. These tend to be older individuals so their phonological difficulties would have usually resolved, yet instead, their

profile seems to correspond more with individuals with SLI (Cleland et al., 2010; Rapin et al., 2009). So there is an evident overlap from each disorder at a behavioural level. Bishop (2010) suggests that there is a genetic overlap as seen when cases of SLI resemble those of ALI and although such overlap represents only a minority of cases, it is unlikely to be due to chance.

However, the typical language profile in ASD is very different to SLI because expression rather than comprehension is more usually impaired in SLI; as well as grammatical and phonological impairments being present (Loucas et al., 2008; Leonard, 2000). In another study that examined performance on measures of structural language and a structured narrative task, it was found that children with ASD were relatively more impaired on receptive language whereas they were equated on expressive language standardised tests compared to their SLI counterparts (Manolitsi & Botting, 2011). More specifically, scores on the CELF-R (5-17 years) and CELF-P (3-7 years) (Clinical Evaluations of Language Fundamentals; Semel et al., 1987; Wiig et al., 1992) showed similar language profiles overall for both ASD and SLI groups but the ASD groups performed significantly less well on the subtests of linguistic concepts and sentence structure. By contrast, the measures using narrative skills elicited a significantly poorer performance in the ASD group where expressive skills were employed. These skills comprised wider story-telling and referencing within sentence-levels. This study is a clear example of where certain tests are sensitive enough to pick up these differences that may otherwise not be revealed by other behavioural tests. The authors conclude that 'narrative' may be a useful tool for showing qualitative differences in language as it provides extra information that is more usually lost in more formal tests.

It could be argued, therefore, that comorbid SLI is not necessarily a major constituent factor of ASD. To dismiss its contribution however would be injudicious and both the Cleland et al., (2010) and Rapin et al., (2009) studies show that in a minority of cases comorbid SLI is a likely contributory cause. This could explain the heterogeneity not just at different points along the spectrum but also at similar severity levels.

However, there is some evidence to suggest that there may be behavioural, neurobiological and etiological differences in a majority of cases (Williams, Botting & Boucher, 2008). From their review of evidence of a possible overlap between ALI and SLI, Williams et al., (2008) concluded that overall there were many more specific differences in the language domain rather than similarities. They also proposed that it would be more useful for research to focus on the varying types of language impairments that are present in ASD and SLI and to examine them separately from one another. Finally, Tomblin (2011) makes a valid point that most of this debate is fuelled by the presumption that SLI constitutes a unique kind of language learner. He argues overall that most of the features that are characteristic of SLI are also found in other neurodevelopmental disorders and that research should re-focus on why there are so many children with ASD who have poor language?

### ***Implicit Mindreading***

It is widely recognised that impaired mindreading is implicated in the communicative impairments that are diagnostic of ASD (Sperber & Wilson, 2002). A deficit in implicit mindreading has to originate from earlier impairments such as dyadic relating and empathy (Charman et al., 1997; Sigman, Kasari, Kwon & Yirmiya, 1992); ability to imitate the actions

of others spontaneously (Carpenter, Tomasello & Striano, 2005; Charman et al., 1997); a predisposition to respond preferentially to faces and voices (Baranek, 1999; Dawson, Meltzoff, Osterling, Rinaldi & Brown, 1998; Dawson et al., 2004; Klin, 1991; Kuhl, Coffey-Corina, Padden & Dawson, 2005); and impairments with timing that would impact on rhythmicity and synchronisation of interactions between infant and caregiver (Gernsbacher, Sazuer, Geye, Schweigert & Goldsmith, 2008; Wimpory, Nicholas & Nash, 2002).

Furthermore, these early impairments of social-communication can be further impacted by abnormal speech perception (Lepisto et al., 2008, 2009), which could then lead to what Boucher (2012) terms as 'self- originating social deprivation'. Most research focuses on isolated (but continuous) instances of specific impairments in ASD. However, it is the combination of impairments intermixed with environmental factors that produce a particular set of varied learned responses (or lack of) that need attention. If an infant is not able to respond or attend to people, specifically their caregiver, this can distort the response and interaction of the caregiver including the amount as well as the quality of language they use (Warren et al., 2010). This in turn will undoubtedly affect the infant by creating a cycle of social deprivation that will diminish the ability and potential for them to acquire language (Kuhl, 2004). This process can be illustrated well again by referring to the metaphor of Waddington's Epigenetic Landscape, which describes a marble 'stuck in a groove' as it takes the fastest and steepest route down. So too does a child with ASD use their only available and immediate social cognition skills that in turn taper and restrict their overall experience from which they continue to learn. In addition, Sameroff and Chandler's Transactional Model (1975) describes how development is a result of a complex interplay between the child and their natural traits, as well as their family experiences and economic, social and community resources. The emphasis is on the continuity over time of this interaction as well as the multitude of potentially ever-changing factors. This describes well the potential situation for

a child with ASD and the consequences of SCI and why structural language impairment can be delayed and limited in ASD.

The various limitations mentioned above will have a dramatic and particular effect on language development and may help explain why after pre-school age, language profiles of children with ASD are likely to contribute to a convergence of what is recognised as an ASD typical language profile (Boucher, 2012). Unlike any other instance of language impairment, the ASD profile contains impaired comprehension relative to expression that can be explained by the inability to take into account other people's knowledge, speech and thoughts when they are interpreting and trying to understand spoken language (Surian, Baron-Cohen & Van der Lely, 1996). In terms of structural language impairment there are many aspects that can be linked to problems with implicit mindreading (Bloom, 2000; Frith and Happé, 1994; Hobson, 1993; Tager-Flusberg, 2000). First, difficulties with words associated with emotions (Hobson & Lee, 1989) and mental state words such as 'know', 'believe' and 'think' (Tager-Flusberg, 2000) will limit the ability to relate to and understand others and consequently impact on how language and more specifically words are learnt. If an infant does not possess the ability to experience the wider social context in which certain words and expressions are formed then their ability to use and learn that word within its communicative social context will not be reinforced. Second, deictic terms that refer to the boundaries between self and other (you/me) and time and place (here/there) if not fully used and understood will not only present difficulties with comprehension but also expression. Deictic terms by definition can only be understood with additional contextual information so their semantic meaning must be fixed but their denotational meaning varies with time, place or person. Children with ASD have been shown to be able to spontaneously produce some person-centred deictic terms but struggle with distal terms in relation to themselves such as 'here/there'; 'come/go' and

‘this/that’ (Hobson, Garcia-Perez & Lee, 2010). The same study also showed that directed head-nods (non-verbal gestural deixis) were not fully comprehended by children with ASD. Thirdly, there is further substantial research which shows that the apprehension of social cues such as direction of gaze, if impaired (as shown in Charman, 2003; Charman et al., 1997; Stone et al., 1997), will have a negative impact on word learning at a young age (Baron-Cohen, Baldwin & Crowson, 2007; Parish-Morris, Hennon, Hirsch-Pasek, Golinkoff & Tager-Flusberg, 2007). Finally, deficits in joint attention are not only associated with language delay but will also predict later language abilities as a whole (Charman, 2003; Siller & Sigman, 2008; Stone et al., 1997). Therefore it is possible to see how a deficit in implicit mindreading skills is a contributory factor to structural language impairment in ASD and also how this particular deficit, can lead to the later manifestation of the impaired language profile that is characteristic of ASD.

### ***Non-verbal IQ***

Findings have shown that non-verbal IQ influences language outcomes in ASD in a variety of ways (Stevens, Fein, Dunn, Allen, Waterhouse, Feinstein & Rapin, 2000). These depend largely on whether an individual has relatively high or low non-verbal IQ. For instance, in cases of high non-verbal IQ, individuals with autism may be able to use compensatory strategies to enable them to learn language albeit via an atypical route. Frith and Happé (1994) found that a high NVIQ in individuals with ALN can help them acquire language in such a way that may result in a precocious reading ability and/or the extended use of computational models that subserve the acquisition of phonology and syntax. Bloom (2000) also found that a high NVIQ can help with the utilisation of superior rote learning and

associative ability often seen in higher functioning individuals with ASD. Although these types of compensatory routes are narrow they are nevertheless extensive enough to equip individuals with the some language skills. In addition, this type of atypically acquired language will likely manifest as more deviant rather than delayed.

Although a high NVIQ can have a positive influence on language outcomes, a normal NVIQ is not sufficient to enable compensatory strategies. Some research has found that it does not offer protection against having a clinically significant language impairment (Eigsti et al., 2007; Stevens et al., 2000). As would therefore be expected, a low NVIQ in ASD is associated with a global learning disability that would contribute to delayed and limited language (Stevens et al., 2000).

What is not known, however, are the individual components that comprise NVIQ and how they may specifically enable these compensatory strategies. For instance, a relatively high score on a non-verbal IQ test such as the Ravens Coloured Progressive Matrices could demonstrate a wide range of specific non-verbal abilities. These abilities would comprise both perceptual and conceptual processes such as extracting the rule that governs the pattern, selecting the correct option and possibly inhibiting salient others. Visual perceptual skills including attention to detail would also be requisite but it is not clear the extent to which each of these skills may contribute or enhance alternative ways of learning. There is still much to be learned of the role of NVIQ and how it interacts with other cognitive mechanisms, even when it is at a normal or lower level.

### *Sensory-Perceptual Processing*

Sensory-perceptual processing is universally atypical in ASD (Mottron & Burack, 2006) and this influences structural language acquisition as well as processing in a variety of ways across the spectrum. These anomalies are conceptualised into three overlapping but nonetheless distinct models comprising ‘weak central coherence’ (Happé & Frith, 2006); ‘enhanced perceptual functioning’ (EPF) (Mottron & Burack, 2001) and ‘enhanced discriminability/reduced generalisation’ (Plaisted, 2001; Rajendran & Mitchell, 2007 (for overview of all three)).

Weak central coherence (Happé & Frith, 2006) and EPF (Mottron & Burack, 2001) will also have predictable effects on language acquisition such as how speech is encoded (Jarvinen-Pasley, Wallace, Ramus, Happé & Heaton, 2008). For instance weak central coherence could influence or alter speech perception by focusing more on the acoustic characteristics of speech rather than its actual meaning (Jarvinen-Pasley et al., 2008; Hermelin & O’Connor, 1970; Toichi & Kamio, 2002). This type of causal factor may contribute to deviance in structural language across the spectrum and may also contribute to the ASD-specific language profile.

More recent research has found evidence of the central coherence deficit in a mixed ability group of children limiting language comprehension on the borderline between syntax and semantics (Stockbridge, Happé & White, 2014). These authors found that the comprehension of dative constructions was more impaired when used in the form of structure of word order rather than by using the explicit preposition ‘to’. For example, ‘he shows the group the



painting' would present more difficulty than 'he shows the painting to the group'.

Additionally, when these syntactic structures were alternated within sentences children with ASD found this relatively difficult compared to their neurotypical (NT) peers. The authors claim that the alternating condition may have made it more difficult for children with ASD to generalise and form a rule (which was to identify the indirect object of the sentence in this case) rather, they would treat each new sentence (in a battery of 80) *de novo*. The authors claim that this research supports the weak central coherence theory because, in short, the children with ASD were unable to process the demands of the test globally (Happé & Frith, 2006). In addition, whilst this global processing deficit is not necessarily relevant to interpretation of a single lexical item, it is relevant *within* more complex sentence structures. These enhanced skills combined with a good immediate and rote memory may contribute to echolalia which in turn would produce rote learned chunks of phrases as well as the formulaicity that constitutes the characteristic nature of expressive language in ASD (Perkins et al., 2006).

Another aspect of sensory-perceptual processing is explained by Plaisted's (2001) enhanced discriminability/reduced generalisation hypothesis that attempts to explain that narrowed meaning of substantive terms is caused by reduced categorisation ability. Plaisted (2001) goes on to state that individuals with ASD find it difficult to draw pieces of information together due to an impaired ability to recognize the similarities between situations and/or stimuli. This reduced ability occurs at the perceptual and attentional level, as so often seen in ASD, and can lead to abnormalities in how they conceptualise information. However, these findings were challenged in a study by Bott, Brock, Brockdorff, Boucher and Lamberts (2006) who found that in a test of perceptual similarity, participants with ALN, compared to ability-matched NT's, did not show a relatively more accurate performance as would be

predicted by the 'reduced generalisation' account. In addition, they took reliably longer to learn new categories during the generalisation phase of the test.

These competing models not only offer insightful explanations specific to individual aspects of sensory-perceptual processing and their potential effects on structural language but also highlight the etiological complexity. Whilst Frith and Happé (2006) and Mottron and Burack (2001) propose a weakening of the central coherence mechanism (albeit for the latter authors this also enhances perceptual functioning), Plaisted (2001) stresses the importance of focussing instead on the 'effects' of weak central coherence, which point to an inability in recognising similarities between stimuli or situations. This particular standpoint is an excellent example of how research is plagued by complex causal and contributing factors. In WCC discourse, how sensory-perceptual anomalies are conceptualised as either a 'weakness' or a 'skill' and/or as a 'cause' or an 'effect' is complex.

Another significant factor is that the majority of research in sensory-perceptual anomalies in ASD is conducted using behavioural paradigms that rely heavily on either computer screens or table-top tests. These types of tests show up skills in 'small-scale' searching and Baron-Cohen (2008) argues that this is due to manifestations of an exaggerated form of an adaptive, evolutionary type of processing known as 'systemising' which is a predominantly 'male' trait (Baron-Cohen, Ashwin, Ashwin, Tavassoli & Chakrabarti, 2009; Baron-Cohen, Knickmeyer & Belmonte, 2005; Baron-Cohen & Belmonte, 2005). If individuals with ASD perform relatively well compared to NT populations on tests of either visual search and/or weak central coherence (Jarrold, Gilchrist & Bender, 2005; Joseph, Keehn, Connolly, Wolfe & Horowitz, 2009; Plaisted, O'Riordan & Baron-Cohen, 1998), can this translate to more real life contexts such as finding milk on a supermarket shelf, looking for your purse in the sitting

room or finding your flight details and instructions on signs and displays at the airport?

Baron-Cohen's 'hypersystemising' account would contend that these skills are transferable, however other research has found that this is not the case. When visual skills are needed in a large scale environment there may be additional cognitive demands (such as short term spatial memory) which may impair or limit performance (Pellicano, Smith, Cristino, Hood, Briscoe and Gilchrist, 2011; Pellicano et al., (2011) demonstrated that individuals with ASD do not show proficient systemizing or foraging skills in a large-scale search task. These authors created a 'foraging room' in a purpose built laboratory where numerous green and red search options were embedded into the floor. 20 school-age children with ASD and 20 age and ability-matched TD controls were instructed to search an array of 16 (green) locations in order to find the hidden (red) target as quickly as possible. The distribution of target locations was manipulated to appear on one side of the midline for 80% of the trials. Surprisingly, the children with ASD showed a far less efficient search behaviour compared to the TD group and they also showed reduced sensitivity to the statistical properties of the search array. In addition the children with ASD were relatively less able to create systematic and optimal search patterns to aid them in the task. The authors thus claim that a facility for systemising in ASD cannot explain why ASD children struggle with 'searching' in large-scale environments and furthermore that this may be attributed to constraints rather than skills in their cognitive repertoire. Whether or not these anomalies are conceptualised as skills or deficits has far reaching implications at an interventional level. It is important for educators to value and use the 'skills' present in ASD to help children to maximise their learning capacity by using pre-existing abilities. This can also contribute to a more positive interpretation of ASD, which is useful amongst peers in a social context. However, the danger of this is that pervasive deficits are potentially overlooked and not addressed, either at an individual level (in an interventional context) or at a conceptual level by researchers.

In addition, how these skills or deficits interface exactly with language anomalies is hard to determine. Nevertheless, research evidence is sufficient as shown above to conclude that there is a significant link between sensory-perceptual functioning and structural language ability in ASD. The nature of this link is not clear-cut but it needs careful consideration in this current research. Thus a test of *visuo-spatial abilities* (The Children's Embedded Features Test, CEFT, Witkin, Oltman, Raskin & Karp, 1971) will be incorporated to investigate any contributions, one way or another, of perceptual processing to lexical semantic ability.

### ***Declarative memory***

The work presented in this thesis will attempt to take into consideration the role of theory of mind, non-verbal IQ and *visuo-perceptual abilities*. However the main focus of this research will be on the role of declarative memory and its contribution to conceptual semantic ability in ASD. Recent theory and research has hypothesised that declarative memory, comprising semantic and episodic memory (Tulving, 1983; 1985) is necessary for lexical acquisition (Ullman, 2001) and would thus affect LI in ASD (Boucher, Mayes & Bigham, 2008).

Boucher et al. (2008) propose that individuals with LFA are not only impaired in episodic memory like individuals with HFA, but also in semantic memory. If there is a 'double' impairment (semantic and episodic) then there could be a deleterious effect on lexical acquisition and ability. This is a broad area of language ability and would not just include learning of individual words such as nouns, adjectives and verb stems but also specific words with grammatical functions such as prepositions, articles and conjunctions as well as irregular

verb endings and irregular plurals. Hence this additional semantic memory impairment could in part explain why verbal intelligence ('crystallized') is relatively lower than nonverbal ('fluid') intelligence in the majority of individuals with LFA (Lord & Paul, 1997; Siegel, Minshew & Goldstein, 1996). This is far reaching and is discussed in greater detail in the following chapter as it forms the main content for this current research.

## **Chapter Three**

### **Memory in ASD**

The aim of this chapter is to examine the role of memory in ASD particularly in relation to language impairment in ASD. Necessary theoretical and empirical paradigms of memory will be outlined first followed by the argument that declarative (and procedural) memory is associated with language ability (Ullman, 2004) in ASD. This will be followed by a literature review of memory in ASD divided into sections relating to recognition and recall and conclusions and summaries will be drawn in relation to familiarity and recollection specifically. The consequences of the ASD memory profile will also be considered.

#### **Introduction**

There is ample research showing that specific memory and learning impairments are present in all individuals with ASD (Boucher & Bowler, 2008). Yet, anomalous memory functioning has never been explicitly included in any diagnostic manual for autism. This is justified at present because memory functioning is sufficiently diverse in individuals for it not to be a useful diagnostic marker for ASD. In addition, the range and depth of anomalies in memory are not unique to ASD. Nevertheless it is a significant area of the ASD profile that has a substantial impact on how and what children learn. From infancy, anomalous memory functioning can influence the developmental course and behavioural outcomes of an individual (Boucher & Bowler, 2008). Equally, how an individual interacts with the external world and how this in turn feeds back during their development can also be shaped by

atypical memory performance (Boucher, 2009) At a very fundamental level structural language acquisition and usage is one critical area that is affected here (Boucher, 2011). This thesis is particularly concerned with this specific role of memory and how it interfaces with language in ASD.

Memory anomalies in ASD have only recently been investigated in relation to whether individuals with autism have either ‘normal’ (ALN) or impaired language (ALI) (Boucher, Mayes & Bigham, 2012). Early studies of memory and learning focused exclusively on groups with impaired language in accordance with early diagnostic criteria. The majority of memory research in autism (Bowler and colleagues; Minshew and colleagues; Mottron and colleagues), however, has since been with higher functioning groups where verbal ability is in the normal range. Very few studies have sought to clarify to what extent memory abnormalities in ASD might vary systematically across the autism spectrum, and to what extent this variability might relate to heterogeneity in other domains such as language impairments. It is this gap that this thesis will attempt to fill.

## **ALI-ALN**

It should be noted that although ALI and ALN are dealt with in separate sections, the boundaries between the two are arbitrary and moreover exist on a continuum. As mentioned in Chapter One, ALI as used here, broadly comprises individuals with ASD who have a verbal IQ of less than 75 on standard test scores whilst ALN broadly refers to individuals with ASD who score above 85. In addition, although their language ability is within the

‘normal’ range, certain anomalies and idiosyncrasies will still be present (e.g., difficulties with pronouns and pragmatics).

## **Theoretical and Empirical Framework**

There are two main approaches to conceptualising memory in empirical research; the ‘processes’ approach, which views memory as the product of a number of interacting psychological and neural *processes*, and the ‘systems’ approach, which considers memory to be the result of a number of distinct systems. Different types of memory tests and experimental conditions have been developed to dissociate the different memory processes and systems, and before turning to the literature on ASD, it is important to provide an overview of the relevant conceptual and terminological distinctions that apply in this literature.

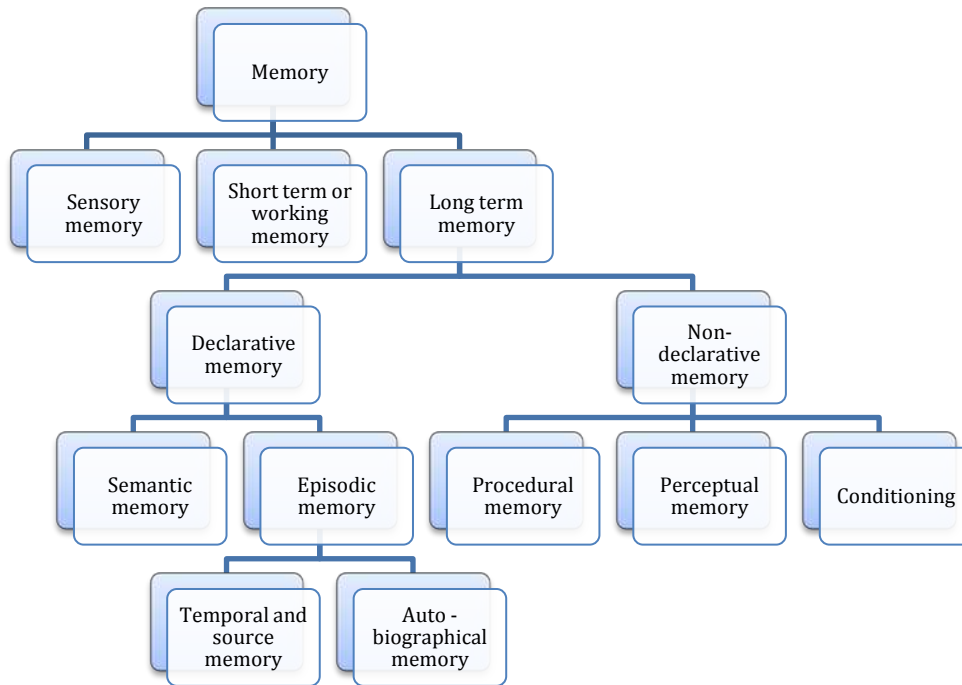
There are three major types of tests of memory. ‘Recognition’ tests provide the most retrieval support of all three types of tests by presenting participants with already seen items alongside new information. They are then asked which items they have seen before. ‘Cued-recall’ tests provide less support as they may present stimuli that prompt retrieval of items in relation to, for example, a category (e.g., which *fruit* did you see) or word fragments (‘Or\_ \_ \_ e’). ‘Free recall’ tests, however, offer no support and participants are simply asked to reproduce already learned material as much as they are able. It is important to set out these distinctions early on because there is a considerable amount of evidence to show that these different types of tests tap into the different memory processes and systems described next in a variety of ways.



### *The “Systems” approach*

The systematic classification of human memory began with several dichotomies, the most dominant being the distinction between short and long-term memory (Atkinson & Shiffrin, 1968) and Tulving’s distinction between non-declarative and declarative types of memory (Tulving, 1972; Tulving, 1985; Schacter & Tulving, 1994). For a visual explanation, these types of memory are encapsulated in Figure 3.1. First, Atkinson and Shiffrin’s model distinguished between sensory memory, short-term memory and long-term memory. Sensory memory holds the sensory form of a stimulus unaltered in the mind for a brief time (can be an auditory or visual trace) and then is rapidly lost through spontaneous decay. Short-term memory refers to a temporary storage place for information that does not alter or process the information in significant ways. It is relatively limited in capacity and can hold only about seven items (Miller, 1956) for about eighteen seconds (Peterson & Peterson, 1959) unless the information is maintained through rehearsal. Stimuli can be held in either the visual or auditory modality, though mainly the latter. There is evidence suggesting that visual and auditory stimuli are held in dissociable sub-systems of short-term memory. For instance, a double dissociation has been shown between verbal and visual or spatial based interference tasks (Brandimonte, Hitch & Bishop, 1992; Logie, Zucco & Baddeley, 1990). These experimental tasks are based on the dual-task interference paradigm, which assumes that if a task selectively interferes with a particular type of processing but not with another, then these two different processes must engage two separate cognitive systems. Brandimonte et al., (1992) found that during learning, verbal recoding of visual stimuli in short term memory can disrupt the ability to elicit veridical images from long-term memory.

**Figure 3.1 shows a taxonomy of memory systems**



The above distinctions between different short-term memory stores are also reflected in Baddeley & Hitch's (1974) working memory model. Working memory is a system not only for the short-term maintenance but also the manipulation of information involving thinking and reasoning (Baddeley, 2002). It consists of three, so called slave systems and a supervisory system. The slave systems comprise the 'phonological loop' that deals with verbal material and consists of an articulatory process and a phonological store. Baddeley and Lewis (1981) found that articulatory suppression did not affect decisions, which involve acoustic (phonological) differences. This suggests that there is a separate store for this, which is supported by a study by Baddeley (1975). He gave participants a sequence of words to recall where typically the participants could perform better with short rather than long words (called the word-length effect). However, when an articulatory suppression task (counting

backwards) was incorporated there was no difference. According to Baddeley this demonstrates that the word-length effect depends on having access to the articulatory process. The 'visuo-spatial sketchpad' holds visual memories in mind and the 'episodic buffer' integrates visual, spatial, and verbal information with information about their sequential order in time. The supervisory system comprises the 'central executive', which allocates resources to the slave systems and is modality free, i.e. not visual or auditory; so it can store information in any sense modality. It also binds information from different sources together into coherent episodes, which also helps to promote the consolidation of longer-lasting memories (Baddeley, 1996). Empirical support for the central executive comes from studies that have found that task similarity impairs performance, e.g. playing the piano and singing a song (both are auditory). This is due to competition within the one component (McLeod, 1977).

Long-term memory refers to the relatively permanent store of information, which has unlimited capacity and is thought to comprise a number of distinct sub-systems, each dedicated to the storage of relatively distinct types of information. Declarative memory, as set out by Tulving (1972; 1985) stores memories of the past that can be consciously recalled, such as facts and events, and it is further subdivided into semantic memory and episodic memory. Semantic memory relates to decontextualised factual information comprising 'who', 'what' and 'why'. It is the remembering of facts gathered from the time we are young such as remembering what a cat is or knowing that the grass is green. We know these facts without any memory of the context in which we have learned them. Episodic memory, by contrast, relates to contextual information associated with time and place as the memory was formed and is specific to the individual. This would include autobiographical experiences and specific events in time such as remembering your first day at school (Tulving, 1972).

In contrast to declarative memory, non-declarative memory uses past experiences to remember things without having to consciously think about them. It differs from declarative memory, which consists of facts and events that can be explicitly stored and consciously recalled, because no conscious thinking is required to access it. Non-declarative memory consists of 'procedural' and 'perceptual' memory. Procedural memory comprises unconscious conditioning and learning, habit formation and acquisition of automatic sensorimotor and cognitive skills and basic level concepts. It is responsible for knowing 'how' to do things, such as playing the piano or riding a bike. Perceptual memory, on the other hand, is the ability to interpret incoming stimuli through categorisation and recognition (Bitterman, 1965; Franklin, 2005). It involves the identification of objects as well as being able to process and recognise the structural elements of language such as grammar. This could be, for example, learning how to distinguish well-formed strings of grammar. It is also responsible for the automatic encoding of spatial information. All of the above are done unconsciously and automatically and form long term memory traces. This is in contrast to short-term sensory memory and short-term perceptual memory (mentioned above) where memories are only held for a maximum of 1 second and either no processing (sensory memory) or only minimal processing (short term memory) takes place. Evidence for a long-term store of perceptual memories came from studies in the working memory model framework. They found that attended information can be stored out of consciousness during gaps between operations which may suggest the need for a longer term memory store which is sometimes referred to as a visual cache (Quinn, 2008)

Both declarative and non-declarative systems acquire and store information in the long term and a considerable amount of evidence, primarily from lesion and patient studies, supports

the distinctions just outlined (Graf and Schacter, 1985; Eichenbaum, 2000; Corkin, 2002).

The declarative/non-declarative distinction can also be mapped onto the explicit (conscious) / implicit (unconscious) pair respectively.

### ***The “Processes” approach***

In the ‘processes’ approach memory is considered to be the outcome of a number of ‘processes’ that include the encoding, storage and retrieval of information. Each of these principal processing stages is under the influence of cognitive factors as well as features of the to-be-remembered information, which has led to a number of sub-distinctions amongst memory processes.

For instance, Craik & Lockhart (1975) argued that information can be encoded into memory by processing surface features of stimuli such as perceptual properties of visual stimuli or phonological properties of words that are relatively void of meaning. Such ‘shallow’ encoding is often engaged when trying to remember information such as abstract paintings or telephone numbers. Alternatively, information can be encoded at a ‘deeper’ level that involves making sense of the to-be-remembered information and relating it to already stored information. In a study by Craik and Lockhart (1975) they showed participants a list of words, each followed by a Yes/No answer. The questions belonged to one of three levels of analysis: shallow (e.g. is the word in capital letters?); phonemic (e.g. does the word rhyme with able?); or semantic (e.g. would the word fit into the sentence “I went to the ---- to buy some bread.”). The words that had been given semantic type questions were remembered the most, with the phonemic the next best remembered; showing that deeper encoding leads to

better memory. There is no definite boundary between what constitutes a deep or shallow memory, and although deeper processing will most typically lead to better memory, there are also conditions where shallow processing can be more effective. For instance, Morris et al., (1977) demonstrated that if participants were given a rhyming recognition test they remembered the words that had received shallow processing better than the words that were more deeply processed.

A second distinction is between that of item-specific and relational processing. Like deep and shallow processing this distinction also occurs at the encoding stage. Item specific information refers to information that is specific to the individual elements of a remembered set of materials. For example a shirt is made of fabric and you wear it and it is a type of clothing. Contrastingly, relational information refers to information that defines the relations between elements such as a shirt is similar to a dress because they are both types of clothing. Relational information pre-supposes item-specific information and it is only possible to relate shirt and dress if relevant item-specific knowledge is available about these two items (Hunt & Einstein, 1981; Gaigg & Bowler, 2012). Certain situations will require a greater degree of relational processing (such as devising the ingredients for a particular meal) whilst others will require greater item processing (such as thinking about which of a number of meals you like best). They are thought to operate in parallel and when combined, they produce optimal recall (Hunt & Einstein, 1981). This has been shown in a series of experiments that used separate word lists and orienting conditions to manipulate the extent to which participants engaged item-specific and relational processing. Superior recall occurred when both processes were employed in a combined single item (rating the likeability of words) and relational (identifying commonalities amongst words) orienting task. Further evidence of superior recall was shown in an interaction of these orienting task the word list structure; where relational

orientation produced the best performance on lists of unrelated words and single item processing elicited the highest recall on lists of related words.

A third pair of closely related processing distinctions can be made between automatic and effortful processing and explicit and implicit forms of memory. These distinctions refer to differences in the level of conscious awareness we have as we encode or retrieve information. Effortful processing requires attention and some degree of conscious effort. Automatic processing refers to our unconscious encoding of incidental information such as space, time and frequency, and of well-learned information. Similarly, at retrieval, conscious awareness ranges from any basic memory such as learning to walk through to a fully conscious awareness where what is remembered is known as a memory rather than a fantasy. Between these two extremes would be conscious speculation along the lines of “I ‘think’ I remember it” as well as varying degrees of confidence in the speculation. Both kinds of processing can occur at encoding and retrieval (see Hasher and Zacks, (1979) for the original model and Arias, (1998) for a meta-analysis).

Theories that centre on what causes us to forget are underpinned by a process-related distinction between decay vs. consolidation. Decay theory (Thorndike, 1914) states that we forget due to passive degeneration or to deterioration of memory traces (Jonides, Lewis, Nee, Lustig, Berman & Moore, 2008). On the other hand, with consolidation, our memories continue to strengthen after they have been formed, and they become more resilient to forgetting over time (e.g. Wixted, 2005). These two processes are primarily concerned with storage rather than encoding or retrieval.

A final process-related distinction can be made between ‘recollection’ and ‘familiarity’. Familiarity is a feeling of memory for a stimulus that involves no recall of any associated information, whereas recollection involves the retrieval of contextual associations from the previous encounter relating to the stimulus (Montaldi & Mayes, 2010). For example, familiarity may involve a sense of knowing that you know a person that you have just passed in the street but any detail as to how, where or why is absent. In contrast, recollection may involve recalling that the person is your local baker and that you bought rye bread and a cinnamon roll from them yesterday. As this example illustrates, familiarity memory is only able to support recognition whereas recollection memory involves the recall of contextual information and of associations between items in memory (e.g., buying rye bread *and* a cinnamon roll). Evidence for a dissociation between recollection and familiarity is underpinned by medial temporal lobe (MTL) dual process theories, which broadly state that the hippocampus is critical for recollection whilst the perirhinal cortex is critical for familiarity (Aggleton & Brown, 1999). The perirhinal cortex receives object/item information whilst the parahippocampal cortex receives contextual information. The hippocampus receives high-level inputs that include both object/item information as well as contextual information and further information that is more complex. It is responsible for integrating information about temporal and spatial relations that are within different elements of experiences. These are then relayed in a segregated fashion through the surrounding MTL cortices (perirhinal and parahippocampal cortices). The hippocampus binds together pattern-separated representations that support recollection for contextually rich memories. By contrast, the MTL cortices only have access to fragmented information and so create pattern-separated memories that support familiarity well, but recollection very poorly (Montaldi & Migo, 2010).



Although familiarity and recollection processes are considered to be distinct, there are also multiple process theories that contrast with the view that both types of memory are mediated by interactions between all the components of the MTL, so that there is no MTL recollection and familiarity functional dissociations (Squire, Wixted & Clark, 2007). This view postulates that recollection and familiarity function more on a continuum as mentioned above by a single memory system that is determined by the strength of memories. More generally however, although recollection and familiarity are often referred to as processes, it is more useful to think of them as 'kinds of memory' each involving several processes working together that depend on a system of linked structures (Montaldi & Mayes, 2012).

There are other process distinctions made in the memory literature but these particular ones mentioned above are mostly relevant to this current research. It is worth noting that these distinctions do not map onto each other in any uniform way and do not bear fixed relationships with one another. The distinctions themselves are also not clear-cut. For example, when we retrieve information we also re-encode it and when we encode information, we do so in part by retrieving information (already stored), which is relevant to the information being encoded. This is also likely to influence the probability of decay and forgetting or the extent to which information may be consolidated. In addition, there are some parallels between the systems and process theories. Of considerable overlap are the similarities between recollection vs. familiarity and episodic vs. semantic memory. Again, these do not map onto one another consistently. Although retrieval of episodic memories generally involves recollection, the nature of the relationship between semantic memory and familiarity is less clear. It is important to note however, that episodic memory and recollection do have something in common and this is a useful basis from which to relate to

current ASD literature where episodic difficulties are often considered as a reflection of difficulties with recollection.

### ***The links between Memory and Language systems***

There is sufficient evidence pointing to a significant number of similarities between the functional aspects of the grammar and lexicon systems in language and the declarative and procedural memory systems (Ullman, 2001; 2004). These concordances underlie the principal claim of Ullman's Declarative Procedural (DP) model; that is that the brain systems that subserve declarative and procedural memory play corresponding roles in the 'mental lexicon' and the 'mental grammar' systems respectively. Language, as conceptualised by a dual-system model, is assumed to have a fundamental distinction between the "mental lexicon" (mechanism that contains memorised word specific knowledge) and the "mental grammar" (mechanism that contains generative rules that combine words into an infinite number of larger words and phrases (Chomsky, 1965; Pinker, 1994, 1999). More specifically, the mental lexicon is a repository for stored information, including all idiosyncratic word-specific information. This ranges from the arbitrary sound-meaning pairings of non-compositional words like *fish* to irregular morphological forms that a word may take such as the past tense *spun* (taken from present tense *spin*). The mental lexicon is not simply a rote memory store but can generalise patterns from previously stored forms; for example the novel irregular *spling-splang* pairing can be derived from *sing-sang*, and then *spring-sprang* (Pinker & Ullman, 2002a, Ullman, 2004). By contrast the "mental grammar" supports the conversion of smaller linguistic elements that are rule governed (like phonemes, morphemes and words)

into larger, more organised units (such as syllables, phrases, sentences and complex words) that are sequentially and hierarchically structured.

### ***Relationships between the declarative and procedural memory systems***

Extensive research on declarative and procedural memory has shown that there are numerous double dissociations that show that these two memory systems are largely independent from one another, but they also interact in several ways (Eichenbaum & Cohen, 2001; Mishkin, Malamut & Bachevalier, 1984; Poldrack & Packard, 2003, Schacter & Tulving, 1994; Squire & Knowlton, 2000). It might be where and how they overlap and interact that is of interest here, as well as their typical roles in addition to their specific roles. These two systems contribute to the formation of a dynamic interactive network that produces simultaneous cooperative and competitive learning and processing so that memory can be optimised (Poldrack & Packard, 2003). The nature of these relationships is demonstrated in neurobiological studies relating to brain structure as well as in animal and human behavioural studies .

First, evidence from the patient H.M. showed that the declarative memory system does not need to be intact for the procedural memory system to continue to learn (Corkin, 1984; Eichenbaum & Cohen, 2001; Squire & Knowlton, 2000). However, when these two systems are both intact they can complement one another in acquiring knowledge. For instance, in motor sequence learning, both systems can be used together to learn a task, which may optimise learning in some cases (Willingham, 1998). The declarative memory system

acquires knowledge initially through its rapid learning abilities whilst the procedural system learns the same or analogous knowledge more gradually (Poldrack & Packard, 2003). Interestingly, if a given sequence that is usually learned in the procedural system is memorised in declarative memory, its structure will likely be limited by the rules that govern the sequence in procedural memory. Furthermore, the time-course of this shift from declarative to procedural memory can be modulated pharmacologically (Packard, 1999). In a study using posttraining intracerebral glutamate infusions in rats, it was found that it is possible to modulate the distinct memory processes mediated by the hippocampus and caudate-putamen (namely declarative and procedural memory systems). More specifically, during a cross-maze task using 'place' and 'response' learning, rats received posttraining intrahippocampal or intracaudate injections of either glutamate or saline. Over the course of 16 days the saline rats displayed place learning on day 8 and response learning on day 16. However, the learning behaviour of the caudate injected rats displayed response learning and the hippocampal injected rats displayed place learning on both days 8 and 16. This demonstrates that it is possible to bias the brain toward the use of a specific memory system to control learned behaviour and thereby influence the timing of the switch from the use of cognitive memory (declarative) to habit learning (procedural) to guide behaviour. This further highlights the degree of interaction and flexibility between the two systems.

Second, at a neurological level, brain structures that are more generally implicated in procedural memory can also perform context dependent selection) of knowledge that has been stored in declarative memory (Ullman, 2004). For example, the cerebellum, which is more commonly implicated in procedural memory with the learning of new motor sequences (such as riding a bicycle) (Molinari, Leggio, Solida, Ciorra, Misciagna, Silveri and Petrosini, 1997), is also involved in searching, retrieving and processing declarative memories

(Desmond & Fiez, 1998; Ivry & Fiez, 2000). Specifically, in a neurological review by Desmond and Fiez (1998) they identified that cerebellum activation has been observed under a variety of explicit retrieval conditions. These include the recognition of previously seen or heard words (Andreasen, O’Leary, Arndt, Cizadlo, Hurtig, Rezai, Watkins, Boles Ponto, Hichwa, 1995a; Nyberg et al., 1995), retrieval of autobiographical information (Andreasen et al., 1995b; Fink et al., 1996;) and the completion of three-letter stems with previously studied words (Backman et al., 1997; Schachter et al., 1996) as well as the recall of words that have been paired with other words (Cabeza et al., 1997). Although the role of the cerebellar activation is currently unknown there are several theories that suggest that the cerebellum aids the ‘effort’ at retrieval. For instance, it can assist in the search for a valid response from semantic memory whilst identifying if the need is to elicit a memory from a few given options or to sort through and choose from a large number of options (Thompson-Schill et al., 1997). Evidence has shown that the right cerebellum shows greater activation when there are few possible responses and the left cerebellum exhibited greater activation when the demands of a task require ‘selection’ from many possibilities (Desmond, Gabrieli & Glover, 1998). Similarly, superior aspects of the temporal lobe may act as a storage repository for learnt skills and habits in procedural memory whilst the same or nearby areas of the ventro-lateral prefrontal cortex is implicated in the encoding of new memories, as well as the selection, retrieval and ongoing evaluation of abstract and verbal memories (Buckner & Wheeler, 2001; Wagner et al., 1998). Whether these structures are part of the procedural system playing a more minimal role in the declarative system, or vice versa, is only a terminological issue. Either way, this evidence provides a certain degree of foundational neurological evidence that the declarative and procedural memory systems can co-operate due to their overlapping and supporting brain structures.

Third, as well as acting cooperatively, the two systems also interact competitively (Poldrack & Packard, 2003) which is what Ullman terms as a “see-saw” effect. If one system is more impaired than the other then this leads to the other system compensating and becoming more enhanced. However, it is equally possible that learning in one system depresses the functionality in the other (Ullman, 2004). Neurological evidence in animal studies has shown that damage to the medial-temporal lobe (MTL) structures, including the hippocampus, can enhance basal-ganglia-based procedural learning (McDonald & White, 1993; Schroeder, Wingard & Packard, 2002). Conversely, learning in declarative memory can be facilitated by damage to the neostriatum in the basal ganglia (Mitchell & Hall, 1988. For further evidence of this see-saw effect in animals see Ullman, 2004). Moreover, evidence from a series of neuroimaging experiments of healthy adults demonstrates the interactions between these two memory systems (Poldrack et al., 2001; Poldrack, Prabhakaran, Seger & Gabrieli, 1999). In tasks employing probabilistic rule learning (procedural learning), activation was shown in the caudate nucleus, as expected. However, there was also simultaneous deactivation in the medial temporal lobe (MTL). Furthermore, there was a negative correlation across participants with the degree of activity in the caudate nucleus and the medial temporal lobe. Hence, participants with higher caudate activity had lower medial-temporal activity, and vice versa. Furthermore, the functional relationship between the MTL and caudate changed over the course of learning. At the early stages of learning the MTL structures were activated but the caudate was not. As learning progressed the MTL structures became deactivated and the caudate activation increased. This stresses that there is a competitive interaction between the two systems and supports Ullman’s (2004) suggestion that in early stages of learning, declarative memory is more dominant and that over time this shifts towards procedural learning; a pattern that seems evident also in language learning (Ullman, 2004). Importantly, individuals vary in their relative dependence on the declarative and procedural systems

during learning, which has implications for a developmental disorder such as ASD, where one or both systems are thought to develop abnormally.

Ullman (2004) associates several developmental disorders with impairments of procedural memory related functions. These comprise Specific Language Impairment (SLI), Attention Deficit Hyperactivity Disorder (ADHD), dyslexia and ASD. According to the DP model, grammatical difficulties and lexical retrieval impairments should be seen in these disorders, although there are likely to be more particular characteristics of their respective language deficits that would be dependent on subtly different procedural memory difficulties. There has been evidence in ASD research to support this, mainly finding associations with cerebellar abnormalities and motor function deficits; as well as difficulties with procedural learning and structural language skills. More recently, as will be discussed below, there is accumulating evidence to implicate declarative memory impairments in both ALN and ALL.

Ullman's DP model has subsequently morphed into the Procedural Deficit Hypothesis (PDH, Ullman & Pierpoint, 2005), which emphasises brain systems that underlie procedural learning and how these interact and affect language systems, specifically with respect to "mental grammar." Although there are some reports of procedural difficulties in ASD (Mostofsky et al., 2000; Ullman, 2004; Walenski et al., 2006), there are also studies that report intact procedural memory (Toal, Murphy & Murphy, 2005; Miller, 1999; Pring, 2008) as well as other relatively preserved areas of non-declarative memory such as implicit learning (Barnes et al., 2008; Travers, Klinger, Mussey and Klinger, 2010; Nemeth, Janacsek, Balogh, Londe, Mingesz, Fazekas & Vetro, 2010). It is therefore important to recognise the large body of evidence relating to declarative memory in ASD as discussed below. With this in mind, Ullman's model provides useful links between memory and language, specifically

procedural memory and syntax. However, less is known about the role of declarative memory anomalies in the language profile that characterises ASD. This will be the focus of the research reported here.

More recently, Ullman has revised his hypothesis by conceptualising the memory deficits as witnessed in developmental disorders as a Procedural Deficit Hypothesis (Ullman & Pierpoint, 2005; Ullman & Pullman, 2015). It is more obvious as to why memory deficits in SLI may be attributed to a procedural memory deficit but it is questionable how useful this concept can be applied in the case of ASD where declarative memory impairments, particularly episodic or relational types of memory have been found to be relatively impaired in ASD (see following section). However, as noted above, how these two systems interact needed attention and may help explain why Ullman and Pullman (2015) have recently speculated that declarative memory can play a compensatory role in developmental disorders.

## **Memory Research in Autism Spectrum Disorder**

### ***Historical Background***

Memory research in ASD has varied in its focus over the years. Early research that often included tests of memory focused on the possibility that autism was partly caused by developmental amnesia (Boucher et al., 2012; Rimland, 1964; Hauser, DeLong & Rosman, 1975; Boucher & Warrington, 1976; DeLong, 1978). For instance, Boucher and Warrington (1976) used tests of recall, recognition and cued recall, similar to those experimental



paradigms used in amnesic syndrome with adults, with children with autism. The group of children with autism were matched to a control group that was age-matched and another control group that was matched on verbal and nonverbal ability. Findings showed that these tests elicited similar results to individuals with amnesia in recall, cued recall and recognition (but not in paired-associate learning) thus prompting speculation that there may be some parallels between amnesia and autism. However, at that point, which predates the publication of the revisions to the third edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-III-R; American Psychiatric Association, 1987), the diagnostic criteria for ASD included structural language impairment that was clinically significant. These studies would therefore have included participants with ASD that would have had clinically significant language impairments (Rimland, 1964; Hauser, DeLong & Rosman, 1975; Boucher & Warrington, 1976; DeLong, 1978). The developmental amnesia hypothesis would therefore have referred only to individuals with ALI and not necessarily to the much broader spectrum of the ASD phenotype that included individuals with ALN in subsequent revisions to the diagnostic criteria (DSM-III-R 1987) and onwards. By contrast, from the publication of the DSM-III-R (1987) onwards, most behavioural research centred on individuals with ASD without any clinically significant language or intellectual impairments. This type of research was much more popular due to the advantage of ‘screening’ out any linguistic or intellectual impairments that would complicate the profile of what was then considered as ‘pure autism’.

During the 1990s, research efforts went into establishing causal theories of autism that gave rise to the Theory of Mind theory, Weak Central Coherence theory and Executive Dysfunction theory (see Chapter One for an outline of these theories). These theories dominated research for some time and memory was relatively neglected. This was also partly due to the fact that this research was with individuals with ALN and therefore did not throw

up any salient memory difficulties that would confirm the hypothesis that developmental amnesia was a cause of autism (Bennetto, Pennington & Rogers, 1996; Bowler, Matthews & Gardiner, 1997; Minshew & Goldstein, 1993; Renner, Klinger & Klinger, 2000). However, these studies did find subtle anomalies and impairments of memory in ALN.

### ***Review of literature of memory functioning in autism***

(See Appendix section for a summary table of studies)

Memory in ASD has been studied under many of the theoretical distinctions between memory systems and processes set out earlier (see Boucher & Bowler, 2008 for a collection of reviews). The current thesis will approach the topic of memory in ASD utilising in particular the declarative/non-declarative distinction. Non-declarative memory comprises procedural memory and declarative memory encompasses the perspective of the dual process theory that distinguishes between recollection and familiarity. Since recollection and familiarity are experimentally operationalised through tests of recognition and recall, the following sections will review evidence stemming from these procedures.

The focus of this research is on declarative memory but it is important to identify the skills and impairments present in non-declarative memory. As mentioned above, individuals with ASD are likely to use their intact skills to compensate for their impairments, in a “see-saw” effect (Ullman, 2004) not only later in life but also during the course of their learning phase as children. These early compensatory skills are likely to have direct effects on the course of their development.

Therefore the memory literature review sections of this chapter will fall under the main headings of ‘recognition’, ‘cued recall’, and ‘free recall’. Source memory is a specific type of cued recall so is presented under the heading for cued recall.

To date there are several behavioural and neuropsychological reviews and extensive studies on memory in autism (e.g. Boucher, Mayes & Bigham, 2012; Williams, Goldstein & Minshew, 2006a; 2006b; Lind, 2010; Mottron, Morasse & Belleville, 2001), which emphasise the relevance of memory functioning as a partial yet valid window to understanding autism. Differences in memory abilities and profiles between ALN and ALI are key in this current research and will be addressed in separate sections and compared later. The purpose of this research is to establish how these differences may have an influential link to structural language ability in children therefore the literature review that follows will consider evidence relating to studies of ALI and ALN separately (see Boucher, 2012). Findings of mixed ability groups are less informative here. In addition, only studies that use non-social stimuli are considered because one of the main defining criteria in the diagnosis of ASD is a deficit in social communication and interaction, which is likely to render tests using social stimuli challenging in their own right for individuals with ASD. It would also be difficult to attribute test performance to the relative contributions of anomalies in either memory and/or social abilities.

### **Non-declarative memory in ASD in groups with language impairments (ALI)**

Studies of non-declarative memory in ALI are sparse, however observational and clinical evidence point mainly towards a relative lack of impairment across most forms of non-

declarative memory. This is most obvious in the case of ‘low ability’ savants with an ASD who demonstrate exceptional abilities in drawing, calculation and/or musical improvisation. In these cases they rely on and use implicit perceptual representations and procedures that underpin non-declarative memory (Miller, 1999; Pring, 2008). Habit formation skills (where behaviour is directed to becoming more automatic) have also been shown to be relatively unimpaired in ALI. This can be explained by spontaneous behaviour that is often modified by habits and routines that would tap into procedural memory (Toal, Murphy & Murphy, 2005). In addition, implicit knowledge of basic-level categories has been shown to be largely intact in ALI in studies by Carter et al., (1998) and Kraijer, (2000). They both showed that daily living skills incorporating the use of everyday objects by individuals with ALI, even including some non-verbal individuals, did not show up any relative difficulties.

### **Non-declarative memory in ASD in groups with normal language (ALN)**

Whilst many areas of non-declarative memory appear to be intact also in ALN, motor skills have been found to be impaired and some researchers argue that implicit learning is implicated (Romero-Munguia, 2008; Walenski, Tager-Flusberg & Ullman, 2006). However, there are many possible causes of motor skills impairments, which are diverse across the spectrum; such as dyspraxia and basic movement kinematic problems (Fournier, Hass, Naik, Lodha & Cauraugh, 2010; Cook, Blakemore & Press, 2013; MacNeil & Mostofsky, 2012). Therefore it is not possible to conclude that an impairment of implicit/non-declarative learning is the sole cause of difficulties with motor skills (Boucher, 2012). In fact, there are three studies that demonstrate that implicit learning of motor sequences is unimpaired in ALN (Barnes et al., 2008; Travers, Klinger, Mussey and Klinger, 2010;

Nemeth, Janacsek, Balogh, Londe, Mingesz, Fazekas & Vetro, 2010). For example, the study by Nemeth et al. (2010) investigated probabilistic implicit sequence learning in children with ALN matched to two separate groups of age matched and IQ matched controls. All three groups of children were tested on the Alternating Serial Reaction Time Task (ASRT), making it possible to separate general skill learning from sequence-specific learning. In the ASRT task, ‘predictable’ pattern trials alternate with ‘unpredictable random’ ones which causes certain “triplets” (a sequence of three trials) to occur at a higher frequency than others. Previous research has shown that participants do not gain explicit knowledge spontaneously in this task, and performance is sensitive to the relative frequencies of triplets, not to the alternating regularity (Howard et al, 2010). The ASRT task was repeated after 16 hours. The study found that both control and ALN children showed similar sequence-specific and general skill learning in the learning phase. Consolidation of skill learning and sequence-specific learning were also intact in the ALN compared to the control groups. The authors suggest that autistic children can use the effects of implicit learning not only for a short period, but also for a longer stretch of time.

There are other areas of non-declarative memory that are also relatively preserved in ALN including perceptual priming (based on the ‘form’ of the stimulus) and conceptual priming (based on the ‘meaning’ of the stimulus) using words, pictures or music (Bowler, Matthews & Gardiner, 1997; Gardiner, Bowler & Grice, 2003; Toichi, 2008). Other implicit skills include category formation, which occurs when subjects encountering a series of stimuli learn about what all the stimuli have in common, with the result that information is acquired about the category defined by the objects (Squire & Knowlton, 1995). For example, in a study of implicit category formation by Molesworth, Bowler & Hampton (2005), participants with ALN matched to a group of age and ability matched TD controls were asked to complete a

picture recognition task. They were then asked to study categories of cartoon animals with either an average prototype structure based on Younger's (1985) stimuli or a modal structure based on Hayes and Taplin's (1993b) stimuli. Following the study phases, participants completed the recognition tests comprising prototypes and other exemplars with varying degrees of similarity to the prototypes. Findings showed that recognition memory appeared intact and a full prototype effect in recognition memory was observed, thus failing to support predictions of impaired prototype effects in autism.

In addition, implicit category formation has not just been shown to be unimpaired but there is also evidence to suggest that it is achieved atypically. Two studies found that compared to ability matched controls performance from ALN groups was slower though not less accurate at perceptual similarity (in the visual domain) and in low-level categorisation tasks (Bott, Brock, Brockdorff, Boucher & Lamberts, 2006; Soulières, Mottron, Giguère & Larochelle, 2011). Soulières et al., (2011) state that individuals with ALN can often use 'guessing' instead of top-down processing involved in rule-learning (in category formation); thus extra time at the learning phase may help them to avoid guessing. In short, when extra support in terms of time is provided, individuals with ALN have been shown to perform similarly to neurotypical adults (NT's).

There is mixed evidence relating to classical conditioning in ALN. Any learning that occurs via classical conditioning is by association between two stimuli and is implicit. In a classical eye-blink conditioning study (where pairing an auditory or visual stimulus (the conditioned stimulus (CS)) with an eye-blink-eliciting unconditioned stimulus (US) (e.g. a minor puff of air to the cornea or throat), participants with ALN showed faster learning of the task but performed short latency, high amplitude conditioned responses (Sears, Finn & Steinmetz,

1994). This suggests that these participants are able to rapidly associate paired stimuli but they may have difficulties with modulating the timing and topography of the learned responses. This may be due to how certain contextual information is processed. Another study showed fear conditioning to be relatively preserved when tested within a fear potential startle paradigm (Bernier, Dawson, Panagiotides, & Webb, 2005). Participants were presented with a red square (CS) that co-terminated with an overlapping 50ms average air puff to the throat (US). After several acquisition trials, participants eye blink startle responses were examined to bursts of white noise that were either preceded by the red square (constituting a threat) or not (safe). Individuals with ALN had 'learnt' the aversive properties of the red square to the same degree as their control group thus showing that classical conditioning was not impaired in this case. In two aversive conditioning studies, (Gaigg and Bowler, 2007; South, Larson, White, Dana & Crowley, 2011) results are mixed. Gaigg & Bowler (2007) added in an additional conditioning level (as compared to the Bernier et al. 2005 study) involving a CS + colour that was paired with a startling noise (US) during acquisition and a CS – colour that was never paired with the UCS. They found that fear acquisition of the CS + colour was significantly reduced in ALN relative to NT controls. Conversely, South et al. (2011) found no reductions in fear acquisition in ALN however they did find that the amplitude of acquired fear responses was associated with autistic severity (using the Autism Diagnostic Observation Schedule (ADOS) Reciprocal Social Interaction scores). In all studies there were no differences in physiological responses to the US which implies that the emotional salience of the aversive stimuli was similar between groups (Gaigg, 2012). Inconsistencies between studies have been argued to reflect difficulties in ALN with adapting to ambiguous stimulus contingencies that would normally allow the prediction of biological events on a probabilistic basis. This would mean that ASD may be

characterised by anomalies in the mechanisms by which emotional salience facilitates associative learning in ‘uncertain’ conditions (Gaigg, 2012).

Brown, Aczel, Jimenez, Kaufman & Grant, (2010) tested four areas of implicit learning: artificial grammar learning; contextual cueing; motor sequence and probabilistic learning. Adults with autistic spectrum condition (ASC) were matched on IQ to NT counterparts and there was evidence of statistical equivalence between all the groups across all four implicit tasks. This further highlights that implicit memory is relatively unimpaired in ALN.

The studies above mainly refer to adults rather than children (with the exception of the Nemeth et al.(2010) study) but the overall picture of a non-declarative memory profile in both ALN and ALI is that there seem to be more areas intact than not. However, the nature of some of the anomalies in implicit memory and learning may warrant further examination and may be helpful in assisting our understanding of declarative memory performance, where there are more striking and obvious impairments.

## **Declarative Memory**

### *Recognition in ALI*

Unlike studies in ALN there are few studies that investigate recognition in ALI and findings are mixed. For instance, there are four studies that report impairments in recognition but three other studies that report unimpaired recognition. First, the four studies that find impairments in recognition are relative to both age-matched neurotypical (NT) individuals and intellectually disabled (ID) individuals except a study by Boucher, Bigham, Mayes &



Muskett, (2008) with children who found that recognition of coloured shapes was impaired relative to a younger, ability matched ALN and NT group but not relative to an age and ability matched ID group. Two of the four studies find impairments in ALI relative to NT, ALN and ID groups in recognition of pictures of everyday objects (Boucher & Warrington, 1976) and named pictures of common objects (Lind, 2008). The fourth study only compares ALI with a younger, ability-matched NT group but nevertheless reports a relative impairment in recognition of words used to name objects (Summers & Craik, 1994). In addition, the studies by Lind (2008) and Summers & Craik (1994) showed that although recognition was compromised, it was improved when participant children handled the stimuli themselves as opposed to the experimenter. This would suggest that there was an effect of self-enactment that is also witnessed in NT children.

Conversely, there are three studies that show recognition to be intact under diverse conditions. For example, the first study by Boucher & Lewis (1992) investigated picture recognition but testing was immediate rather than delayed which may have been advantageous, thus possibly accounting for the discrepancy between the mixed evidence so far. However, two other studies that reported intact recognition both tested recognition unexpectedly; thus participants did not have the chance to use effortful and/or intentional learning that would normally be expected to elicit more positive results. First, Hill and Russell's (2002) study with children tested recognition of common objects that had been handled in a preceding task and the objects were later presented unexpectedly in a different experiment. Similarly, Hauck, Fein, Maltby, Waterhouse & Feinstein (1998) assessed recognition of pictures of common objects which were presented in a previous matching task and later used unexpectedly in the test. It would be plausible to conclude that the 'unexpected' element of the test made it more difficult for comparison but not ALI

participants suggesting that relatively automatic processes involved in recognition memory may be preserved in ALI.

### *Recognition in ALN*

Findings from recognition studies in ALN are also varied but unlike in ALI the evidence overall favours the view that recognition is generally preserved. There are only a few cases that show mild impairments, specifically of written words (Bowler, Gardiner & Berthollier, 2004) and when foils (non-target stimuli) that are used in forced choice tests are notably similar to the target item (Bowler, Gaigg & Gardiner, 2010a; Williams, Goldstein & Minshew, 2006a). Toichi and Kamio (2002) also found that performance on a task using semantically encoded words was unimpaired. However, whilst a control group showed enhanced recognition of words selected to describe or not to describe themselves with, e.g. shy; the ALN group did not perform in this way. Similar findings have been shown by Henderson et al., (2009) and by Lombardo, Barnes, Wheelwright and Baron-Cohen (2007). Interesting results have been found when effects of different encoding conditions have been used. For example, Bowler, Gaigg and Gardiner (2008a) investigated recognition of written words that were presented in the context of a semantically related second word or when unrelated to the target word. They found that recognition was enhanced by relatedness in both ALN and NT groups demonstrating an intact ability in ALN.

Otherwise, in contrast to these few mixed and anomalous findings, most other studies in this area point to either normal or superior performance in recognition across a wider range of specific skills especially when compared to the current research in ALI. First, Toichi et al., (2002) found superior word recognition when followed by phonological encoding and

interestingly in an unexpected recognition test also. Further evidence of superior recognition performance was noted by Hillier et al., (2007) where different coloured and numbered geometric shapes and symbols were used. An additional three studies have found unimpaired but not superior recognition with non-meaningful shapes or patterns (Buitelaar, van der Wees, Swaab-Barneveld and van der Gaag, 1999; Bigham, Boucher, Mayes & Anns, 2010; Boucher, Bigham, Mayes & Muskett, 2008) and similarly unimpaired performance with common objects and colours (Hillier et al., 2007). Recognition of both spoken and written words have also been shown to be intact (Beversdorf et al., 2000; Hillier, Campbell, Keillor, Phillips & Beversdorf, 2007; Salmond et al., 2005; Boucher et al., 2005; Bowler, Gardiner & Grice, 2000; Bowler, Gardiner, Grice & Salavalainen, 2000b) as well as spoken sentences (Kamio & Toichi, 2007) and heard stories (Salmond et al., 2005; Williams, Goldstein & Minschew, 2006a). Pictures of common objects have been the most popular stimulus for testing recognition in ALN to date and evidence across four studies demonstrates intact performance on this type of task (Lind, 2008; Boucher et al., 2005; Joseph, Steele, Meyer & Tager-Flusberg, 2005; Ambery, Russell, Perry, Morris & Murphy, 2006). Recognition tests rely on a combination of familiarity and recollection and so far the evidence points towards familiarity being mostly preserved in ALN at this stage.

There are, however, a number of studies that show impairments on recognition tests that probe recollection (Bowler, Gardiner & Berthollier, 2004; Bowler, Gardiner & Grice, 2000; Bowler, Gaigg & Gardiner, 2008a; 2009; 2014). For example, in a recent study, participants with ALN were matched to controls on the number of years in formal education and on cognitive ability measured by the Wechsler Adult Intelligence Scale (WAIS-III, The Psychological Corporation, 2000). Participants were asked to study grids in which some cells contained drawings of objects in non-canonical colours. They were then told that at the study

phase which features relating to colour, item and location, would be tested later. In a second experiment, the participants studied similar grids and were told that they would be tested later on object-location or object-colour combinations. The findings from this study demonstrated that even when recognition was tested for specific combinations of items or item features that the ALN group performed significantly worse than their NT counterparts. The encoding of relations between items and between items and their contexts appears at this stage to be compromised in ALN whilst the encoding of item-specific information is relatively preserved (Bowler, Gaigg & Gardiner, 2014; Gaigg et al., 2008).

In summary, there is considerably more evidence concerning recognition memory in ALN than ALI, both in amount and breadth of analysis. ALI demonstrates a more complex mix of diverse recognition profiles, and the limited research and heterogeneous findings make any conclusions difficult. Straightforward recognition is most usually preserved but will be diminished when the task is more embedded in something more complex such as source memory or relational memory that will also employ recollective processes. It is therefore difficult to identify the exact contributions of familiarity and recollection in such tasks and then to pinpoint where impairments may lie. In relation to ALN, evidence overall points to intact performance on recognition with some notable exceptions that point toward a pattern of preserved familiarity but compromised recollection processes.

### *Free recall in ALI*

Tests of free recall in ALI have highlighted interesting findings relating particularly to whether the material used in tests is semantically related or unrelated to other items used.

Overall it appears that individuals with ALI show more relative impairments when material is related. Early studies such as one by Hermelin and O'Connor (1970) found that children did not show any impairments with immediate free recall of unrelated word lists. However, when semantic relatedness or syntactic structure was incorporated into the material for recall, children with ALI performed relatively poorly. Some later studies echoed this performance where performance on free recall tests of supra-span unrelated word lists was relatively unimpaired whilst conceptually or semantically structured lists posed difficulties (Boucher, 1978, 1981a; Fyffe & Prior, 1978; Tager-Flusberg, 1991). This implies difficulties with deep levels of encoding or use of organisational strategies during retrieval (e.g., the extent to which semantically or categorically related items are recalled adjacently during retrieval (e.g., Hunt & Seta, 1984).

Looking more closely at recall performance in children with ALI, equivalent recency effects to age-matched typically developing (TD) children have been observed, sometimes offsetting reduced primacy effects when recalling lists of semantically unrelated words (Boucher, 1978, 1981a). Fyffe and Prior (1978) suggested that uneven primacy vs. recency effects might contribute to difficulties on memory tests involving semantically related material. They found that impaired recall of sentences (semantically related words) in ALI was associated with the magnitude of the recency effect. Frith (1970) also noted that enhanced recency effects in ALI can disrupt serial recall, which may contribute or perpetuate the difficulties in using category clustering as noted in studies such as by Tager-Flusberg (1991).

There are a few earlier studies that found impaired delayed free recall in ALI (Boucher & Warrington, 1976; Boucher & Lewis, 1989) and findings are further complicated by possible enactment (self-performed tasks) effects (Boucher, 1981b;). Boucher (1981b) showed that on

activities performed by an ALI group, their free recall of participation in these activities was impaired relative to children with ID. Another study reported a similar finding but compared children with ALI to a younger group of NT children (Millward, Powell, Messer & Jordan, 2000). They also reported that recall of what another child did was not impaired showing a *reverse enactment effect*. However, this study was replicated by Hare et al., (2007) who later found no reverse enactment effect in very low ability adults compared with adults with ID. Yet there was a trend in each of these groups towards a self-enactment effect with the ALI group performing less well than the ID group but not at a significant level. Furthermore, the group sizes in this study were small and some of the participants in each group performed at floor (Boucher, 2012). Overall, the findings from these studies demonstrate that delayed free recall in ALI is impaired (Boucher & Lewis, 1989; Millward et al., 2000).

#### *Free recall in ALN*

As in ALI, findings for ALN for free recall are diverse but show a similar pattern where free recall of related items are relatively impaired to NT's whilst unrelated items are more congruent with typical performance. In studies using sets of unrelated words or pictures of everyday objects or words from a single category, intact performance has been shown regardless of whether recall is delayed or immediate and regardless of age (Ambery et al., 2006; Bowler, Gaigg & Gardiner, 2008a; Bowler et al., 1997; Minshew, Goldstein, Muenz & Payton, 1992; Mottron, Morasse & Belleville, 2001; Renner et al., 2000; Smith, Gardiner & Bowler, 2007; Williams et al., 2006a). There is slightly mixed evidence with the ability to learn long lists of unrelated words over repeated trials. In a study by Minshew and Goldstein (2001) recall of unrelated words was shown to be mildly impaired on Trial 1 and subsequent

trials in adults with ALN. Otherwise most other studies report performance to be unimpaired (Bowler, Limoges & Mottron, 2009; Buitelaar, van der Wees, Swaab-Barneveld & van der Gaag, 1999; Salmond et al., 2005). The exception to this was the subjective organisation study by Bowler et al., (2008a) where ALN and TD groups were similar in performance over the first few trials, but later the group with ALN reached a plateau thus demonstrating a deficit in recall.

In spite of the majority of findings pointing towards this equivalent ability to NT's of free recall of unrelated words and everyday items, there is also evidence of anomalous learning in both single and multiple trial tests. Renner, Klinger & Klinger (2000) found that children showed a lack of the usual primacy effect (memory for items at the beginning of the trial/list) on single-trial recall of items to be remembered whereas recall for the items at the end of the list (recency effect) was shown to be intact. The authors suggest that these findings show that children with ALN use different organisational strategies during encoding and/or retrieval of items from declarative memory. In addition, Bowler, Limoges et al., (2009) found that the primacy effect increases atypically slowly in adults with ALN over repeated trials. Also, in repeated trials, the subjective organisation of unrelated words in recall, both written and oral, has been found to be idiosyncratic in adults with ALN but convergent in an NT comparison group (Bowler, Gaigg et al., 2008a). In the Bowler et al., (2008a) subjective organisation study, strategies in the learning phase were different in the ALN group who showed lack of improvement on subjective organisation and free recall compared to NT individuals over the course of the repeated trials.

In free recall tests using semantically related word lists and items ALN performance is less intact than in free recall of unrelated items. In two studies mentioned above where adults

were shown to have intact performance of free recall of unrelated items, a test of free recall using a word list of semantically related words presented more difficulties and thus showed relative impairments (Bowler et al., 1997; Smith et al., 2007). The effects of either related or non-related context in recall and recognition were tested in a study with adults with ALN (Bowler, Gaigg & Gardiner, 2008b). Participants were asked to study words that were shown inside a red rectangle. They were also told to ignore context words that were shown outside the red rectangle. The context words were either related or unrelated to the study words. Results from this study showed that whilst recall of words presented in the context of an unrelated word was intact, when words were presented in the context of semantically related words that NT ability matched adults with ALN showed diminished recall. In addition, another study found that amongst adults with ALN who studied lists of associated items, their responses were characterised by excess false positive responses (Bowler, Gardiner, Grice & Saavalainen, 2000). The authors suggest that this anomaly is due to a difficulty with the use and organisation of semantic information.

There are two studies which showed that immediate recall of a list of related words by adults with ALN was impaired initially but then resolved over subsequent trials (Salmond, Ashburner, Connelly, Friston, Gadian & Vargha-Khadem, 2005; Minshew & Goldstein, 2001). Moreover, if items in a list of words are organised under hierarchical category headings, or if participants are instructed to encode words whilst sorting them into their respective categories, adults with ALN appear to be unimpaired (Bowler, Gaigg & Gardiner, 2009, Gaigg, Gardiner & Bowler, 2008). This suggests that the ability to utilise semantic information is in principle preserved but not spontaneously engaged in ALN.



In addition, free recall of sentences and stories are generally more impaired in individuals with ALN also (Botting & Conti-Ramsden, 2003; Williams et al., 2006a; Salmond et al., 2005; Minshew & Goldstein, 2001; Williams, Goldstein & Minshew). There are some exceptions with story recall but this may be due to the fact that age of participants is of relevance (Boucher, 2012). For instance, there are three studies that report intact abilities of story recall but these studies were conducted with adults only (Ambery et al., 2006; Boucher et al., 2005; Williams, Goldstein & Minshew, 2005). It is also possible that this discrepancy in the findings may result from the differences in the stories used and the varying level of social understanding required (Boucher, 2012).

#### *Cued recall in ALI*

Standard tests of cued recall have been used in four studies with ALI groups. The ability to use phonological cues has been found to be unimpaired relative to an age and ability-matched group without autism and also to an age-matched neurotypical (NT) group (Boucher & Warrington, 1976). In addition, the ALI group's performance was superior in terms of number of items recalled. In the same article, but a separate study, the ability to use semantic cues was also found to be intact in ALI in relation to an ability-matched group without autism and an age-matched NT group. Rhyme cues and category cues have also been tested and found to be unimpaired (Tager-Flusberg, 1991). There were also no differences between any of the three groups between the ability to use rhyme or category cues. Farrant, Boucher & Blades (1999) investigated the spontaneous use of visually available category cues (e.g. a picture of a bathroom to cue verbal recall of *toothbrush*, *soap* etc.) and found intact performance again in an ALI group. Also Klin, Sparrow, de Bildt, Cicchetti, Cohen &

Volkmar (1999) reported intact ability to recall the location of a picture on a page when cued with the picture. This was relative to a group of children with non-ASD related developmental or psychiatric disorders.

Paired associate learning (PAL) constitutes a type of cued recall where a novel and arbitrary relationship is established between two different stimuli during the study phase. One stimulus is then used to cue recall of the other. This was also shown to be intact by the Boucher & Warrington (1976) study in that ALI performance was at an age-appropriate level and superior to that of ability-matched groups. Finally, in studies of free recall where performance has been impaired, using informative cues such as “what did you buy in the shop?” significantly improved recall (Boucher & Lewis, 1989).

Source memory tests are a specific type of cued memory task where stimuli that have been correctly identified in a previous recognition task are used as cues to (contextual) information associated with that stimulus when it was seen in the study phase. Source memory can be assessed by either cued recall (e.g. “what colour was this word printed in?”) or cued recognition (“Which of these colours was the word printed in?”). At test the associations between the cues and the targets may be explicitly encouraged by the experimenter to be remembered (intentionally) or not mentioned directly (incidentally).

There are only two studies of source memory using participants with ALI, one of source recognition (Russell & Jarrold, 1999) and one of source recall (Bigham, Boucher, Mayes & Anns, 2010). In the source recognition study, picture cards were taken from, and returned to, one of four differently coloured boxes during the study phase. In one condition the experimenter moved the cards, and in the other condition the child participant moved the

cards. Source memory was tested by asking children to return correctly recognised picture cards to their appropriate boxes. Children with ALI were not impaired on this task but they did differ from their ID and younger NT comparison groups when a reverse enactment effect occurred. Children in the ID and NT groups recalled colour source more accurately in the experimenter-performed condition but the ALI group showed no differences in either experimenter or self-performed conditions.

In the source recall study testing temporal source memory (recollection) (Bigham et al, 2010), participants were shown a set of everyday objects one by one, with a banana always being presented as one of the objects in the middle of the sequence. At test, participants were asked whether they had seen the everyday object before or after the banana. Teenagers with ALI showed impaired performance relative to their nonautistic ID and young NT comparison groups on this task.

#### *Cued recall in ALN*

As in ALI, performance on standard tests of cued-recall and PAL is largely intact. Mottron et al., (2001) used category names to cue delayed recall of category exemplars as well as initial syllables to cue recall of polysyllabic words. Bowler et al, (1997) and Gardiner et al., (2003) reported intact performance on delayed recall of words in response to written word-fragment cues, and Ambery et al., (2006) found unimpaired delayed recall of unfamiliar proper names in response to cues relating to occupations in a study with adults. In relation to PAL paradigms, both the study by Gardiner et al., (2003) and Ambery et al., (2006) showed that

paired word associate learning was preserved in ALN and this was also shown in further studies by Minshew & Goldstein (2001) and by Williams, Goldstein and Minshew (2005).

Further evidence for preserved cued recall in ALN stems from studies that use leading or direct questions as cues to recall. This has been shown in two separate studies. First, a study by McCrory, Henry & Happe (2007) tested free recall of passively observed naturalistic events and found that performance was impaired but when leading or direct questions were incorporated as recall cues (e.g. what were they wearing?) performance improved to the levels of comparison groups. Similarly, in an eye-witness testimony study with adults with ALN by Maras and Bowler (2010) it was shown that non-informative prompts and direct questions could elicit unimpaired recall relative to ability matched NT adults. It was important that the questions were phrased in a way that was sensitive to the needs of the individuals.

In source memory, the findings with ALN are mixed. Bowler et al. (2004) found unimpaired ability to recognise a description of what participants had been asked to do when a particular word had appeared on a screen during the study phase (e.g. “think of a related word,” or “find a rhyme”). However, on a recall test of the same contextual information the same participants were impaired, even though only four options were incorporated. Bowler et al. (2000) have also showed impaired recall in a ‘remember – know’ study which tested recall of self-experienced contextual information associated with remembered words by adults. Likewise with children, and based on a remember-know paradigm also, Bigham et al. (2010) found impaired recall of manual actions that had been arbitrarily associated with a non-meaningful shape. These studies rely on the use of recollection skills because they rely on the ability to recall contextual information present at study rather than recognise them. There are two

studies that tested recall of temporal source using a word recognition test. Salmond et al. (2005) found adolescents with ALN to be unimpaired whereas Bennetto et al. (1996) found children of mixed ability (ALN & ALI) to be impaired. In another more recent mixed ability study (the mean full IQ score was 108, but the lowest went down to 73) spatial memory was investigated using tests where participants were presented with pictures of rooms and pictures of objects (Ring, Gaigg & Bowler, 2015). The location of the objects was highlighted in the rooms and participants were then asked which locations belonged to the objects and vice versa. ASD individuals found it relatively difficult to retrieve the object locations and the authors reported that these difficulties result not from a specific difficulty with spatial information but rather the relational encoding of both location and object.

## **Conclusions and Predictions**

### *Summary of similarities and differences of the memory profile between ALI and ALN*

Although ALN groups will generally be expected to perform better on most tests than ALI groups there are some exceptions and anomalies that are difficult to explain. In the main, the memory profile in both ALI and ALN is broadly similar and the strengths and weaknesses in each group reflect their appropriate control group. Similarities in declarative memory between ALI and ALN include preserved functioning in areas of cued recall, PAL and immediate free recall of semantically unrelated materials. In terms of non-declarative memory it is more difficult to draw firm conclusions as there are not many studies in ALI. However, the evidence that does exist points toward shared strengths across the autism

spectrum (Boucher et al., 2012). There are shared impairments in both ALI and ALN in free recall of semantically related stimuli and on source memory tasks that require the recall of contextual information, there is little evidence relating to ALI.

What is different between ALI and ALN is centred on evidence concerning recognition memory. There is sufficient evidence that finds recognition to be relatively preserved in ALN whereas in ALI it is most often found to be compromised. When stimuli are related in free recall word list learning there is mixed performance in ALN but in ALI it is highly compromised. Overall the memory profile for ALI points to a more pervasive declarative memory impairment comprising both familiarity as well as recollection, which is also present in ALN. The consequences of such compromised memory abilities are considered below.

### ***Conceptualising memory impairments in ALI and ALN***

The profile of memory strengths and weaknesses set out above has led to a number of different interpretations in the ASD literature. Early attempts to explain the profile, took recourse to prevalent theories at the time such as the weak central coherence theory (difficulties with semantic relations) or executive dysfunctions account (using organisational strategies) but these theories do not fully capture all the nuances in the ASD memory profile that recent evidence highlights, such as why semantic relations pose difficulties on tasks of recall but not on recognition (e.g., Bowler et al., 2007). More recent conceptualisations of the ASD memory profile, capture these various nuances much better.

For example, Minshew's complexity hypothesis (Minshew & Goldstein, 1998; Williams, Minshew & Goldstein, 2015) states that the cognitive profile in ASD, including various difficulties in the domain of memory, reflects complex information processing demands. 'Complex information processing' is described as the detection or use of organisational strategies, a high processing load or a requirement for the integration of information. This is in contrast to 'simple information processing' that is described as the use of basic perceptual processes or a low information-processing load. This can be usefully applied to understanding memory deficits in ASD in two ways. First, at a conceptual level, it has already been noted that the process of familiarity involves memory for single facts (such as how old you are) and could be assumed to be relatively less complex than the process of recollection which involves a richer, contextual and autobiographical content of different elements that combine into one memory event (such as a memory of a previous birthday party). It is consistent with the literature discussed so far that individuals with ASD find recollection more difficult than familiarity. Therefore Minshew's complexity hypothesis at first glance is a useful explanation here.

A second way of defining complexity could be along the lines of establishing a scale of complexity in relation to memory tasks. For example, findings have indicated that individuals with ASD perform typically on short-term memory and paired-associate tasks but on more complex tasks such as list-learning and delayed recall of stories their performance is poorer (Minshew & Goldstein, 2001). Considering the former types of tasks less complex than the latter is intuitively a sensible conclusion. However it does not involve a formal operationalisation of complexity such as the amount of information that is processed. Halford (1993) offers a useful framework in this context. He explains that 'binary relations' between a studied item and its activation set is relatively simpler than when a categorised list of items

is learnt that allows information to be stored in a way that may support recall. This is much more complex and Halford terms this 'ternary relations' where not only inter-word relations need to be processed but also the relations between the words and their category label (Bowler & Gaigg, 2008). Hence, these two ways of defining 'complexity' in terms of either 'amount to be processed' verses 'the level of complexity' are not obviously dissociable. It is therefore difficult to operationalize 'complexity' in the domain of memory, whether at a conceptual or empirical level. Another way of formalising the notion of complexity in memory is the Task Support Hypothesis (TSH) that has been proposed by Bowler, Gaigg and Lind (2011).

The TSH (Bowler, Matthews & Gardiner, 1997) addresses levels of complexity in test conditions at retrieval and suggests that certain levels of support can enable individuals with autism to improve their performance, sometimes up to a similar level of NT's. This could be in a variety of ways that scaffold memory retrieval such as by cueing recall. So, although reducing the complexity of the retrieval situation can boost memory performance, the TSH does not attempt to explain why individuals with ASD rely on more support at retrieval. It could be the case that at retrieval, if there is more than one item to remember (such as a memory of how old you are), a combination of items and how they intermesh to form a single event (such as a memory of a birthday party) is too complex. Hence it may be useful to conceptualise this type of memory processing as relational processing (memory of a birthday party), contrasted with single item memory (how old you are).

It is useful at this point to see how relational vs. item-specific information relate to recollection vs. familiarity. Neurological evidence shows that the entorhinal and perirhinal cortices of the medial temporal lobe (MTL) process item-specific information whilst the



hippocampus processes relational information (Yonelinas, Otten, Shaw & Rugg, 2005; Mayes, Montaldi & Migo, 2007; Mayes, Montaldi, Spencer & Roberts, 2004; Brown & Aggleton, 2001). The pre-frontal cortex (PFC) is implicated invariably at both encoding and retrieval stages. Moreover, the PFC and hippocampus work together to establish a contextual (spatial and/or temporal) memory at the stage of retrieval that constitutes a process of 'recollection'. On the other hand, when the perirhinal and entorhinal cortices yield information that either relates to single items or decontextualized facts about the past, the process of familiarity is created (Brown & Aggleton, 2001; Eichenbaum, 2004). Relational and item-specific processing do not directly map onto recollection and familiarity but there is a significant overlap and they are seen as complementary processes (Gaigg et al., 2015). This overlap is of importance when investigating the memory profile in ASD. However, although these theories attempt to explain to a useful degree the memory difficulties experienced by individuals with ASD, none of them pays sufficient attention to the functional consequences.

The functional consequences stemming from such uneven memory abilities are long lasting and significant. For individuals with ALN, the ability to compensate for their impairments by capitalising on their preserved abilities can be advantageous. From a developmental perspective these compensatory adaptations can take place from a very early age (Boucher, 2012) and will likely have a dramatic effect on the course of an individual's development. At best, this can be beneficial, where individuals with ALN can use their preserved abilities in habit forming and routines (procedural memory) combined with their knowledge for facts (semantic memory) and verbal ability. Longer-term outcomes may then be more positive as these types of skills can be utilised in the workplace especially if combined with a high IQ (Boucher, 2012).

However, in ALI, whilst research is less well established, there is still enough evidence to suggest that if familiarity is additionally impaired by comparison with recollection then the behavioural consequences are likely to be more significant. As discussed in Chapter Two, in spite of phonology and syntax being intact, the acquisition of word meanings and factual knowledge will be impaired. Again, this is likely to occur from a very early age and the overall developmental consequences within structural language can be great. In the context of Ullman's DP hypothesis, if there is a pervasive impairment in declarative memory particularly in ALI, then it is likely that this is contributing to those individuals' structural language impairment. It is also worth noting that in the several ways that the declarative and procedural systems are able to interact, compensate and co-operate with each other, this may also have an influence on particular aspects of structural language that may account for the extreme diversity up and down the ASD spectrum as well as among individuals with ASD.

### *Aims and predictions*

The primary aim of the research reported in this thesis is to investigate the contribution of declarative memory impairment to impaired semantic knowledge and its possible role as a cause of structural language impairment in lower-functioning children with ASD.

There are two secondary aims. The first of these is to obtain data on possible causes of language impairment in children with intellectual disability (without ASD). The second is to compare memory abilities and their relations with semantic knowledge in language-impaired and non-language-impaired children with ASD.

The design of this research consists of two major experiments each assessing the dual components of declarative memory - familiarity and recollection - and how they relate to semantic knowledge as assessed by the Pyramids and Palm Trees Test (PPT; Howard & Patterson, 1992). Anticipated effects on semantic knowledge of age, nonverbal IQ (measured using raw scores from Ravens), theory of mind (ToM) and visuo-perceptual abilities (measured using the Children's Embedded Figures Test, (CEFT), Karp & Konstadt, 1963) will be controlled for. Four groups of child and adolescent participants will be assessed: two ASD groups (with typical language (ALN) and impaired language (ALI)), one intellectually disabled (ID) group and a typically developing (TD) group, as set out in the following chapter.

### ***Predictions***

On tests of familiarity in both Experiments 1 and 2: the ALI group will be impaired relative to the TD and ALN groups; the TD and ALN groups will perform similarly and the ID group will perform similarly to the ALI group, or at a level intermediate between the ALI and the TD and ALN groups. On tests of recollection in both Experiments 1 and 2: the ALI and ALN group will be impaired relative to the TD group; the ID group will either perform similarly to the ALI and ALN groups, or at an intermediate level between these two groups and the TD group.

Correlation tests to assess the main determinants of semantic knowledge will show: in the combined groups, scores on the PPT and WASI verbal intelligence tests will correlate with each other and with scores on the familiarity measures. In the 4 groups separately,

correlations between scores on the PPT and WASI with scores on the familiarity measures may not reach significance, but will be greatest in the ALN group [because they compensate for impaired recollection, using familiarity], followed by the ALI group [because the impairment of familiarity may show up in a correlation, as it did in the early recognition experiment by Boucher et al., 2008], with small or non-significant correlation in the TD group. No prediction is made concerning correlation in the ID group [because there is little research on likely causes of ID-without autism – but it is expected that NVIQ is likely to contribute].

In the combined groups, the PPT scores will correlate with nonverbal IQ. In the four groups separately, correlations between scores on the PPT and NVIQ may not reach significance, but will possibly be greatest in the ID group and least in the ALI group.

In the combined groups, scores on the CEFT (visuo-perceptual abilities) will correlate with scores on 3 out of the 4 subtests used to assess recollection and familiarity, all of which involved attention to visuo-spatial detail. In the groups separately, we predict relatively high CEFT scores in both ASD groups, facilitating correct responses to the three memory subtests. We made no specific predictions concerning relations between CEFT scores and memory subtest scores in either of the two other groups.

## **Chapter Four**

### **General Methodological Design, Points and Procedures**

In this chapter, general points relating to experimental design, participant recruitment and testing will be described first, including ethical procedures.. Materials and procedures used in the subsidiary tests will be outlined in Chapter Five. The majority of these tests used standardised materials and methods. Details of participant groups, material and methods used in the two major experiments, both of which comprise tests of declarative memory, will be given in Chapters Six and Seven, in which these two experiments are described separately.

#### **Design**

Two separate experiments formed the core of this empirical research and each experiment assessed the contributions of familiarity and recollection to declarative memory. In addition conceptual semantic knowledge (a component of structural language) was assessed using the Pyramids and Palm Trees Test (PPT) – Picture Version (Howard & Patterson, 1992) and formed the outcome measure.

There are other known factors that contribute to semantic knowledge which include non-verbal ability or fluid intelligence as assessed by the Ravens Coloured Progressive Matrices and theory of mind (ToM) which was assessed using a standard false belief task (SFB, ‘unexpected contents’ task). A test of implicit ToM was also intended to have been included but shortage of time as well as problems with the timing settings within Tobii software meant

that the data analysis would have been too time-consuming. Chronological age (CA) was also recorded and noted as it contributes to semantic knowledge.

Finally, both experimental tests used visuo-spatial materials and this was because it was important that the familiarity and recollection could be tested as independently from language as possible. Therefore the tests had to be as non-verbal as possible and be appropriate for children. It was expected that these type of stimuli might have advantaged the ASD groups due to their visuo-spatial skills therefore to control for this potential group difference a test of central coherence was included (The Children's Embedded Figures Test, Karp & Konstadt, 1963) to account for any influence of the material on the results of declarative memory tests.

Four separate participant groups were formed to assess possible structural language differences between children with ASD with typical language (ALN) and those with language impairment (ALI). A group of typically developing children (TD) was recruited to act as a comparison group, mainly for the ALN group; and a group of children with intellectual disability with no autism (ID) acted as either a potential control group to the ALI group and/or a clinical group with their own distinct language anomalies to be investigated that may be different from those with ASD. Further details are set out below.

## **Participants**

Four groups of children were recruited to the study: two groups of older children and teenagers, one group with lower functioning autism or autistic disorder (ALI); and the other group with intellectual disabilities without autism (ID); and two further groups of children,

one group with high functioning autism or Asperger syndrome (ALN); and another group of typically developing (TD) children. The ALI group were equated with the ID group for chronological age (CA) and verbal ability, and the ALN group was equated with the TD group for CA and verbal ability. Verbal ability was assessed using the two verbal subscales 'Vocabulary' and 'Similarities' from the Weschler Abbreviated Scales of Intelligence (WASI; 1999). Scores on these two tests combined to give a verbal intelligence quotient score (VIQ). In the ALI and ID groups, VIQ scores below and including 75 were allowed and in the ALN and TD groups, VIQ scores above and including 90 were allowed with no upper limit.

In the ALI group, all children and young people attended special schools catering for autism either exclusively or inclusive of intellectual disabilities without autism. All had been diagnosed as autistic by experienced Psychiatrists or Clinical Psychologists using the DSM-IV (APA, 1994) and statements were provided by the schools to the experimenter. In the ALN group all children attended mainstream schools that catered for Asperger's syndrome and ALN either by attending a special unit or by being integrated into normal class and in some cases with a learning support assistant. All had been diagnosed as autistic by experienced Psychiatrists or Clinical Psychologists using DSM-IV (APA, 1994). In the ID group all children and young people attended special schools catering for autism and intellectual disabilities without autism. None of them had a diagnosis on the autistic spectrum or had a record of any autistic features of behaviour. They also displayed no obvious autistic traits as observed by the experimenter; apart from one child in the ID group who was excluded from the study from the start. This child evidently displayed signs of both SCI's and RRB's despite no diagnosis of autism. All children in the TD group attended mainstream junior schools serving mixed catchment areas and had no record of autistic

features of behaviour as well as showing no obvious signs of autistic traits as observed by the experimenter.

Every participant in Experiment 1 also took part in Experiment 2 but Experiment 2 included extra participants across all four groups. A summary of all included participants and their descriptive statistics is shown in Table 4.1.

**Table 4.1 Descriptive Statistics for Participant Groups**

Measure	ASD					
	ALI ( <i>n</i> = 20)			ALN ( <i>n</i> = 26)		
	Mean	SD	Range	Mean	SD	Range
Age (months)	178.1	24.99	123-218	108.96	15.99	75-136
VIQ <sup>a</sup>	64.75	6.17	55-75	104.92	11.92	91-135
Ravens <sup>b</sup>	25.9	7.54	7-36	24.31	8.11	8-36
Measure	Non-ASD					
	ID ( <i>n</i> = 26)			TD ( <i>n</i> = 32)		
	Mean	SD	Range	Mean	SD	Range
Age (months)	176.42	21.72	136-214	98.53	9.44	81-114
VIQ <sup>a</sup>	61.96	4.84	55-74	109.9	11.35	90-142
Ravens <sup>b</sup>	17.11	6.93	6-27	24.68	5.78	10-36

<sup>a</sup> WASI verbal subscales

<sup>b</sup> Ravens CPM

### ***Exclusion Criteria***

The criteria for exclusion included hearing impairment, neurological condition or epilepsy but no participants had any of these. Further exclusions of participants, from an initial total of 133 were made based on incomplete datasets (*n* = 17), attrition due to pupils leaving their school (*n* = 7) and where participants were untestable due to the tasks being too demanding (*n*



= 5). These exclusions occurred across all groups but with 12 from the TD group where schools were changed and testing was incomplete for Experiment 1.

### ***Participant Recruitment***

Special and mainstream schools were identified for potential participants mainly in the Sussex area. Schools were contacted by letter and then followed up with a meeting between the experimenter and a representative from the school (Headteacher or Special Needs Co-ordinator). Schools gave their consent for children to participate subject to parental consent. In total, 10 schools agreed to work with the experimenter and the numbers of children recruited ranged from 6-24 per school.

The first visit between each child and the experimenter involved ensuring the child was at ease with the experimenter; either by general talking or doing an activity of the child's choice, for example, threading beads or looking at pictures. In some cases the child preferred to start doing the verbal tests straight away. In several cases, if a child was a little unsettled, the Ravens Coloured Progressive Matrices test was administered first due to its non-verbal and engaging nature. In addition, this change of order in testing contributed to counterbalancing all the tests in order to avoid test effects. The child was asked for their continued consent during all contact with the experimenter to ascertain that they would like to continue with any of the tests. This continued throughout the testing phase that included a number of visits sometimes totalling up to 9 or 10 per child.

### ***Ethical procedures***

The experimental procedures outlined below for both experiments adhere to the ethical guidelines set out by the British Psychological Society and were approved by the City University London's Senate Ethical Committee.

During all testing procedures, continued consent was conducted mainly verbally at approximately 10-minute intervals where the experimenter asked the child if they were happy to continue with the 'activity.' If the child became tired or lacked concentration testing would cease and resume at another appropriate time. It was never the case that a child received no credit because of failure to complete a test. In order for children to perform well in their tasks they needed to not only feel settled and content but also be willing to sit down and keen to do the tasks. It was established at the outset of each testing period with each child that they and their teacher were happy for testing to proceed.

### ***Recruitment Difficulties***

There were several delays associated with the University's Ethics Committee procedures; very slow responses from schools initially approached; failures of schools to respond to letters or e-mails; as well as time-consuming demands made by individual schools (e.g. that the experimenter sit in children's classes for a week before taking any child out for testing); time-wasting restrictions on child availability and numerous other factors. Most of this would be considered typical for recruiting children but on advice, it was quite extreme.

Despite the numerous challenges, strict and rigorous testing in terms of consistency and organisation was employed by the experimenter. Every effort went into establishing a stringent methodological approach which was exercised in all of the tests, both experimental and subsidiary, which are described in the following chapter.

## Chapter Five

### Methods and Results of Subsidiary Tests

#### Method

##### *1) The Social Responsiveness Scale – Second Edition, (SRS, Constantino, 2012)*

The SRS identifies social impairment associated with Autism Spectrum Disorders and quantifies its severity. It is sensitive enough to detect even subtle symptoms, yet specific enough to differentiate clinical groups, both within the autism spectrum and between ASD and other disorders. This questionnaire is on a likert scale and is filled in by teachers and/or teaching assistants that know the child. Parents did not fill in the questionnaire as teachers were considered to be able to provide a more objective assessment of each child.

Unfortunately, this was the most difficult test from which to gain feedback from teachers and only 28 questionnaires in total were returned despite numerous attempts by the experimenter to follow this up with schools. It is therefore not possible to use this test in any analyses.

However, there were no children with scores that would suggest that a participant should be excluded from any groups. For example, from the questionnaires returned, there were no TD children or ID children displaying autistic traits above what would be considered normal for a non-ASD population. The experimenter also used their own judgement when informally observing children. There was one child in the ID group who did display ‘autism-like behaviours’ (such as lack of eye contact, monotone prosody, repeating phrases and obsession with threading beads) which was confirmed in a conversation with their class teacher and the child was then excluded from the study.

## **2) *Weschler Abbreviated Scales of Intelligence (WASI; 1999)***

The WASI consists of four subtests: Vocabulary (verbal), Similarities (verbal), Block Design (non-verbal), and Matrix Reasoning (non-verbal). In the present study, two of the verbal subtests (Vocabulary and Similarities) were combined to provide a VIQ score which was then used for selecting and matching participant groups. The Vocabulary subtest is a measure of word knowledge, verbal concept formation, and fund of knowledge; the Similarities subtest measures verbal reasoning and concept formation. Both provide a brief and reliable measure of cognitive ability for use with children and measure crystallized abilities (Cattell, 1961). The Vocabulary subtest asks participants to describe a word verbally such as ‘shoes,’ ‘cart,’ ‘alligator.’ The Similarities subtest asks participants to describe verbally how two things are similar such as ‘blue and red,’ ‘bowl and spoon,’ ‘song and photograph.’

## **3) *The Children’s Embedded Figures Test (CEFT, Karp & Konstadt, 1963)***

The Children’s Embedded Figures Test is a measure of weak central coherence involving visual search for simple figures or objects embedded in larger, more complex figures. 24 test items were presented on black and white laminated paper A4 sheets. The Embedded Figures Test (EFT) was originally designed to assess the concepts of “field dependence – independence” (e.g., Witkin & Goodenough, 1981). Good performance on the EFT is taken as a marker of field independence, the ability to disembed information from context or surrounding gestalt. The test requires the participant to spot a simple form within a more

complex figure; the colour and form of the latter create a gestalt within which the part is hidden (see Figure 5.1). In the Children's EFT, the complex figure is also meaningful (e.g., a pram, within which the triangle to be found is hidden in the hood of the pram).

**Figure 5.1** Example of a test item from the CEFT



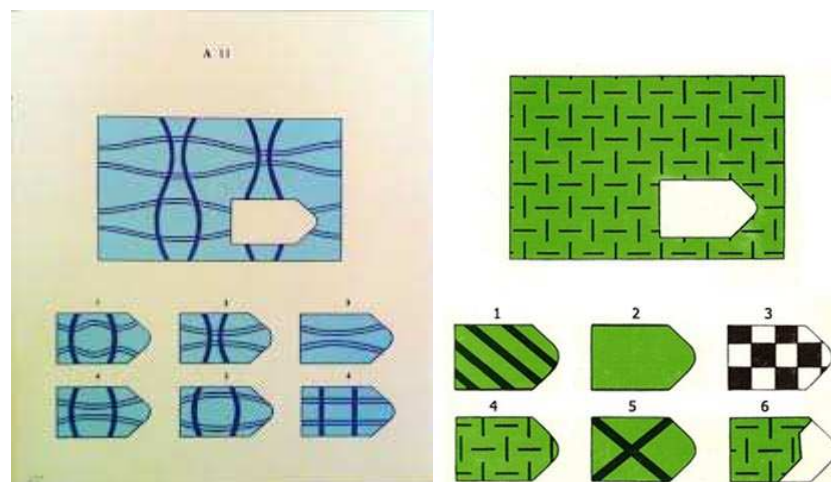
#### **4) Ravens Coloured Progressive Matrices (1976)**

This is a non-verbal test comprising 60 multiple-choice tasks, presented in ascending order of difficulty. It is designed to measure reasoning ability involving the capacity to store and reproduce information, as well as the educative component of general intelligence which involves the ability to think clearly and make sense of complexity. In each test item, the participant is asked to identify the missing element that completes a given pattern. A series of patterns is presented in the form of a 4x4, 3x3, or 2x2 matrix (see Figure 5.2). Raven's Coloured Progressive Matrices (CPM) measures clear-thinking ability and is designed for young children ages 5:0-11:0 years and older adults. The test consists of 36 items in 3 sets (A, Ab, B), with 12 items per set.

The CPM produces a single raw score that can be converted to a percentile based on normative data and which is generally accepted as being a measure of non-verbal intelligence (NVIQ) and what Cattell (1961) has termed *fluid intelligence*. In this research it is largely referred to as fluid intelligence (FI) as it is not a strict measure of NVIQ.

In addition, the raw scores were used for the analysis because conversions to a standard scoring system are limited to steps of five points which may not provide a sufficiently sensitive measure. A minority of participants had only been tested on the Standard Progressive Matrices (SPM) and so their score was converted to a CPM score using the Tables provided in the Ravens manual.

**Figure 5.2. Examples of two test items from the CPM**



**5) Pyramids and Palm Trees Test (PPT) – picture version (Howard & Patterson, 1992)**

This test consists of 3 trial items and 40 test items and is a forced-choice test. The participant is shown three pictures, one above the other two and is asked to match the top picture to one of the other two pictures with which it is most closely associated. No names of the pictures

are mentioned, and the participant is asked not to name the objects. Because the task requires no overt language, it is considered a relatively pure measure of conceptual semantic processing and can test the degree to which a participant can access meaning from pictures and words. The pattern of results can be used to build up a picture of the participant's ability to access semantic and conceptual information. For this reason the scores from this test were used as the clinical outcome measure for both experiments one and two.

#### ***6) Standard Explicit False Belief Task – Unexpected Contents Test***

There is a great deal of evidence to suggest a significant relation between mindreading skills and structural language ability therefore it was important to include a test of implicit and explicit mindreading ability in the experiments. The capacity to mind-read is often measured by false belief tasks, one of which, the unexpected contents task, was used here. Originally, an implicit mindreading test was devised using video materials from a study by Senju, Southgate, White and Frith (2009). As mentioned above this was not possible to complete. However, a simple explicit false belief task was conducted with a subset of participants across groups.

The standard false belief task (SFB) was based on the ‘Smarties’ test, or ‘unexpected contents’ test used to test mindreading skills (Gopnik & Astington, 1988). In case the child was familiar with this test a different set of materials was used to the more familiar box of ‘Smarties’ and pencils. Here, a jar looking as if it contained hot chocolate was used and inside there was a highlighter pen.



The experimenter asked the participant what they believed to be the contents of a jar that looks as though it contained hot chocolate. After the child guessed (usually) "hot chocolate", it was shown that the jar in fact contained a highlighter pen. The experimenter then closed the box and asked the child what he/she thought their teacher, who has not been shown the true contents of the box, would think was inside. The child passed the test if they stated that another person would think that there was "hot chocolate" in the box, but failed the task if they stated their teacher would think that the jar contained a highlighter pen. Typically developing children usually pass this test around the age of four to five years (Gopnik & Astington, 1988). This task tested the mentalizing ability that other people may have beliefs that diverge from their own as well as their ability to attribute to another person a mental state or standpoint that is different from their own. Due to the pass/fail scoring on the test the data was unable to be used for covariant purposes.

### **General Procedures for all Tests (Subsidiary and Experimental)**

Children were tested individually and they were seated at a table with the experimenter in a familiar room or working area in their school. They either sat next to or opposite the experimenter depending on the test. In some cases a teaching assistant would also be present to either ensure that the child was not anxious or to supervise children who were prone to difficult behaviour.

Scoring of the tests was mainly done after the child had left the room. All children were continuously encouraged and made to feel that they were always succeeding. The experimenter helped focus their attention when necessary by, for example, pointing to objects

or tapping the laptop screen to encourage looking when appropriate. A certificate was shown to each child and after each test the child ticked a box to confirm success and completion. When boxes for all the tests were ticked, the child received the certificate and was thanked by the experimenter.

## Results

Scores from the subsidiary tests are presented in Table 5.1.

**Table 5.1 Mean scores on subsidiary tests, *n* in parentheses**

Measure	ASD			
	ALI (20)		ALN (26)	
	Mean	SD	Mean	SD
Voc Raw <sup>a</sup>	21.3 (20)	8.33	31.81 (26)	9.32
Sim Raw <sup>b</sup>	17.9 (20)	7.12	25.11 (26)	5.72
SFB <sup>e</sup>	45% (11)	0.52	70% (14)	0.47
PPT <sup>f</sup>	35.9 (20)	2.95	35.77 (26)	2.52
CEFT <sup>g</sup>	16.35 (20)	5.83	15.15 (26)	6.09
Ravens <sup>h</sup>	25.9 (20)	7.54	24.31 (26)	8.11

Measure	Non-ASD			
	ID (26)		TD (32)	
	Mean	SD	Mean	SD
Voc Raw <sup>a</sup>	17.38 (26)	4.3	29.41 (32)	5.87
Sim Raw <sup>b</sup>	17.12 (26)	3.91	24.72 (32)	3.45
SFB <sup>e</sup>	50% (10)	0.53	100% (8)	0
PPT <sup>f</sup>	35.23 (26)	2.93	37.41 (32)	1.9
CEFT <sup>g</sup>	8.31 (26)	4.42	15.47 (32)	4.81
Ravens <sup>h</sup>	17.12 (26)	6.94	24.69 (32)	5.78

a Raw scores from the Vocabulary verbal subtest of the WASI

b Raw scores from the Similarities verbal subtest of the WASI

e Standard False Belief test – Unexpected Contents task

f Pyramids and Palm Trees Test (PPT)

g Children’s Embedded Figures Test

h Fluid Intelligence (FI) as measured by the Ravens Coloured Progressive Matrices

Separate scores from the WASI verbal subtests are given and due to the fact that some participants scored at floor when scores were standardised, raw scores were used as outcome measures in the analysis. The standard false belief task is a correct/incorrect test therefore the

percentage score represents a group percentage of correct answers. The PPT test has a total score of 40, and the CEFT test is scored out of 24. The Ravens test has a maximum of 36 and represents a raw score.

The data summarised in Table 5.1 will be analysed in conjunction with data from the two main experiments, to be reported in Chapters Six and Seven. Inspection of the Table shows that the TD, ALN and ALI groups are matched on Ravens, a measure of fluid intelligence and non-verbal ability, whereas the ID group scores are relatively lower. Similarly, the TD, ALN and ALI groups score very similarly on the CEFT, whereas the ID group scores are markedly lower. Further discussion of these observations will be presented in Chapter Eight.

## Chapter Six

### Experiment 1 - Forced Choice Recognition Test

#### Background

The aim of this experiment was to identify the distinct contributions of recollection and familiarity to performance on a declarative memory task by children in each of the four groups using a pair of specially designed forced choice recognition tasks. These tasks were initially developed for use in studies of amnesic adults by Migo, Montaldi, Norman, Quamme and Mayes (2009). However, the stimuli to be used here are from a later study conducted by Migo, Montaldi and Mayes (2013), which will be discussed below. The next aim, which relates to the hypothesis of this research, was to determine the relative contribution of familiarity to semantic knowledge across the different diagnostic groups.

The basic task for children was to try to remember a series of black and white photographs of everyday objects. The test phase comprised 12 items containing the target and three foils in a forced choice recognition paradigm. The two separate tasks in this experiment differed only in the kind of foils used. In one of the tasks, referred to as the ‘forced choice corresponding test’ (FCC, see Figure 6.3), foils resembled the target stimulus, whereas in the other task, referred to as the ‘forced choice non-corresponding test’ (FCNC, see Figure 6.4) foils did not resemble the target stimulus, but instead comprised pictures closely resembling other recently seen target stimuli. The former FCC test is thought to favour the use of familiarity to achieve correct performance (Parkin, Yeomans & Bindschaedler, 1994) because the very similar options to choose from would trigger indistinguishable levels of recollection; whilst the

correct target gives rise to a somewhat greater sense of familiarity that thus allows for a correct response. By contrast the FCNC test favours the use of event recollection to achieve correct performance because the sense of familiarity the foils give rise to cannot be directly compared to the levels of familiarity of the relevant target item.

This involvement of both familiarity and recollection in recognition tests is consistent with the Complementary Learning Systems (CLS) model proposed by Norman and O'Reilly (2003). This dual-process computational model of memory comprises a neocortical component that supports familiarity processing and a hippocampal component that supports recollective processing. The model predicts that where targets and foils are very similar (FCC), familiarity will be relied upon rather than recollection because the targets' familiarity can be directly compared to the familiarity of the foils. In a FCNC such a direct comparison between the familiarity signals of the targets and foils is not possible because all the foils are related to different target items and so they will be nearly as likely to be more familiar than the target as they will be less familiar. Therefore there is no principled decision rule that can allow targets to be reliably distinguished from their foils based on familiarity alone and participants are thus biased to rely on their recollection skills (See Migo et al. (2009) for a more in depth description). In short, the FCC test is a reliable test of familiarity whilst the FCNC test relies more upon the process of recollection. This method has been used reliably and repeatedly with amnesic patients and patients with hippocampal damage (Mayes and colleagues; Holdstock and colleagues; Westerberg and colleagues), in whom performance on the FCNC test is more substantially impaired than on the FCC test where there is no impairment. Given its non-verbal nature, the task is ideally suited to be adapted for use with the children that comprise the sample for the current research. For such children, alternative paradigms such as the Remember/Know paradigm that has been used with adults with ASD

(e.g., Bowler et al., 2007) would be unsuitable because they ask participants if they have a sense that they ‘know’ an item and have seen it before, or whether they ‘remember’ some contextual details about a given item. These type of questions or instructions require a high level of receptive and expressive language that participants may not have. Therefore the familiarity and recollection paradigm developed by Migo and colleagues is a more effective test for children.

## Method

### *Participants*

Ninety one children and adolescents were recruited for this experiment, including 24 TD, 23 ID, 18 ALI and 24 ALN as set out in Table 6.1.

**Table 6.1** Descriptive statistics for participant groups

Measure	ASD					
	ALI (n = 18)			ALN (n = 26)		
	Mean	SD	Range	Mean	SD	Range
Age (months)	180.17	25.54	123-218	108.96	15.99	75-136
VIQ <sup>a</sup>	65.17	6.23	55-75	104.92	11.92	91-135
Ravens <sup>b</sup>	27.67	5.43	16-36	24.31	8.11	8-36
Measure	Non-ASD					
	ID (n = 23)			TD (n = 24)		
	Mean	SD	Range	Mean	SD	Range
Age (months)	175	21.66	136-213	98.42	10.8	81-114
VIQ <sup>a</sup>	62.48	4.84	55-74	107.04	7.36	95-119
Ravens <sup>b</sup>	17.57	7.11	6-27	22.5	4.41	10-28

<sup>a</sup>WASI verbal subscales

<sup>b</sup>Ravens CPM

All participants were recruited in line with the general recruitment procedures outlined in Chapter Four and their descriptive statistics are re-presented in Table 6.1 as this dataset represents a subset of the overall dataset presented in Chapter Four.

### ***Materials***

The stimuli used for the experimental tasks were taken from Migo et al (2013) and comprised a series of grayscale photographs of everyday items on a plain background (see Figures 6.3 and 6.4). Through a set of carefully designed pilot studies, Migo et al (2013) derived 50 sets of picture quartets comprising four very similar items (e.g., four forks or four dolls) of which one could serve as a to-be-remembered target and the rest as foils during the recognition test. From this original set of 50 quartets, 12 were selected for each condition (as in the previous Migo and colleagues studies; FCC and FCNC) for the current experiment with an additional 4 for each practice phase (FCC and FCNC), totalling 32. The item quartets were selected on the basis that they would be age and gender appropriate. For example, an item portraying a nail varnish bottle was omitted on the grounds that it may not be familiar to all younger participants, in particular younger boys. The stimuli were presented on a 15” screen laptop computer and the images shown in Figures 6.3 and 6.4 have been directly taken from the experimental files; hence they represent the exact size proportion of the individual items and images to the laptop screen size. The introductory learning phase used laminated A4 cards with coloured pictures of items on them (see Figures 6.1 and 6.2).



**Figure 6.1. FCC Introductory Learning Phase**



Figure 6.1 shows the target item on the left that would be shown at study; and the quartet of items on the right constitutes the choices during the recognition test.

**Figure 6.2 FCNC Introductory Learning Phase**

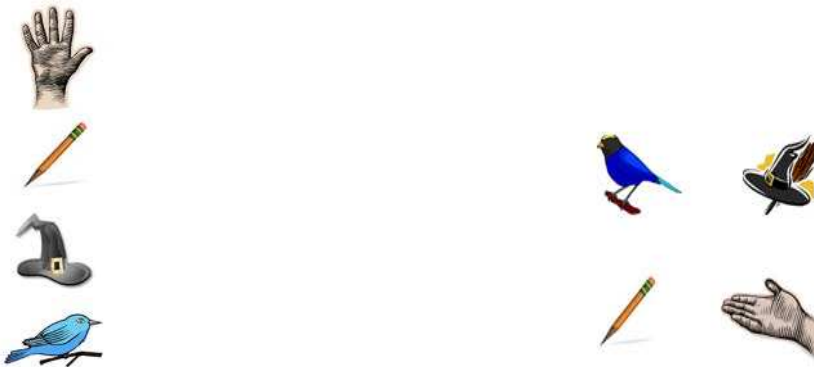


Figure 6.2 shows the study items on the left; and the quartet of items on the right constitutes the choices during the recognition test showing that the pencil is the only item that has been seen before.. The bird, witch's hat and hand are similar but have not been seen before.

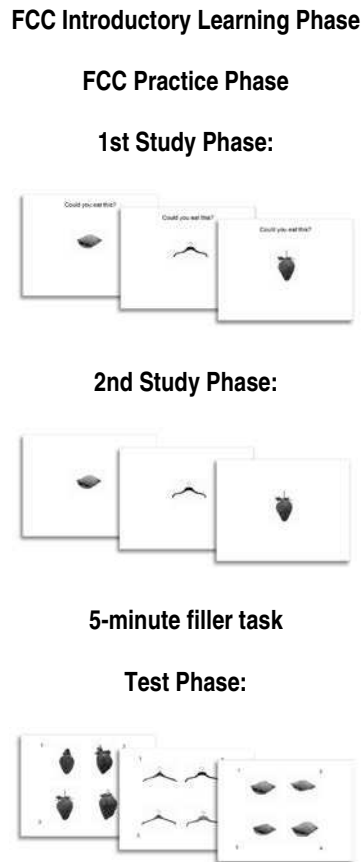
## *Procedure*

In the original study by Migo et al. (2009), the FCC and FCNC items were interleaved in a single test with one study trial and one test trial. To adapt this task for use with children the FCC and FCNC tasks were run as separate blocks comprising 2 study trials and 1 test trial to simplify the task demands. The task was then piloted on 11 children with ASD or ID following the same procedure as in the original Migo et al. (2009) study but with instructions adapted for our children. The initial piloting indicated that the task was too difficult and therefore an additional ‘introductory learning phase’ was required prior to the experimental practise phase. Hence, new materials were devised specially for this phase and the test was then re-piloted with a different set of children from the same school. The new ‘introductory learning phase’ consisted of showing the children 3 coloured pictures of everyday items to remember during the study phase. Then at test, for the FCC test, 3 foils were shown in addition to the target. For the FCNC test, 3 items were also presented but at test, the first item only had one foil, the second item had two foils and the third item had three foils. This ‘introductory learning phase’ was necessary to train children not only in the test format but also on how their memory would be tested in two different ways. It was important for the children to realise that the foils were similar but different to the target and that it was necessary to study the items properly rather than just make a guess. This was particularly the case with the FCNC condition where the participants needed to realise that the foils were NOT other targets, but rather that they were very similar to other previously seen targets. This is why the number of foils was built in gradually on the FCNC introductory learning phase. It was established during piloting that during the first ‘run through’ of either the FCC or FCNC learning phase it would be necessary to confirm to participants why and how their responses were correct. This was done by pointing to the targets and foils and showing where

they were different and where they were the same. Success on the 3<sup>rd</sup> item led to inclusion to the experiment. However, if this last item was not remembered correctly, an explanation followed with the participant looking at the pictures to establish similarities and differences between the target and foils. A second round then be administered with no assistance provided and success on the final item would ensure inclusion. All participants achieved success at this stage.

The overall test procedure for each condition (FCC and FCNC) therefore consisted of the ‘introductory learning’ phase (described above), a practice phase followed by the experimental condition. The two practice phases included a study and test phase in immediate succession of one another. The experimental condition consisted of a study phase, where items were presented twice, followed by a 5-minute filler task and then the recognition test phase (see Figure 6.3 for a procedure summary).

**Figure 6.3 Overall experimental procedure including practice phases (e.g. FCC)**



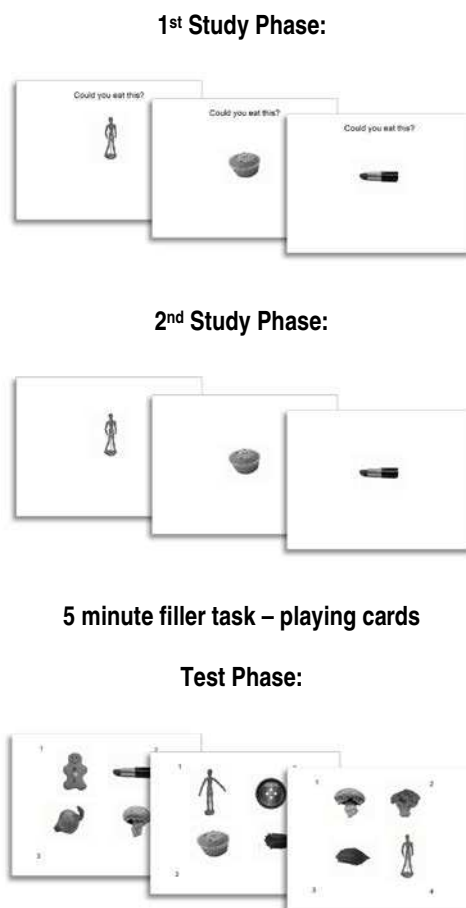
## **Experimental Phase**

The order of the FCC and FCNC conditions was counterbalanced across participants to counter potential practice effects. In addition, each condition was administered on a different day for each participant to avoid effects of tiredness or fatigue. For both FCC and FCNC conditions, individual participants were shown 12 items, one by one, until the participant had looked at it for a total of 3 seconds. This ‘looking rate’ was considered more appropriate than a standard presentation rate to allow for participants becoming distracted whilst watching the

materials. The 3 seconds of looking time was monitored carefully by the tester using both a stopwatch, and from vigilantly observing the participant's attention to the stimuli.

Some participants required encouragement from the tester who softly tapped or pointed to the laptop screen to enhance the focus of the participant during the study phase. Participants were shown the 12 items twice in the same order before the 5-minute filler task and recognition test. See Figure 6.4 for FCC/FCNC test procedure.

**Figure 6.4 FCNC (same for FCC) Experimental Procedure**



When the participant had arrived and was ready to begin, the tester asked something along the lines of: *“Are you good at remembering things, I wonder? Today, we are going to do a fun memory test; what’s your memory like?”* It was very important to instate at the outset that a test or game involving memory is what they have come to do. The following dialogue sets out what and how instructions were consistently given and emphasised by the tester throughout the different stages of the experiment.

## **Practise Phase**

### *a) Study phase*

*“First, before we start the memory game I will show you some pictures on this computer. I want you to look at each picture and tell me if it’s a picture of something you could eat. So, if you think it is a picture of something you could eat then say “yes” and if you think it is not a picture of something you could eat then say “no” – do you understand?”*

The tester then said: *“Ok, ready?”* This was taken as a form of verbal continued consent that the participant was happy to continue with the test. The first item was shown on the laptop screen and the tester said: *“Could you eat this?”* The tester discouraged labelling and ensured that the participants simply said “yes” or “no”. If a participant was unsure they were then encouraged to: *“have a guess, quick as you can.”*

When all the pictures were seen, the tester paused and said: *“Ok, now we’re going to look at the same pictures again. This time I want you to look VERY, VERY carefully at each one, look at everything about them and try to remember them, because later on I’m going to see*

*how many of them you can remember. Ok, ready?"* The tester paused again once all the items had been presented.

*b) Test phase (following immediately from the study phase)*

The tester then said: *"Ok, now I'm going to show you four pictures. You only saw one of these pictures earlier on. The others look a bit like ones you saw, but are not quite the same. I want you to point to the picture that is EXACTLY the same as one you saw earlier. Have a good look at each picture and then point to the one EXACTLY like one you saw earlier. If you're not sure which one you saw earlier then just take a guess. Ok, ready?"*

When necessary, correction was given on the first example of each condition. The tester would say: "this one is EXACTLY the same, these aren't quite the same" The second example of each condition must be correct in order to proceed (i.e. 2/4). When the test format changed from FCNC to FCC, the child was reminded that only one of the pictures had been seen before. The tester would say: *"This time all the pictures look nearly the same, but still you've only seen one of them before."* When the format changed from FCC to FCNC the tester would say: *"These ones are a bit tricky. You might think that you've seen all of them before, but only one is EXACTLY the same as one of the pictures you saw earlier."*

## **Test Phase**

*a) Study phase (same procedure as during practice)*

When the practise phase was finished, the tester said: *"Very good! Ok, that was just a practice. Now I'm going to show you some more pictures. Just like before, I want you to look at each picture and tell me if it's a picture of something you could eat."* If the

participant hesitated they were encouraged by the tester to respond quickly by saying: *“fast as you can/guess if you’re not sure.”* The tester went on to say: *“Good, now just like before, we’re going to look at the pictures again and I want you look VERY, VERY carefully at each one, look at everything about them and try to remember them, because later on I’m going test your memory/see how many of them you can remember.”* The 12 picture items were presented again one by one.

*b) Filler task (Playing cards)*

When all 12 items had been presented the tester congratulated the participant on their excellent concentration and said: *“Before I ask you to remember those items, we are going to play a game of cards for five minutes.”* The tester then ascertained with the participant a version of ‘snap’ appropriate to their age and ability, which used a full pack of normal playing cards. The tester asked the participant to share out the pack of cards between each of them. It was then established that they would turn over their cards, one by one, adjacent to one another, and if their cards simultaneously matched on either suit, colour or number (depending on the participant) then the participant should put their hand down quickly on the cards and say “snap!” All participants managed this at least once. 5 minutes was recorded using a stopwatch, which included time to deal and put away the cards.

*c) Test phase (same procedure as during practice)*

The tester then said: *“Ok, let’s see how many of the pictures you can remember from before. Now I’m going to show you four pictures. You only saw one of the pictures earlier on, and I want you to point to the picture that is EXACTLY the same as one you saw earlier. If you’re not sure which one you saw earlier then just have a guess.”*



Slides were then presented with a 3 second looking time. When the test format changed from FCNC to FCC, the child was reminded by the tester that only one of the pictures had been seen before: *“This time all the pictures look nearly the same, but still you’ve only seen one of them before.”* When the format changed from FCC to FCNC, the tester said: *“These can be difficult because you might think that you’ve seen them all before, but only one is EXACTLY the same as one of the pictures you saw earlier.”*

The tester praised the child by saying *“good”* or *“well done”* for the first two correct responses for each test format. The tester recorded responses, with the participant pointing to one of the four pictures (in all cases) to be the item they selected as having seen before. This was the case in each the FCC and FCNC condition. Pre-prepared score sheets were used by the tester, which included the two practice phases and the experiment FCC or FCNC. The tester filled these in during the tests but disguised the responses using ticks (a normal tick for a correct answer, and a normal tick with a tiny tail on the end for an incorrect answer) to ensure that the participant felt success throughout the test, regardless of their performance. Scores were calculated by the tester as soon as the participant left the room and prior to the next participant.

## **Results**

### *Analysis*

The analysis conducted for Experiment 1 initially addressed the predictions relating to the processes of familiarity as assessed by the FCC test, followed by the predictions relating to the processes of recollection as assessed by the FCNC test. Briefly, the main predictions were that on FCC, the ALI group would perform significantly worse relative to the TD and ALN groups and the ID group would perform either similarly to the ALI group or at a level between the ALI and the TD/ALN groups. On FCNC, it was predicted that the ALI and ALN groups would perform significantly worse than the TD group and that the ID group would either perform similarly to the ALI group or midway between the ASD groups and the TD group.

After addressing these predictions concerning the functional integrity of declarative memory processes in the ASD and ID groups, the final analyses examined the role of these processes in relation to conceptual semantic knowledge. Correlation tests were run to identify the main correlates of semantic word knowledge (measured by the Pyramids and Palm Trees Test, PPT) and analyses of co-variance (ANCOVA) and regressions were used to test specific predictions regarding the role of familiarity (FCC) in this context, as well as the role of visuo-perceptual abilities (CEFT) and fluid intelligence (FI, Ravens). For a fuller description of the predictions, please refer back to the end of Chapter Three. All analyses relating to the FCC and FCNC used the proportion of correct responses as the dependent variable. For all statistical tests, a standard alpha criterion of  $p < .05$  was used to reject the null hypothesis and as estimates of effect sizes Cohen's  $d$  (t-tests) and partial eta square (Analyses of Variance)

will be reported. Unless otherwise stated,  $p$  values were reported as exact when results were non-significant.

For an overall picture initially, correlation matrices were created and examined at both the group and combined groups level incorporating all the key variables (see Table 6.2). First, it was important to see if chronological age (CA) correlated with any scores related to the predictions. As expected, CA did not correlate with any of the memory measures apart from recollection in the ALN group. The age range of younger children in this group was relatively wide so this was not surprising. CA was therefore not considered to be a factor affecting performance however this was re-checked at a later stage of the regression analyses.

**Table 6.2 Correlation matrices for combined and separate groups using Pearson  $r$**

All Groups ( $n = 91$ )		CA	VIQ	Ravens	CEFT	PPT	Familiarity	Recollection	DecMemory
CA	1								
VIQ	-0.85**	1							
Ravens	-0.05	0.19	1						
CEFT	-0.15	0.28**	0.65**	1					
PPT	0.01	0.19	0.30**	0.41**	1				
Familiarity	0.06	0.06	0.48**	0.59**	0.44**	1			
Recollection	-0.24*	0.39**	0.24*	0.42**	0.44**	0.29**	1		
DecMemory	-0.13	0.29**	0.44**	0.55**	0.62**	0.77**	0.84**	1	

Group ALI ( $n = 18$ )		CA	VIQ	Ravens	CEFT	PPT	Familiarity	Recollection	DecMemory
CA	1								
VIQ	-0.10	1							
Ravens	0.16	0.20	1						
CEFT	-0.01	0.21	0.56*	1					
PPT	0.44	0.51*	0.48*	0.47*	1				
Familiarity	0.23	0.11	0.53*	0.75**	0.63**	1			
Recollection	0.28	0.17	0.37	0.57*	0.47*	0.64**	1		
DecMemory	0.28	0.16	0.49*	0.60**	0.72**	0.90**	0.91**	1	

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

Table 6.2 continued overleaf.

*Table 6.2*

ALN (*n* = 26)

	CA	VIQ	Ravens	CEFT	PPT	Familiarity	Recollection	DecMemory
CA	1							
VIQ	-0.01	1						
Ravens	0.11	0.38	1					
CEFT	0.39*	0.35	0.55**	1				
PPT	0.35	0.31	0.14	0.38	1			
Familiarity	0.29	0.26	0.38	0.65**	0.60**	1		
Recollection	0.41*	0.31	0.30	0.36	0.64**	0.36	1	
DecMemory	0.43*	0.34	0.41*	0.75**	0.61**	0.82**	0.84**	1

ID (*n* = 23)

	CA	VIQ	Ravens	CEFT	PPT	Familiarity	Recollection	DecMemory
CA	1							
VIQ	-.63**	1						
Ravens	-0.29	0.32	1					
CEFT	-0.30	0.52*	0.65**	1				
PPT	-0.07	0.22	0.30	0.56**	1			
Familiarity	-0.25	0.36	0.50*	0.56**	0.43*	1		
Recollection	-0.15	0.40	0.13	0.44*	0.16	0.21	1	
DecMemory	-0.25	0.49*	0.38	0.36	0.63**	0.73**	0.82**	1

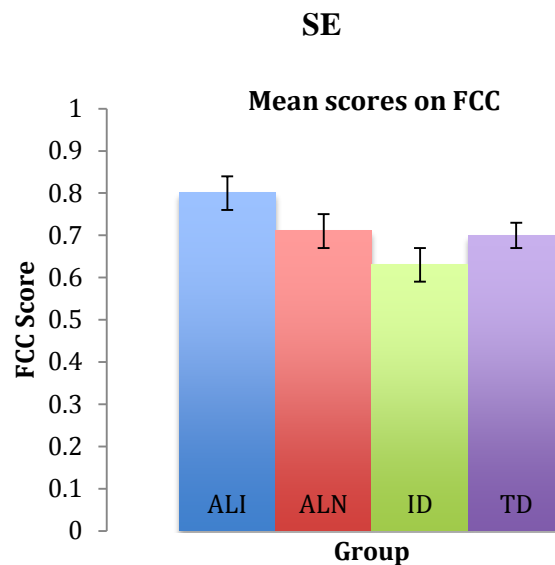
TD (*n* = 24)

	CA	VIQ	Ravens	CEFT	PPT	Familiarity	Recollection	DecMemory
CA	1							
VIQ	-0.13	1						
Ravens	0.59**	-0.07	1					
CEFT	0.22	-0.31	0.42*	1				
PPT	0.43*	0.18	0.57**	0.23	1			
Familiarity	0.38	-0.31	0.26	0.16	-0.07	1		
Recollection	-0.02	0.03	-0.15	0.02	0.37	-0.16	1	
DecMemory	0.26	-0.21	0.07	0.24	0.14	0.62	0.68	1

## 1) Familiarity – FCC

Figure 6.5 sets out the average proportion correct responses on the FCC as a function of group.

**Figure 6.5** Mean proportion correct scores on the FCC test. Error bars represent +/- 1



A univariate ANOVA was conducted to assess whether or not there was an overall group difference on this measure of familiarity. As predicted this was the case where  $F(3, 87) = 2.91, p < .05, \eta_p^2 = .09$ . However, the  $F$  score was only just significant indicating that the model might be underpowered for further pairwise comparison tests. Sheffé post hoc comparisons revealed a significant difference only between ALI and ID groups only where  $p < .05$ . The predictions were also tested with individual planned comparisons using t-tests.

In order to test the prediction that the ALI group would be impaired relative to the TD and ALN group, two separate independent samples t-tests were run. Unexpectedly, the mean

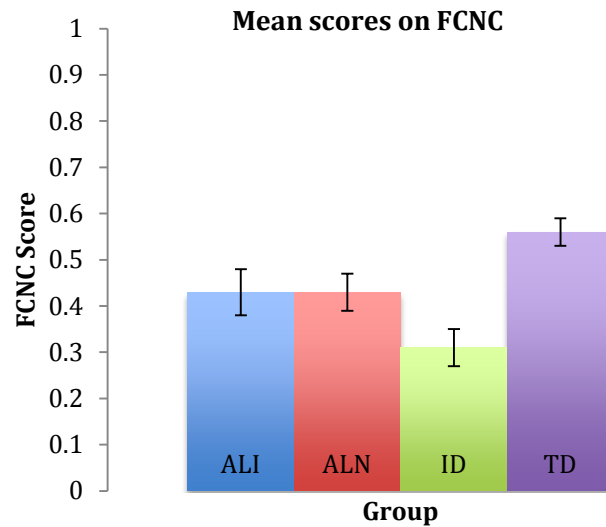
proportion of correct responses showed no significant difference between the TD and the ALI group  $t(40) = 1.74, p > .05, d = .53$  or between the ALN and ALI group  $t(42) = 1.54, p = .13, d = .48$ . In fact, the ALI group achieved the highest performance of all groups (mean score ( $M$ ) = .8,  $SD = .19$ ) as illustrated in Figure 6.5.

In relation to the ALN group, it was predicted that scores on FCC would be unimpaired compared to the TD group, which was the case:  $t(48) = 0.05, p = .96, d = 0.00$  It was also predicted that the ID group would either perform similarly to the ALI group or at an intermediate level between the ALI and the TD and ALN groups. This prediction was not supported. The ID group performed lowest of all groups with a mean accuracy score of .63 ( $SD = .17$ ). Although this was not significantly different from the performance of the ALN ( $t(47) = -1.40, p = .17, d = .40$ ) or TD group ( $t(45) = -1.56, p = .13, d = .45$ ) the difference from the ALI group:  $t(39) = -2.96, p < .05, d = .94$  was significant. It is worth noting, however, that the performance of the ID group in relation to the TD and ALI groups was not in line with predictions because of the unexpectedly high performance of the ALI group. Overall, one of the three predictions was supported which was the similar performance in the ALN and TD groups. However, due circumspectness is required at this point because the overall  $F$  score for the initial overall group comparison only just reached significance and there was variability within each group. Subsequent analyses attempt to address this factor.

## **2) Recollection – FCNC**

Figure 6.6 sets out the mean proportion correct scores for the FCNC test.

**Figure 6.6** Mean proportion correct scores on the FCNC test. Error bars represent +/- 1 SE



Following the analyses for the FCC test, overall group differences for FCNC were tested first using a univariate ANOVA. Again, as predicted there was a significant difference between groups where  $F(3,87) = 6.45, p < .001, \eta_p^2 = .18$ ; which was stronger than the overall comparison for FCC with a larger effect size. Scheffé post hoc comparisons showed that there was a significant difference between ID and TD where  $p < .001$ .

For tests on FCNC it was predicted that both the ALI and ALN group would be impaired relative to the TD group and the ID group would either perform similarly to the ALI and ALN groups or somewhere at an intermediate level between these two groups and the TD group. To test these predictions independent t-tests were used for the relevant comparisons. As predicted, the ALI group (mean (M) = .42; standard deviation (SD) = .19) performed at a significantly lower level to the TD group (M = .56; SD = .16):  $t(40) = -2.45, p = .02, d = .75$ . Also as expected, the ALN group (M = .43; SD = .2) performed significantly worse than the TD group:  $t(48) = -2.36, p = .02, d = .68$ .

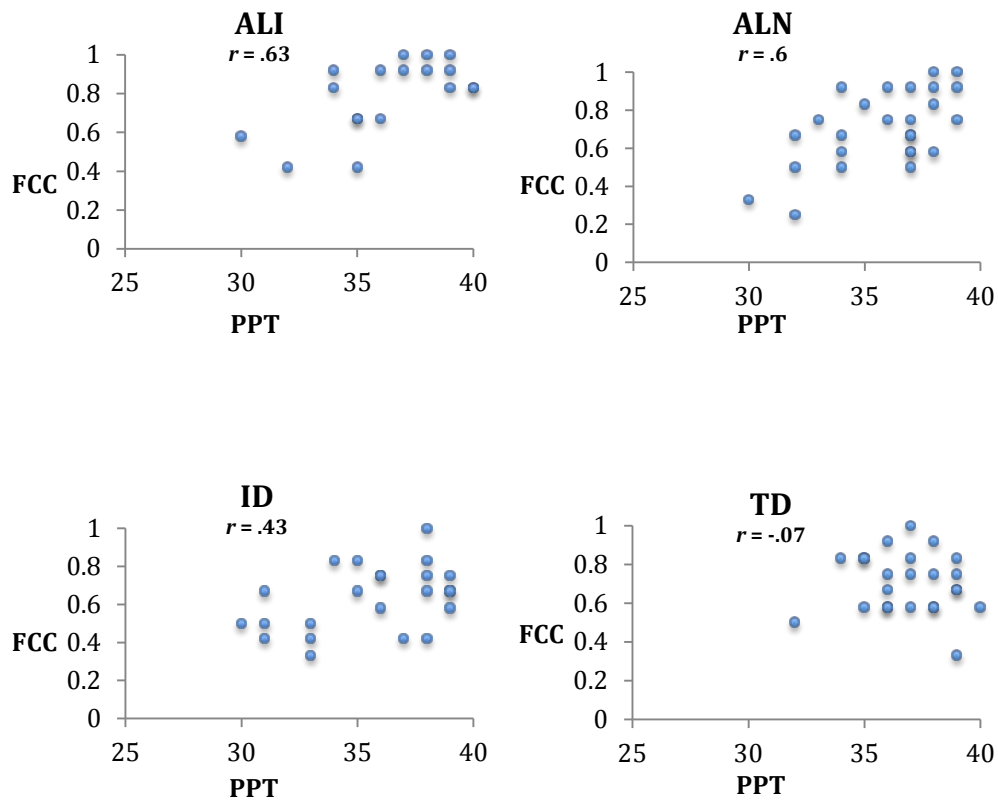


The ID group, similarly to the FCC test, performed worse again out of all groups with a mean score of .31 (SD = .17), which was not predicted. Independent t-tests between the ID and TD groups demonstrated highly significant differences with a large effect size:  $t(45) = -4.59, p < .01, d = 1.31$ . The difference between the ID and ALN group ( $t(47) = -2.09, p = .04, d = .57$ ) was also significant with a moderate effect size and although the difference between the ID and ALI group was only marginally significant, the effect size was again moderate ( $t(39) = -1.77, p = .09, d = .54$ ). Thus, overall for recollection, the pattern of results was again largely as predicted, apart from the ID group, who again achieved the lowest scores as in FCC.

### **3) Determinants of conceptual semantic knowledge**

To test for the main determinants of semantic knowledge the following correlational tests were conducted. First it was important to establish whether the familiarity measure (FCC) did relate to the lexical semantic measure (PPT). Across all groups Pearson's correlation confirmed that this was indeed the case ( $r(89) = .44, p < .001, 2$ -tailed). To examine this association within each of the four participant groups, the correlations were repeated within groups and the results are illustrated in Figure 6.7.

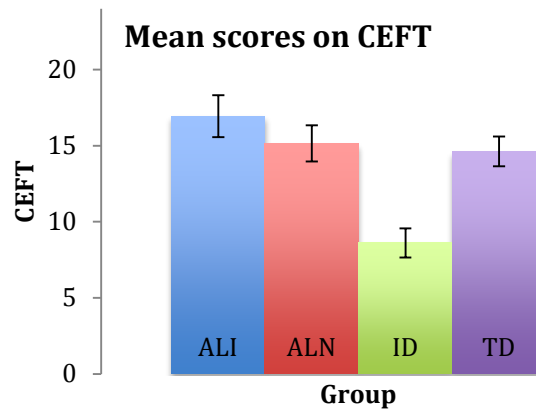
**Figure 6.7. Graphs showing relationship between PPT and FCC tests in ALI, ALN, ID and TD groups**



It was predicted that in the four groups separately, correlations between the PPT and FCC would be greatest in the ALN group, followed by the ALI group, with a small or non-significant correlation in the TD group. This pattern was almost confirmed with both ASD groups demonstrating similarly robust correlations (ALI group:  $r(16) = .63, p < .05$ ; ALN group:  $r(24) = .60, p < .001$ ) the ID group demonstrating a moderate correlation ( $r(21) = .43, p < .05$ ) and no correlation in the TD group ( $r(22) = -.07, p > 0.05$ ), although this last observation is tempered by the near ceiling performance on the PPT as illustrated in Figure 6.7 above.

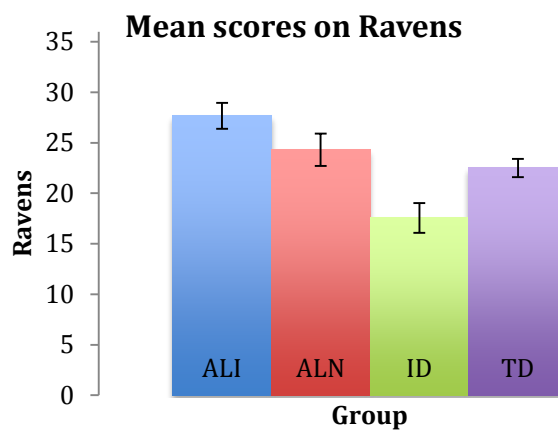
At this point it is clear that there was a relation between familiarity and semantic knowledge in ASD as predicted; however, the strikingly high scores on FCC in the ALI group were unexpected and require further attention. The FCC and FCNC tests used visual stimuli so it was important to consider the possible effects participants' visual-perceptual skills might have on their memory performance. As noted in the 'participants' section in Chapter Five, the ALI group demonstrated very strong visual-perceptual skills as measured by the CEFT as well as the Ravens matrices, which may have benefitted their performance. For ease of reference, the data on these measures have been replicated in Figures 6.8 and 6.9. To test this conjecture, the correlation was calculated between FCC and both Ravens (fluid intelligence) and CEFT (visuo-perceptual abilities) to determine how strongly these measures correlated with FCC across all groups and within each group. Results showed that across groups, the FCC measure of familiarity did indeed correlate highly with CEFT:  $r(89) = .59, p < .001$  and Ravens:  $r(89) = .48, p < .001$ . However, when these associations were examined within groups a different pattern emerged. FCC and CEFT correlated highly in the ALI:  $r(16) = .75, p < .001$ , ALN:  $r(24) = .65, p < .001$  and ID:  $r(21) = .56, p < .005$  groups but not in the TD group:  $r(22) = .16, p = .45$ .

**Figure 6.8** Mean scores (out of 24) on CEFT. Error bars represent +/- 1SE



For Ravens, in the ALI group, Ravens and FCC also correlated significantly ( $r(16) = .53, p < .05$ ) and in the ALN group this association almost reached significance ( $r(24) = .38, p = .06$ ). There was a significant correlation in the ID group ( $r(21) = .50, p < .05$ ) but no significant association in the TD group ( $r(22) = .26, p = .28$ ).

**Figure 6.9** Mean raw scores on Ravens. Error bars represent +/- 1SE



It was also predicted that across groups, scores from the CEFT would correlate with FCNC scores which depended upon very similar visuo-spatial detail to FCC. This was found to be the case where  $r(89) = .42, p < .01$ . In the analysis of the groups separately, it was predicted that the CEFT scores in the ALI and ALN groups would correlate with the FCNC test. Indeed this was the case in the ALI group ( $r(16) = .48, p < .05$ ), with the relation approaching significance in the ALN group ( $r(24) = .36, p = .07$ ). CEFT also correlated with FCNC in the ID group ( $r(21) = .43, p < .05$ ) but not at all in the TD group ( $r(22) = .02, p = .93$ ).

Given these significant relations, it was important to determine to what extent CEFT and Ravens performance may be contributing to the group differences observed on FCC and FCNC tests noted above. Thus the univariate ANCOVA testing for any effect of Group was conducted again but this time adding CEFT and Ravens as covariates. When CEFT and Ravens were controlled, the Group difference in FCC became non-significant:  $F(3, 85) = .7, p = .56, \eta_p^2 = .02$ . CEFT was highly significant as a covariate ( $F(1,85) = 19.2, p < .001$ ), but Ravens was not ( $F(1,85) = 2.14, p > .1$ ). Including CA as a covariate had no effect on this pattern of results.

The results outlined so far have confirmed that processes of familiarity as measured by FCC are associated with conceptual word knowledge as measured by PPT. This appears also to be the case for recollection but not for chronological age, fluid intelligence or visuo-perceptual abilities. Contrary to more specific predictions however, the ALI group outperformed all other groups on the FCC measure of familiarity, which the correlational analyses suggest might be due to the visual-perceptual nature of the task, which constitutes an area of relative strength for the ALI group. To examine the relative contributions of processes of familiarity (FCC), visual perceptual skills (CEFT) and fluid intelligence (Ravens) to semantic word

knowledge (PPT) further regression analyses were run looking first at the pattern of these relations within each group. An initial exploratory regression analysis using the ‘enter’ method showed that there was a different pattern of predictors for each of the four groups (see table 6.3).

**Table 6.3 Results for regression analysis for the main predictors in each group with PPT as the outcome variable**

Group	R	Adj RSQ	Sig F	FCC	FCNC	CEFT	Ravens	CA
ALI	0.72	0.31	0.09	0.40	0.03	0.07	0.17	0.35
ALN	0.78	0.51	<b>0.01**</b>	<b>0.50*</b>	<b>0.53**</b>	-0.04	-0.19	0.02
ID	0.61	0.19	0.13	0.21	-0.14	<b>0.65*</b>	-0.19	0.10
TD	0.77	0.48	<b>0.01**</b>	-0.21	<b>0.43*</b>	-0.05	<b>0.61**</b>	0.18

\* Correlation is significant at the 0.05 level (2-tailed)

\*\* Correlation is significant at the 0.01 level (2-tailed)

The ALI and ID groups did not show any overall significant predictability for PPT although CEFT was a strong predictor for the ID group. In the higher functioning groups (ALN and TD), FCNC was a significant predictor but the ALN group also had FCC whilst the TD group had Ravens. Although FCC was not a significant predictor in the ALI group as expected, it was still a relatively higher score (.40) compared to the non-ASD ID (.21) and TD (-.21) groups. These current patterns warrant further investigation into differences between ASD more generally compared to ID or TD.

The group sizes were not large enough to run individual regression analyses and it was important to minimise potential problems with group matching between the two age and VIQ ‘tiers’ (ALI/ID and ALN/TD). First, to test for any effects of CA, a regression analysis using

the 'enter' method was run with CA as a predictor variable and PPT as the outcome variable. CA was not a significant predictor in this model where  $p = .892$ . However, a second regression was then run incorporating dummy group variables, Dummy group variables were created by recoding the existing group variable into 3 separate variables for ALI, ALN and ID. For example, to create the ALI dummy variable 'ALI' was coded from 'group' using binary coding where '1' was assigned to ALI participants and '0' was assigned to ALN, ID and TD participants. There are only 3 degrees of freedom in a factor with four levels so the TD group variable acted as a baseline control. When dummy group variables were included in the model CA became a significant predictor of PPT where  $p < .05$ . Therefore it was deemed necessary that CA should be included in the next regression analysis.

As individual groups had low numbers for a powerful regression model it was difficult to obtain robust between group findings. So in order to test the existing findings from the correlational between groups analyses, differences between ASD and Non-ASD required further exploration. Therefore one grouping variable was created called 'ASD' with a 1 for ALI and ALN and a 0 for ID and TD groups. A value of 1 for this variable represented an ASD participant, and a value of 0 a non-ASD participant.

Two regressions were then run, combining the ASD groups and comparing them first with TD cases, and then in a second analysis comparing them with ID cases. Backward elimination was used since the sample size was small, and the purpose of the analysis was therefore primarily exploratory. Each regression analysis included PPT as the dependent variable and independent variables: FCC, FCNC, CEFT, Ravens, CA, theory of mind (ToM; with ID not TD because of no data), ASD and interaction variables: ASD\*FCC, ASD\*FCNC. The comparison with ID showed no significant effects for the two interaction terms as all the

predictors were excluded from the model. However, for the comparison with TD there was a significant effect for ASD\*FCC. Backward elimination for the TD comparison left FCC, FCNC, ASD and ASD\*FCC as significant predictors for PPT with CA, Ravens, ToM, CEFT, ASD\*FCNC excluded. This is shown in table 6.4

**Table 6.4 Regression table comparing ASD with TD showing the final model from backward elimination**

Coefficients with PPT						Final Model		
	B	Std. Error	Beta	t	Sig.	R	R Square	Adjusted R Square
FCC	6.10	1.59	0.46	3.84	0.01**	0.65	0.44	0.39
FCNC	4.52	1.33	0.37	3.41	0.01**			
ASD	4.95	2.28	0.99	2.17	0.03*			
ASD*FCC	-6.23	3.04	-0.91	-2.05	0.05*			

Both FCC, FCNC and ASD status (versus TD not ID) seem to predict PPT but also there is an interaction of ASD status with FCC performance on PPT performance. In terms of the predictions, this shows that there does seem to be a relationship between ASD and FCC (familiarity) in explaining PPT performance. Namely, FCC predicts performance on PPT for participants with ASD but not for typically developing children. So those in the ASD groups who have better FCC find that this helps them in the PPT task (if some kind of causal explanation is considered). Or it may be that the PPT task and FCC tasks tap into the same cognitive skill that some children with ASD have more than others.

It was then necessary to see if CEFT and Ravens account for variance in PPT once FCC is controlled. A hierarchical (blockwise entry) regression analysis was selected where



familiarity, as predicted, was entered as the first predictor of PPT in the model, allowing for further contributions from CEFT and Ravens in the second step. A hierarchical model was chosen over a ‘forced entry’ model, where all predictors are added simultaneously, because of the specific predictions concerning the role of FCC based on the existing literature. A ‘stepwise’ model, where predictors are ordered on a purely mathematical basis as determined by SPSS was also decided against for the same reasons (i.e., it is already known that memory and language are associated with one another Ullman, 2004). The regressions were carried out for the four groups separately so that group differences could be explored. Table 6.5 provides an overview of the results.

**Table 6.5 Regression table showing 2 block entry phases presented by group**

Group	Model (Block)		B	SE	Beta	t	Sig.	Final Model		
								R	R Square	Adjusted R Square
ALI	1	FCC	9.33	2.90	0.63	3.22	0.01	.627a	0.39	0.36
	2	FCC	8.41	4.63	0.56	1.82	0.09	.652b	0.43	0.30
		CEFT	-0.03	0.15	-0.07	-0.23	0.82			
		Rav*	0.11	0.13	0.22	0.89	0.39			
ALN	1	FCC	7.67	2.08	0.60	3.69	0.00	.601a	0.36	0.34
	2	FCC	7.92	2.84	0.62	2.79	0.01	.610b	0.37	0.29
		CEFT	0.02	0.10	0.04	0.16	0.87			
		Rav*	-0.04	0.06	-0.12	-0.60	0.55			
ID	1	FCC	7.46	3.42	0.43	2.18	0.04	.430a	0.19	0.15
	2	FCC	3.47	3.98	0.20	0.87	0.40	.589b	0.35	0.24
		CEFT	0.36	0.17	0.55	2.11	0.05			
		Rav*	-0.07	0.11	-0.16	-0.65	0.52			
TD	1	FCC	-0.91	2.61	-0.07	-0.35	0.73	.074a	0.01	-0.04
	2	FCC	-2.90	2.24	-0.24	-1.30	0.21	.617c	0.38	0.29
		CEFT	0.00	0.08	-0.01	-0.03	0.98			
		Rav*	0.28	0.09	0.64	3.20	0.00			

\* Ravens

a Predictors: FCC

b Predictors: FCC, Rav, CEFT

c Predictors: FCC, CEFT, Rav

As Table 6.5 illustrates, when FCC was entered into the model in the first step, it predicted a significant proportion of variance in PPT in all groups apart from the TD group. When CEFT and Ravens were added into the model, the pattern was largely unchanged for the two ASD groups with FCC remaining a marginally significant predictor of PPT in the ALI group ( $p = .09$ ) and a significant predictor in the ALN group ( $p < .05$ ) with non-significant contributions from either CEFT or Ravens. However, in the ID group, FCC was no longer a significant predictor; instead PPT is now predicted by CEFT with no significant contribution from Ravens. Finally, in the TD group, Ravens was a highly significant predictor of PPT whereas neither FCC nor CEFT were significant predictors.

The prediction that FCC was a main contributor to semantic knowledge in the ALI group was demonstrated by the adjusted R square values. FCC was a significant predictor of semantic knowledge in both ASD groups, explaining 36% of PPT in the ALI and 34 % in the ALN group. This is partly surprising given the strong association between CEFT and FCC demonstrated earlier, but indicates that although CEFT may assist with performance on FCC and FCNC, it does not contribute to semantic knowledge (PPT) in ASD. When CEFT and Ravens are added into the model there is only a small change between blocks one and two but there are salient changes in the ID and TD groups. In the TD group the PPT scores were at ceiling and so caution in interpretation is required here. However, to confirm that the association between PPT and FCC was significantly different between the ALI and TD groups a Fisher's Z calculation showed that  $Z = 1.99, p < .05$ . This significant difference was also shown between the ALN and TD groups:  $Z = 2.06, p < .05$ ; but there were no other between group associations that were significant. These calculations go further to support the hypothesis that there is a significant relationship between FCC (familiarity) and PPT

(conceptual word knowledge) not just in individuals with ALI but also with ALN, but this does not seem to show up in either typically developing or intellectually disabled individuals.

### *Summary and comments*

Correlational analyses confirmed a significant relationship between familiarity and conceptual semantic ability in ASD but not in Non-ASD groups, which supports the main prediction. This was still the case despite the unpredicted raised familiarity scores in the ALI group. These higher scores may have resulted from enhanced influence of visuo-spatial ability induced by the nature of the stimuli in this experiment. This possibility highlighted the importance of testing the same components of memory but within a different testing paradigm. Instead of using known photographed grayscale objects it would also be worth trying non-meaningful shapes via a different medium to a computer laptop.

What appears to drive semantic knowledge in the ID group appears to have nothing to do with familiarity but possibly more to do with CEFT. However, as other variables were not entered into the model that could be possible predictors of semantic knowledge in ID, it cannot be concluded that CEFT is the only significant factor involved. It is more useful to note that familiarity was *not* associated with conceptual semantic knowledge unlike the two ASD groups.

Overall, the mean scores for recollection as assessed by the FCNC test were as predicted and in line with current research stating that ASD groups would be impaired relative to a TD control group. The FCNC scores for the ID group were lower than expected however. Also,

for a purer test of recollection, an element of free or cued recall may be more reliable rather than the recognition test used for FCNC. Experiment 2 in Chapter Seven attempts to address these factors.

## Chapter Seven

### Experiment 2: Shape Recognition-Action Recall (SR-AR) Test

#### Background

The aim of this experiment was to tease apart the skills of familiarity and recollection in children (and adolescents) using a shape recognition (SR) and cued action recall (AR) test. The main task for the participants was to remember 16 non-meaningful shapes for the shape recognition (SR) test and then for the action recall (AR) test, using 10 of the previously seen shapes recall an action that was paired with the shape. To avoid any effects of verbal or semantic knowledge, non-meaningful shapes were used to test familiarity in the SR test. In contrast to the forced choice non-corresponding (FCNC) test in Experiment 1, it was expected that the action recall element of this experiment may be a purer test of recollection. This is because recollection skills are employed more in a cued recall task rather than a recognition task where familiarity can also contribute. Another aim of this experiment was to re-test and devise a set of stimuli that could be used in a non-verbal test with children with severe developmental difficulties. This test could then be used as an alternative to tests using the remember/know paradigm with neurotypical adults.

The stimuli have been used once before with higher functioning children with ASD (ALN) and with typically developing children and findings were reported in Bigham, Boucher, Mayes and Anns (2012). This study showed that a group of ALN children were relatively impaired to a TD group on recollection skills as tested by the cued action-recall test; but their familiarity skills, as measured by a forced choice recognition test were relatively preserved. Bigham et al., (2012) judged the two tests to be both valid and reliable tests of recollection

and familiarity and effective with children also. The stimuli were re-piloted here with language-impaired children with ASD (ALI) and intellectual disabilities (ID) and the modifications are reported in the ‘piloting’ section below.

## Method

### *Participants*

102 children and adolescents were recruited to this experiment as set out in Table 4.1 in Chapter Four. Table 4.1 of participant characteristics reported in Chapter Four is repeated here as an aid to the reader. All participants were recruited in line with the procedures described above in Chapter Four.

**Table 7.1 Descriptive Statistics for Participant Groups**

Measure	ASD						
	Mean	ALI ( <i>n</i> = 20)			ALN ( <i>n</i> = 26)		
		SD	Range	Mean	SD	Range	
Age (months)	178.1	24.99	123-218	108.96	15.99	75-136	
VIQ <sup>a</sup>	64.75	6.17	55-75	104.92	11.92	91-135	
Ravens <sup>b</sup>	25.9	7.54	7-36	24.31	8.11	8-36	
Measure	Non-ASD						
	Mean	ID ( <i>n</i> = 26)			TD ( <i>n</i> = 32)		
		SD	Range	Mean	SD	Range	
Age (months)	176.42	21.72	136-214	98.53	9.44	81-114	
VIQ <sup>a</sup>	61.96	4.84	55-74	109.9	11.35	90-142	
Ravens <sup>b</sup>	17.11	6.93	6-27	24.68	5.78	10-36	

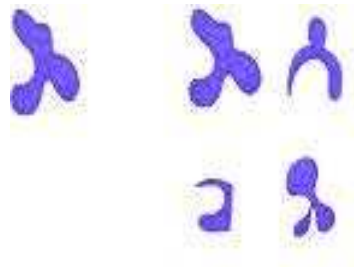
<sup>a</sup> WASI verbal subscales

<sup>b</sup> Ravens CPM

## **Materials**

For the main SR test, a set of 16 non-representational shapes were cut out of blue card and stuck onto pieces of white card approximately 15x10cms. There were also 16 A4 cards, each containing one target plus 3 foils. An example of a target card and target-foil card is shown in Figure 7.1.

**Figure 7.1** An example of the target on the left shown at study; and the target plus 3 foils on the right shown at test.



For the main AR test, 10 target shapes from the Shape Recognition (SR) test were used, and each of these was paired with only one foil (different from those used in SR). Use of target shapes from SR, and use of a single foil, was designed to facilitate recognition, because we were aiming for 100% correct recognition in both groups to exclude any effects of impaired familiarity in this second test.

Each target shape was paired with a target-focused manual action, such as picking up the card and placing it face down or placing a clenched fist on the card. Actions involving bringing the card into relation with the participants' own body were not used because tests of imitation suggest that this kind of action may be difficult for children with autism to encode (Hobson & Lee, 1999), whereas object-directed actions are imitated normally (Williams, Whiten, & Singh, 2004).

**Figure 7.2** A child recalling the ‘karate chop’ action cued from the blue shape on card



### ***General Procedures for SR-AR***

#### **Piloting**

Calibrating difficulty levels for mixed ability groups constitutes a particularly significant element of research design when working not only with children but particularly with children with developmental difficulties. There are two obvious hurdles that need to be addressed. First the tasks must not be beyond the cognitive capacities of the least able, risking floor effects. Second, the tasks must not be too easy for the most able, risking ceiling effects. The SR-AR test has been used before (Bigham et al, 2012) but only with ALN and TD children who were ‘higher functioning’ in terms of their verbal ability. Therefore, it was necessary to re-pilot the test with ALI and ID children and adolescents who may find the tests more challenging.

As a result of the current piloting phase a few minor changes were made. In the Shape Recognition (SR) task, verbal encouragement was introduced after presentation of the 11th item (16 items in total) to encourage further concentration. This was felt necessary due to the



addition of the ALI and ID groups who may find it relatively more difficult to maintain focus and concentration. The tester said, “Well done, just a few more to go now.” This was particularly important because the study phase (which contains 16 items) is quite long; however with continued encouragement all participants were able to complete the task.

In the Action-Recall task, 4 out of 10 actions were re-invented. In addition, the link between each stimulus (a card with an abstract shape drawn on it) and the action to be recalled (for example, placing a clenched fist on the card) was tightened by making the to-be-recalled action relate more directly to the stimulus. This involved for instance, an action of tracing round the shape on the card; or doing an action of a gentle karate chop next to the card rather than anywhere on the table (see Figure 7.2). This was a key change in ensuring the validity of the task; that is that recall was definitely being cued by the stimuli thus testing cued recall.

The method of scoring was also changed to ensure that children were not distracted by what the tester was writing down and to also ensure that the tester was able to administer the test more smoothly and consistently. Hence, after the presentation of each test card, it was immediately placed into a file with pre-labelled and scored dividers (not visible to the participant) and the scores were calculated after the test when the child was not present. The system used for awarding points was unchanged.

## **Procedure**

The SR-AR tests were administered during one session and consisted of two subtests, one shape-recognition test (SR) and one action-recall test (AR). Each test had a practice phase. The recognition test was always presented first and then immediately followed by the action recall test. Each child sat opposite the tester at a table where the test materials were presented.

A stopwatch was used to maintain presentation rates and time allowed for recall in the AR test. Pre-prepared score sheets were used to record the children's responses and score their accuracies. Practice in the procedure of either SR or AR was given immediately prior to each test, using 4 easy-to-be remembered stimuli and precisely the same procedures to be used in the actual test. Two practice runs were given for each practise phase, with instruction and support on the first run if necessary to ensure correct responding. No support was given on the second practice run. None of the children failed more than one item on the second practice run and therefore none were excluded on the grounds of failure to understand the procedure. All of the children were thanked at the end and awarded a certificate as set out in Chapter Four.

Details of the test procedures are given under the individual test headings, below.

#### *Shape Recognition (SR): Procedure*

Practice was given to ensure that all children fully understood what they were required to do. For practice, 4 non-representational shapes cut out of red card and stuck on pieces of white card were used as stimuli, with recognition tested using an easy 4-choice forced recognition task (foils were relatively unlike target stimuli). The procedure used during practice was identical to that described below for the test proper. Two practice runs were given, with additional instruction and support provided on the first run, if needed to ensure correct responding. All participants recognised at least 3 shapes correctly on one or both of the practice runs, and none were excluded.

The tester introduced the study phase by saying: "*We'll play that game again, but it will be a bit harder this time as I have many more shapes and they are different from the ones that I*

*have just shown you.*” – (i.e. the practice materials). *“Try to remember exactly what each shape looks like. They all look a bit the same, so you need to look at each one carefully. Are you ready?”* Each card with the target shape was presented in a predetermined order and orientation, at three-second intervals. When all of the target items had been presented the tester said: *“Let’s see how many of the shapes you can remember. I’m going to show you four shapes and I want you to tell me which one is exactly the same as one of the ones you just saw. Are you ready?”*

During the test phase, the tester presented the target-foil cards one at a time in a predetermined order, different to that used at study, and said, *“Which one of these shapes have you seen before?”* Children were required to point to the item of their choice. When the child responded the target-foil card was removed from sight and the next one was presented. If the child was reluctant to respond the tester elicited a response by saying, *“Just have a guess, quick as you can”*. There were no instances in which a child perseverated to a particular location. A child was credited with one point for each correctly recognised target item. Incorrect responses did not result in any points. Possible scores therefore ranged from 0 to 16, which were then converted to percentages of total scores prior to analysis.

#### *Action Recall (AR): Procedure*

For practice, 4 non-representational shapes cut out of red card and stuck on pieces of white card were used as stimuli, with recognition tested using an easy 2-choice forced recognition task (as opposed to 4-choice which was used in the SR test previously). Each target shape was paired with a target-focused manual action, demonstrated by the tester twice, such as blowing it or moving it from side to side. The procedure used during practice was identical to that described below for the test proper. Two practice runs were given, with additional

instruction and support on the first run, if needed, to ensure correct responding. All participants recognized at least 3 shapes and recalled at least 2 actions on one or both of the practice runs, and none were excluded.

The Action-Recall (AR) test immediately followed the SR test. Children were congratulated on their success in SR and asked: *“Do you want to play another game? It is a bit harder this time but more fun?”* Every child chose to continue. After the practise phase, the tester said, *“I’ve got some more shapes here, different to the ones I showed you before”* (indicating the practice materials). *“ This time I’m going to do a different action with each of them, and I will show you the action twice. I’m going to go a bit faster than before. Try to remember what each shape looks like and the action that goes with it. Are you ready?”* The 10 target shapes were presented one at a time in a predetermined order and orientation, each being placed centrally in front of the child. After 3 seconds, the tester performed the action associated with the target item twice, quite slowly in succession, checking that the child was attending to the action. The target shape was then removed and the next shape-action pair were presented until all 10 shape-action pairs had been presented and actions performed by the tester.

Then, at test, the tester said: *“Let’s see how many of the shapes and actions you can remember. I’m going to show you two shapes and I want you to point to the one that I just showed you ”* - placing the first target-foil pair centrally in front of the child, in a pre-prescribed orientation and with the position of the target stimulus to the left or right of the foil in a pre-determined order. The order in which target-foil pairs were presented was different to the order of presentation during study. If the child failed to respond or looked uncertain the tester prompted by saying: *“Have a guess. Which one did you see before, this*

*one? Or this one?*” If the child indicated the incorrect picture, that target-foil pair was removed and the next pair of shapes were presented. However, if the child indicated the correct picture, the foil was removed, the target item moved to a central position in front of the child, and the tester said: “*What was the action that went with it?*” Five seconds were allowed for the child to reproduce the original action. The tester prompted if necessary by encouraging the child to have a guess if uncertain.

Performance on the recognition pre-test was scored out of 10, each correctly recognized shape was awarded one point. Not all participants achieved 100% correct recognition: two children in the ALI group scored 9 out of 10 and one child scored 8 out of 10. In the ALN group one child scored 9 and one child scored 8; and in the ID group one child scored 9 and the other 7. Scores for the main action-recall test were therefore calculated as percentages of correct responses out of the number of action-recall items given. ‘Correct’ recall was operationalized as an unambiguous attempt to reproduce the required action, not taking into account person-related detail such as the hand used, or the direction in which an action had been carried out (e.g. sliding the card from one side of the table to the other).

## Results

### *Analysis*

The analysis conducted for Experiment 2 dealt first with predictions relating to familiarity, as assessed by the shape recognition (SR) test; and then recollection as assessed by the action recall (AR) test. The main predictions were that on SR, the ALI group would perform significantly worse relative to the TD and ALN groups and the ID group would perform either similarly to the ALI group or between the ALI and the TD - ALN groups. On AR, it was predicted that the ALI and ALN groups would perform significantly worse than the TD group and the ID group would either perform similarly to the ALI group or midway between the ASD groups and the TD group. Having established what the individual group scores were on the memory tasks, the primary aim of assessing the main predictors of conceptual semantic knowledge was addressed. As in Experiment 1, correlation tests were run to identify the main predictors of semantic knowledge (measured by the Pyramids and Palm Trees Test, PPT) followed by regression analyses to ascertain what specific contribution familiarity (SR) makes to semantic knowledge, over and above any effects of visuo-perceptual abilities (CEFT) and fluid intelligence (Ravens). Performance on a standard false belief task (attempting to measure theory of mind) was compared between groups with the expectation that ASD groups would perform more poorly than the ID and TD groups. Unless otherwise stated, *p* values were reported as exact when results were non-significant.

To begin, correlation matrices were created and examined at both the group and combined groups level incorporating all the key variables. First, it was important to see if chronological age (CA) correlated with any scores related to the predictions. As expected, CA did not correlate with any of the memory measures apart from recollection in the ALN group. The

age range of younger children in this group is relatively wide so this is not surprising. CA was therefore not considered to be a factor affecting performance however this would be rechecked at the later stage of the regression analyses.

**Table 7.2 Correlation matrices for combined and separate groups using Pearson's *r***

**All Groups**

<b>(n = 104)</b>	<b>CA</b>	<b>VIQ</b>	<b>Ravens</b>	<b>CEFT</b>	<b>PPT</b>	<b>Familiarity</b>	<b>Recollection</b>	<b>DecMemory</b>
<b>CA</b>	1							
<b>VIQ</b>	-0.85**	1						
<b>Ravens</b>	-0.17	0.35**	1					
<b>CEFT</b>	-0.23*	0.37**	0.67**	1				
<b>PPT</b>	-0.13	0.34**	0.43**	0.46**	1			
<b>Familiarity</b>	-0.34**	0.39**	0.49**	0.51**	0.42**	1		
<b>Recollection</b>	-0.18	0.25*	0.23*	0.30**	0.33**	0.45**	1	
<b>DecMemory</b>	-0.30**	0.37**	0.41**	0.44**	0.47**	0.83**	0.87**	1

<b>Group</b>	<b>CA</b>	<b>VIQ</b>	<b>Ravens</b>	<b>CEFT</b>	<b>PPT</b>	<b>Familiarity</b>	<b>Recollection</b>	<b>DecMemory</b>
<b>ALI (n = 20)</b>								
<b>CA</b>	1							
<b>VIQ</b>	-0.04	1						
<b>Ravens</b>	0.29	0.25	1					
<b>CEFT</b>	0.07	0.27	0.58**	1				
<b>PPT</b>	0.49*	0.50*	0.63**	0.53*	1			
<b>Familiarity</b>	-0.14	0.31	0.65**	0.65**	0.39	1		
<b>Recollection</b>	0.19	0.25	0.13	0.16	0.31	0.50*	1	
<b>DecMemory</b>	0.06	0.31	0.40	0.39	0.42	0.81**	0.91**	1

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).



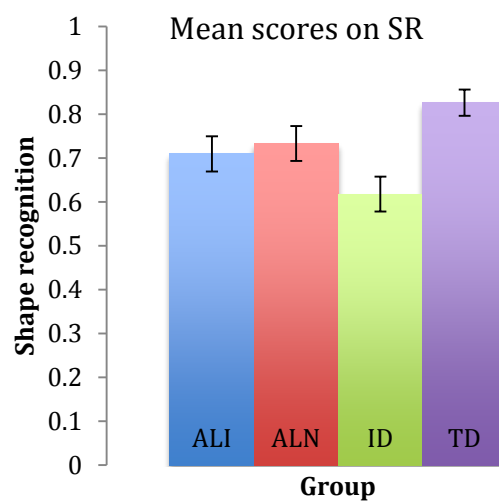
**Table 7.2 contd**

<b>ALN (n = 26)</b>	<b>CA</b>	<b>VIQ</b>	<b>Ravens</b>	<b>CEFT</b>	<b>PPT</b>	<b>Familiarity</b>	<b>Recollection</b>	<b>DecMemory</b>
<b>CA</b>	1							
<b>VIQ</b>	-0.01	1						
<b>Ravens</b>	0.11	0.38	1					
<b>CEFT</b>	0.39*	0.35	0.55**	1				
<b>PPT</b>	0.35	0.31	0.14	0.38	1			
<b>Familiarity</b>	0.20	0.32	0.48*	0.64**	0.44*	1		
<b>Recollection</b>	0.13	0.19	0.18	0.61**	0.52**	0.42*	1	
<b>DecMemory</b>	0.19	0.30	0.38	0.57**	0.74**	0.82**	0.87**	1
<b>ID (n = 26)</b>	<b>CA</b>	1						
	<b>VIQ</b>	-0.60**	1					
	<b>Ravens</b>	-0.26	0.38	1				
	<b>CEFT</b>	-0.31	0.53**	0.65**	1			
	<b>PPT</b>	-0.14	0.29	0.33	0.58**	1		
	<b>Familiarity</b>	-0.37	0.44*	0.53**	0.52**	0.42*	1	
	<b>Recollection</b>	-0.21	0.59**	0.46*	0.22	0.17	0.48*	1
	<b>DecMemory</b>	-0.33	0.61**	0.57**	0.33	0.41*	0.83**	0.88**
<b>TD (n = 32)</b>	<b>CA</b>	1						
	<b>VIQ</b>	-0.16	1					
	<b>Ravens</b>	0.34*	0.40*	1				
	<b>CEFT</b>	0.16	0.09	0.53**	1			
	<b>PPT</b>	0.35*	0.40*	0.68**	0.34	1		
	<b>Familiarity</b>	0.17	-0.02	-0.02	-0.09	0.01	1	
	<b>Recollection</b>	0.14	-0.20	0.10	0.12	0.12	0.19	1
	<b>DecMemory</b>	0.20	-0.14	0.06	0.08	0.02	0.77**	0.77**

## 1) Familiarity - SR

The Figure 7.3 sets out the mean scores in each group for the shape recognition (SR) task.

**Figure 7.3** Proportion correct mean scores on SR and AR. Error bars represent +/- 1SE



First, a univariate ANOVA was conducted in order to see whether there was an overall group difference on SR scores. As predicted, there was a significant difference where  $F(3,104) = 6.48, p < .001, \eta_p^2 = .16$ . Individual group proportion correct scores can be seen in Figure 7.3.

In order to test the prediction that, on the test of SR, the ALI group would be impaired relative to the TD and ALN group, two separate independent samples t-tests were run to compare the relevant groups. These comparisons confirmed that there was a significant difference between the TD group (mean (M) = .83, standard deviation (SD) = .15) and the ALI group scores (M = .71, SD = .19) with the ALI group scoring significantly worse ( $t(50)$

= -2.48,  $p < .05$ ,  $d = .68$ ). However, compared to the ALN group, the ALI group did not score significantly worse ( $t(44) = -.40$ ,  $p > .05$ ,  $d = .12$ ). As Figure 7.1 indicates, this unexpected similarity between the ALI and ALN groups is a result of significantly worse performance by the ALN as compared to the TD group:  $t(56) = 2.02$ ,  $p < .05$ ,  $d = .52$ , contrary to predictions. Compared to Experiment 1 however, the ALI participants did not perform at the highest level of all groups.

In relation to the ID group it was predicted that they would either perform similarly to the ALI group or at an intermediate level between the ALI and the TD and ALN groups. However, similar to the results reported in Experiment 1, the ID group performed worse than all of the other groups. There were no significant differences in mean scores between the ID and ALI group:  $t(44) = 1.64$ ,  $p = 0.10$ ,  $d = .49$ ; but the ID group performance was the lowest of all groups with a mean score of .62 (SD = .18) The ALN mean score was .73 (SD = .2) and in the ALI group, as mentioned above, it was .71 (SD = .19). There was a significant difference between the ID group and the ALN group scores:  $t(50) = 2.14$ ,  $p < .05$ ,  $d = .59$  and the TD group:  $t(56) = 4.78$ ,  $p < 0.001$ ,  $d = 1.25$ .

Due to the high CEFT scores in the ASD groups in Experiment 1, as well as the strong relationship between CEFT and the test of familiarity (FCC), this relation was tested for earlier on in this analysis. Across all groups it was expected that scores on the CEFT (test of visuo-perceptual abilities) would correlate with the SR (familiarity) test scores, which requires attention to visuo-spatial detail to discriminate targets from distracters.

However, this was not predicted for the AR test, which involved recalling actions that had been performed by the tester. Indeed this was the case with SR scores highly correlated with

CEFT across all groups:  $r(102) = 0.51, p < .001$ , whereas the correlation between CEFT and AR was  $r(102) = .3, p < .01$ ; which was still significant but less than on FCNC where  $r(102) = .42, p < .001$ . Based on the observations in the previous chapter, it was expected that CEFT would correlate more strongly with SR performance in the two ASD groups compared to the TD and ID groups because the SR test also relies heavily on visuo-spatial skills (advantaging ASD groups) whereas AR has the element of cued action recall which does not employ these skills, unlike FCNC in Experiment 1. Again, these predictions were confirmed, whereby in the ALI group there was a highly significant relationship:  $r(18) = 0.65, p < .001$ , as well as in the ALN group:  $r(24) = 0.64, p < .001$ . There was no significant link in the TD group on SR:  $r(30) = -.10, p = .64$  but in the ID group there was also evidence also of a strong association.  $r(24) = 0.52, p < .001$ .

Therefore, given some of these significant relationships it was still important to determine to what extent CEFT and Ravens may be facilitating SR scores in the ASD groups, even though they were not as unexpectedly high as in Experiment 1. A univariate ANCOVA was conducted again across groups looking at scores on SR and an effect of group but this time controlling for CEFT and Ravens. Unlike Experiment 1, the effect of group remained significant at  $F(3, 98) = 3.33, p < .05, \eta_p^2 = .09$ . However, there were also significant effects from CEFT:  $F(1,98) = 8.20, p < .01, \eta_p^2 = .08$  and Ravens:  $F(1,98) = 5.45, p < .05, \eta_p^2 = .05$ .

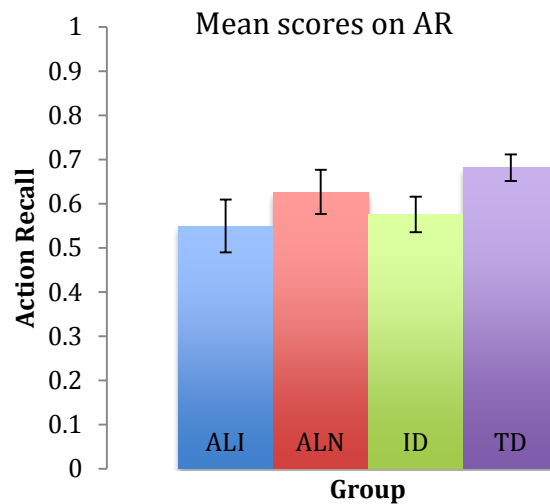
## **2) Recollection - AR**

For tests of AR it was predicted that both the ALI and ALN group would be impaired relative to the TD group, and the ID group would either perform similarly to the ALI and ALN

groups or somewhere at an intermediate level between these two groups and the TD group.

Average group scores for AR can be seen in Figure 7.4.

**Figure 7.4 Proportion correct mean scores on AR. Error bars represent +/- 1SE**



To test the aforementioned predictions individual t-tests were used, as before, to determine mean scores and group differences. As predicted, the ALI group (mean score = .55) performed at a significantly lower level than the TD group (mean score .68):  $t(50) = 2.29, p < .05, d = .61$ . However, unexpectedly the ALN group (mean score = .63) did not perform significantly worse than the TD group:  $t(56) = -1.08, p = .28, d = .28$  and although their scores were numerically lower, the size of this effect was relatively small.

For the ID group, their mean score was .58, which was marginally better than the ALI group's score of .55 but not near significance. This was confirmed by a t-test between the ID and ALI group:  $t(44) = -0.36, p = .72, d = .11$ . The ALN group scored a little higher with .63 but not significant:  $t(50) = 0.81; p = .42, d = .22$ . As predicted the ID group did perform significantly worse compared to TD's:  $t(42.1) = 2.11, p < .05, d = .57$ .

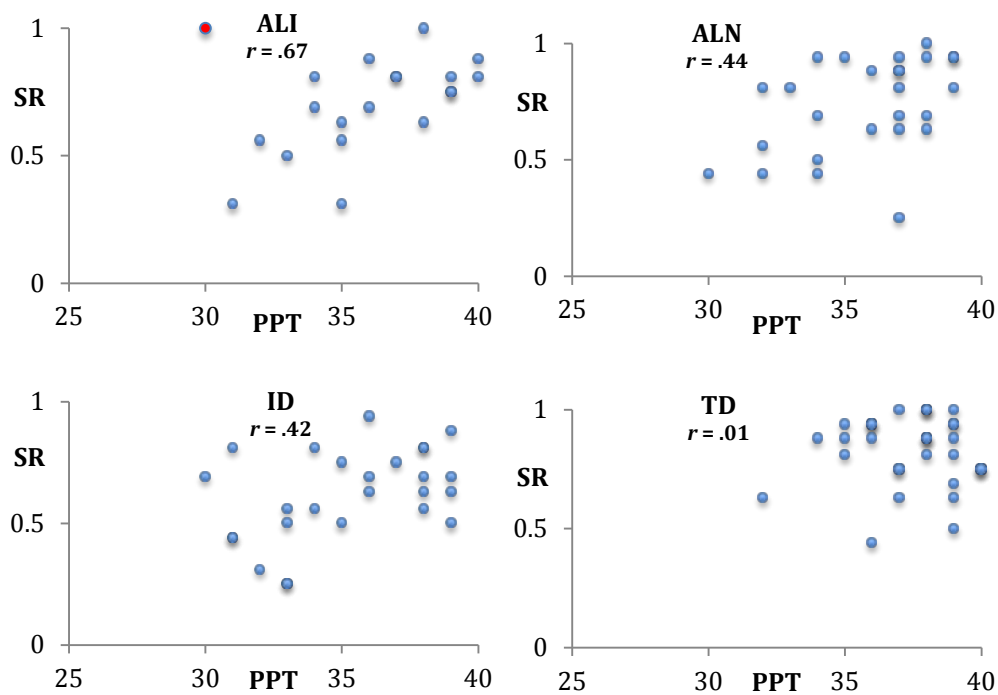
### 3) Determinants of conceptual semantic knowledge

To identify the principal predictors of semantic knowledge the same analysis strategy was adopted as in Experiment 1, beginning with a set of correlational tests to gain insight into the main correlates of semantic knowledge. First it was necessary to establish that the familiarity measure of SR did indeed correlate with the semantic knowledge measure (PPT) as predicted. A two-tailed bivariate Pearson's correlation confirmed that these variables were indeed significantly correlated  $r(102) = .41, p < .001$ .

It was predicted that in the four groups separately, correlations between scores on the PPT and performance on SR would be greatest in the ALN group (because they compensate for impaired recollection using familiarity), followed by the ALI group (possibly mirroring findings from Boucher et al., (2008)), with a small or non-significant correlation in the TD group. Individual two-tailed Pearson's correlations within groups supported this pattern. Specifically, in the ALN group there was a significant correlation between SR and PPT:  $r(24) = 0.44, p < .05$ . In the ALI group the correlation was of a similar magnitude although not significant:  $r(18) = .39, p = .09$ . It is evident from looking at Figure 7.5 that this marginal significance level in the ALI group may be due to an outlier (labelled in red), who performed at ceiling on the SR test but was the worst performer on the PPT. By contrast, the remaining participants fall on a clear diagonal resembling a strong correlation between SR and PPT. In fact, when the outlier was omitted from the dataset the correlation in the ALI group became significant:  $r(17) = .67, p < .01$ . In the TD group there was no evidence for a relationship between SR and PPT:  $r(30) = .01, p = .96$ , whereas in the ID group, a significant relationship was found that was similar in magnitude to the ALN group:  $r(24) = .42, p < .05$ . As already

noted in the previous chapter, the non-significant correlation in the TD group needs to be interpreted with some caution due many participants in this group performing at or near ceiling on the PPT.

**Figure 7.5** Graphs showing the relationship between PPT and SR tests in ALI, ALN, ID and TD groups



The initial correlation matrices for the ALI and TD groups showed that CA correlated with PPT so partial correlations were run between groups controlling for CA. Results remained broadly unchanged where ALI:  $r(16) = .70, p < .001$ ; ALN:  $r(23) = .41, p < .05$ ; ID:  $r(23) = .40, p < .05$  and TD:  $r(29) = -.06, p = .77$ . However in the ALI group the relationship was stronger.

The following prediction set out that PPT and Ravens would correlate across all groups. So a bivariate correlation was conducted that demonstrated, as predicted, that PPT and Ravens were highly correlated:  $r(102) = .40, p < .001$ . Within groups it was predicted that correlations between scores on PPT and Ravens might not reach significance but would possibly be the greatest in the ID group and the least in the ALI group. These predictions were not supported as the ALI group had the highest correlation where  $r(18) = .62, p < .01$  and in the ID group there was a small correlation but not significant: as  $r(24) = .32, p = .10$ .

In order to assess the relative contributions of familiarity, recollection, fluid intelligence, visuo-perceptual abilities and chronological age to conceptual semantic ability, an initial exploratory linear regression model using the ‘enter’ method was run. The aim of this was to see if there was a differing pattern of key predictors of PPT between the groups. This is set out in table 7.3.

**Table 7.3 Results for regression analysis showing the main predictors of PPT (outcome variable) by group**

Group	R	Adj RSQ	Sig F	SR	AR	CEFT	Ravens	CA
ALI	0.79	0.48	0.02*	0.04	0.27	0.27	0.43	0.09
ALN	0.64	0.27	0.04*	0.35	0.49*	-0.26	-0.01	0.32
ID	0.61	0.22	0.08	0.21	0.03	0.60*	1.16	0.09
TD	0.69	0.38	0.01**	-0.01	0.04	-0.03	0.65**	0.12

\* Correlation is significant at the 0.05 level (2-tailed)

\*\* Correlation is significant at the 0.01 level (2-tailed)

Table 7.3 demonstrates a different pattern in each group with the ASD and TD groups showing an overall significant predictability for PPT. Although the ALI group shows the



model as significant where  $p < .05$  there are no individual significant predictors. This is similar to Experiment 1. However, in the other groups there was one clear and differing significant predictor in each group. In the ALN group, AR (recollection) was a significant predictor of PPT whereas in the ID group it was CEFT (as in Experiment 1) and in the TD group it was Ravens (as in Experiment 1).

CA was not a significant predictor of PPT in any of the groups and an additional regression to test for its overall predictability in explaining the variance in PPT was run using the 'enter' method. CA remained an insignificant predictor where  $p = .173$ . This was important to establish due to the 'two-tiered' ages of the 4 groups.

Although group sizes were slightly larger in Experiment 2 they were nevertheless too small to run individual regression analyses. In order to investigate differences between ASD more generally compared to Non-ASD, one similar regression was run using backward elimination as in Experiment 1. However, instead of doing two separate comparisons for ID and TD, this was combined in one model (because there was SFB (theory of mind) data for both ID and TD groups). Individual groups were therefore dummy coded and an ASD variable was created from the ALI and ALN groups (see Experiment 1). PPT was included as the dependent variable and SR, AR, CEFT, Ravens, CA, SFB, ASD and interaction variables: ASD\*SR, ASD\*AR were added as independent variables. CA was included for cautionary purposes and it did show up as a significant predictor as shown in table 7.4. Backward elimination yielded 7 variables in the third model as significant predictors for PPT whilst Ravens and SFB were excluded (see table 7.4).

**Table 7.4 Regression table comparing ASD and NonASD showing the 3<sup>rd</sup> final model using backward elimination**

Coefficients with PPT	B	Std. Error	Beta	t	Sig.	Final Model		
						R	R Square	Adjusted R Square
ASD	-4.99	2.38	0.87	-2.09	0.04*	0.82	0.67	0.60
SR	-21.39	6.02	-1.47	-3.55	0.01**			
AR	11.60	4.13	0.98	2.81	0.01*			
ASD*SR	16.42	3.91	2.62	4.20	0.01**			
ASD*AR	-7.41	3.06	-1.29	-2.42	0.02*			
CEFT	0.29	0.06	0.66	4.63	0.01**			
CA	0.03	0.01	0.40	3.36	0.01*			

\* Significant at level of  $p < .05$

\*\*Significant at level of  $p < .001$

Both SR, AR and ASD status (versus both ID and TD) predict PPT but there is also an interaction of ASD status with SR and AR performance on PPT performance. CEFT and CA were also significant predictors although CA should be interpreted with caution due to the two-tier groups and its effects so far have been shown to be inconsistent. In relation to the predictions, there is a strong relationship between ASD and SR (familiarity) in explaining PPT where  $p < .001$ . AR (recollection) showed a weaker relationship with ASD in explaining PPT where  $p < .02$ . SFB (Theory of mind) although only included as a dichotomous variable was excluded in model 1 of the regression.

To return to the overall hypothesis of whether familiarity predicts difficulties with conceptual semantic ability in ASD, another regression analysis was needed to assess the relative contributions of SR (familiarity) to semantic knowledge (PPT), as well as CEFT (visuo-perceptual abilities) and Ravens within groups. A hierarchical (blockwise entry) regression

analysis was selected where familiarity, as theoretically predicted, was the main predictor in the model, allowing for further contributions from CEFT and Ravens in no particular order. As in Experiment 1, a hierarchical model, where predictors are selected based on past work and theoretical contributions, was chosen. The outlier in the ALI group was omitted and then SR was entered in the first block. CEFT and Ravens were then added simultaneously in the second block and the dependant variable was PPT. Groups were split so that group differences could be determined. Table 7.5 shows the coefficients for each group as well as the relevant statistical values.

**Table 7.5 Regression table showing 2 block entry phases presented by group examining the contributions of SR, CEFT and Ravens to PPT**

Group	Model		B	SE	Beta	t	Sig.	Final Model		
								R	R <sup>2</sup>	Adjusted R Square
ALI	1	SR	9.82	2.61	0.67	3.76	0.00	.674a	0.45	0.42
		SR	3.98	4.19	0.27	0.95	0.36			
	CEFT	0.83	0.11	0.16	0.75	0.47				
	Ravens	0.13	0.10	0.38	1.50	0.16				
ALN	1	SR	5.50	2.27	0.44	2.42	0.02	.442a	0.20	0.16
		SR	4.66	3.09	0.38	1.51	0.15			
	CEFT	0.10	0.11	0.23	0.89	0.39				
	Ravens	-0.05	0.07	-0.17	-0.75	0.46				
ID	1	SR	6.63	2.94	0.42	2.26	0.03	.418a	0.18	0.14
		SR	3.14	3.30	0.20	0.95	0.35			
	CEFT	0.38	0.16	0.57	2.46	0.02				
	Ravens	-0.06	0.10	-0.15	-0.65	0.53				
TD	1	SR	0.11	2.36	0.01	0.05	0.96	.008a	0.00	-0.03
		SR	0.24	1.79	0.02	0.13	0.89			
	CEFT	-0.01	0.06	-0.03	-0.19	0.85				
	Ravens	0.23	0.05	0.70	4.31	0.00				
2	SR	0.24	1.79	0.02	0.13	0.89			0.41	
	CEFT	-0.01	0.06	-0.03	-0.19	0.85				
		Ravens	0.23	0.05	0.70	4.31				

a Predictors: SR

b Predictors: SR, Ravens, CEFT

c Predictors: SR, CEFT, Ravens

The regression table set out in Table 7.5 shows that in the ALI group, SR in the first block is a significant predictor variable for PPT where  $p < .01$ . However, when CEFT and Ravens are added into the model in block 2, there are no significant predictors. CEFT and SR are no longer significant predictors unlike in Experiment 1 where familiarity remained a predictor of PPT performance in ASD groups. In the ALN group a similar pattern emerges where SR is a significant predictor at block 1,  $p < .05$ , but when CEFT and Ravens are added in block 2, none of the factors seem to significantly predict PPT performance. This was likely due to collinearity of the variables and that they all correlated with one another. In the ID group, SR is significant at block 1 but then CEFT becomes the significant predictor at block 2 and SR and Ravens are not significant. In the TD group, SR is not a predictor at either block 1 or 2, nor CEFT at block 2, but Ravens is a highly significant predictor of PPT. However, there may be other factors in the TD group that would contribute to PPT performance such as VIQ but this was not part of the model so results should be interpreted with caution. Another regression was run to check any effects of CA and AR in block 2 (because they have been shown in analyses above to make a contribution) but there were no significant changes other than AR significantly predicting PPT performance in the ALN group where  $p < .05$ . CA remained insignificant and the CEFT and Ravens remained significant in the ID and TD groups respectively.

The prediction that SR (familiarity) would be a main contributor to PPT (semantic knowledge) in the ALI group was demonstrated by the adjusted R square values of 42% which is higher than Experiment 1. However there was more collinearity of the variables in Experiment 2 making it difficult to distinguish the individual contributions of SR, AR, CEFT and Ravens. However, the correlational analyses point to a clear association between SR and PPT in ALI. To confirm that the association between SR and PPT was significantly different

in between the ALI and TD groups a Fisher's Z calculation (2-tailed) showed that  $Z = 2.57$ ,  $p < .01$ . There were no other between group differences that were significant. These calculations go further to support the hypothesis that there is a significant association between SR (familiarity) and PPT (conceptual semantic knowledge) in ALI which does not seem to exist in ID or TD populations and to a lesser extent in ALN.

#### **4) ID group**

Another key aim of this research was to obtain data on memory and language measures for children with ID. A different profile of scores was predicted for the ID group compared to the ASD groups.

Overall, the striking findings for the ID groups reflect a very low performance compared to other groups, on ALL measures in both Experiments 1 and 2; excluding the WASI on which they were matched and on the PPT where their scores were equated to both ASD groups. CEFT was shown to be associated with PPT performance unlike TD, ALI or ALN.

#### **5) Between test results**

Correlation tests of the experimental tests were run on the Experiment 2 dataset because it contains more participants than Experiment 1. The familiarity tests of FCC and SR correlated with  $r(91) = .54$ ,  $p < .001$  but, as would be expected, the recollection tests of FCNC and AR did not correlate as  $r(91) = .17$ ,  $p = .10$ .

## *Summary*

One of the aims in Experiment 2 was to devise a test of recollection that avoided employing skills of familiarity (as well as visuo-spatial skills) as much as possible, unlike FCNC. The fact that FCNC and AR did not correlate might explain that this was achieved and that the AR test employed more recollective skills than the FCNC test.

The overall memory scores for Experiment 2 for each of the diagnostic groups were more consistent with the predictions as well as the existing literature than Experiment 1. The results of Experiment 2 have successfully demonstrated that there is a relation between familiarity and semantic knowledge in ASD although the findings from the regression analysis complicate this relation. This will be discussed in the next chapter.

## **Chapter 8**

### **Discussion**

#### **Overview of results**

The main aim of this research was to investigate the possible causes of structural language impairment in children with ALI looking specifically at the contributions of declarative memory impairment (familiarity and recollection) to semantic knowledge. The main prediction was that the ALI group would be impaired on familiarity and that this would relate to impairments in semantic knowledge. The main findings in ALI on familiarity were both mixed and unexpected with the ALI group unimpaired in Experiment 1 but performing worse than the TD and ALN groups in Experiment 2. On recollection they were relatively impaired to TD's as expected and so were the ALN group. In both Experiments there was a clear correlation between familiarity and lexical semantic knowledge as measured by the Pyramids and Palm trees test in both ASD groups but not in the TD group. In Experiment 2, fluid intelligence also played a role in lexical semantic knowledge, overtaking the contribution from familiarity in the ALI group only.

The secondary aim of the work was to obtain data on possible contributions to language impairment in children with ID and to compare their memory abilities and their relations with semantic knowledge with children with both ALI and ALN. The overall pattern of findings for the ID group was striking in that they were significantly impaired relative to the ASD groups on most measures. More specifically, their performance on familiarity and

recollection was significantly worse than all other groups in both experiments (apart from recollection in Experiment Two) as were their scores on fluid intelligence and visuo-perceptual abilities. Familiarity was associated with lexical semantic knowledge in Experiment 1 but not in Experiment 2; however visuo-perceptual ability rather than familiarity was the dominant predictor of lexical semantic knowledge in both experiments.

The pattern of results obtained across the two experiments has a number of implications for the literature on both ASD and ID. The following sections will first outline the implications of the data for the literature in ASD, beginning with implications for declarative memory and structural language followed by a discussion of issues relating to ASD more generally. Next the implications for our understanding of ID will be discussed. The final three sections will acknowledge some limitations of the current research as well as future directions before concluding with some implications for applied settings.

## **Implications for literature on ASD**

The findings from this research on declarative memory performance in ASD, comprising familiarity and recollection processes, will be discussed in the context of past and current literature. How these processes may underpin structural language in ASD will then be considered.



## **Familiarity**

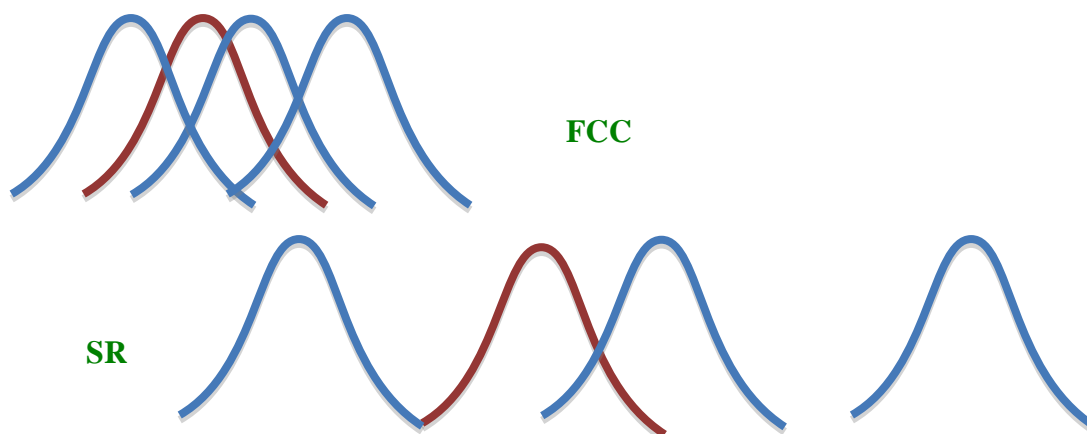
### *ALI*

In Experiment 1 the ALI group performed numerically best out of all groups, contrary to predictions, but in Experiment 2 they were significantly impaired relative to the TD group but not the ALN group who scored only numerically higher. These mixed findings, though unexpected, are representative of some inconsistencies in the literature on familiarity in ALI. In one study, familiarity in ALI was impaired compared to both an age and ability matched ID and TD group when coloured shapes were used as the stimuli (Boucher et al., 2008), which were similar to the stimuli used in the current SR test of Experiment 2. By contrast, other studies have shown that familiarity is intact in ALI compared to NT controls (Boucher & Lewis, 1992; Hill & Russell, 2002; Hauck et al., 1998) and these studies all used stimuli that involved common objects, similar to the materials used in the current FCC test. It may be the case, therefore, that the difference in stimuli (abstract/novel shapes vs. common objects) contributes to the inconsistencies in the current performance where ALI were impaired on SR but not FCC relative to the TD group. Although such an explanation is appealing, it is important to note that an early study by Boucher and Warrington (1976) also used pictures of everyday objects, and Lind (2008) used named pictures of common objects and performance in the ALI groups was impaired relative to NT, ALN and ID groups in both studies. Therefore it is unlikely to be the content of the stimuli alone that accounts for differences in findings.

The tests of familiarity that were employed in this research were specifically designed to minimise demands on verbal processes. This may have favoured the ASD groups – in particular the ALI group – due to their superior visuo-spatial skills relative to their language skills. At first, this may not seem to explain why the ALI performance was relatively

impaired to the TD group on SR but not on FCC. However, there are important differences in the nature of the foils used within the forced choice quartets. In the FCC test the foils were very slightly different to the target. For example, with a target item such as a paper clip, the foils would also be paper clips, but with only very small differences between them. However, in the SR test, the difference between the foils and the target (non-meaningful blue shapes), and between the foils themselves, was much greater than on the FCC test (see Migo et al., 2013). A visual representation of this situation can be seen in Figure 8.1 below where 4 Gaussian curves represent hypothetical feature distributions of the forced choice options comprising a test trial including one target (red) and three foils (blue) on the FCC test (left) and SR test (right and below). In the FCC test, there is much greater overlap between the signals representing the different options, making it more difficult to identify the target amongst the distracters than in the SR tests.

**Figure 8.1: Gaussian curves represent the relationship of the target (red) to the foils (blue) in similarity on the forced choice quartet in FCC (left) and SR (below right).**



It is possible that on the FCC test individuals with ALI find it easier to discriminate these differences at retrieval and may in fact be relying more on a process of eliminating the foils,

rather than the feeling of ‘knowing’ that they had seen the target previously. In the SR test however, foils were relatively different from the target and this may draw more attention to the target rather than the foils at retrieval and to establish whether or not it has been seen before. These two processes, although they constitute the skills involved in a task of familiarity, are different from one another. The former skill of identifying the differences in the foils to achieve success in identifying the target may not be the same as the feeling of ‘knowing’ that you have seen something before. This is something future studies could address by systematically varying the extent to which foils are similar to targets and by varying the task (e.g., pick the one that is least similar to the one you have seen vs. pick the one you saw earlier).

Another alternative could be more related to encoding. Children with ALI may have performed better on FCC than SR because their relatively superior perceptual skills allow them to discriminate the foils more on FCC, essentially stretching the x-axis in Figure 9.1. In TD and ALN groups preserved language skills may interfere with the processing of perceptual details because all items are simply ‘paper-clips’ so their encoding is primarily verbally mediated whereas in children with ALI it is primarily mediated through visual processes.

The lack of impairment found on FCC in the ALI group, and the arguments above, would be consistent with the literature that suggests individuals with ASD have an enhanced ability for discrimination (Plaisted, 2001; O’Riordan & Plaisted, 2001) that confers an advantage on tasks where perceptual similarity plays a role (Bott et al., 2006). The similarity between foils in the FCC test entails that success on this task depends on the ability to identify small differences amongst foils, rather than having to determine whether or not a novel, largely

dissimilar foil has been seen before, as in the SR test. Retrieval of the correct response in the FCC test is therefore facilitated in the ALI group, whereas the novel foils used in the SR test constitute a distracting, rather than facilitating, factor.

Bowler's Task Support Hypothesis (Bowler et al., 2004) states that help at retrieval can often aid success on declarative memory tasks in ASD. If this is the case, not only may this explain the preserved performance on FCC, but also it brings into question how tests of familiarity can really probe familiarity processes 'purely' (i.e. involving as few other cognitive processes as possible) in ASD and has future methodological implications. For instance, although the FCC test has been used successfully with amnesic patients and patients with hippocampal damage (Migo et al., 2009), it might be that this type of test is less suitable for testing ASD populations due to their tendency to be oriented towards visuo-spatial differences. However, what it may also show is that children with ALI may not necessarily have a quantitative impairment in familiarity processes but a qualitative one that will very often confer a disadvantage (i.e., in a world that dominated by language) but can confer advantages (i.e., when visual perceptual details are key to remembering what one has and hasn't seen before).

In summary, it appears that despite mirroring inconsistencies of familiarity performance in the ALI literature, the research presented in this thesis has unveiled some possible explanations for such diversity. Familiarity, as measured by SR, did demonstrate a significant impairment in ALI and this is important, particularly for reasons that implicate educational interventions and practice. It is still useful for educators to understand that familiarity is at least anomalous in ALI and will often be impaired if visuo-spatial skills cannot support retrieval. In classroom settings this may affect overall reading and comprehension and learning of new information. Educators could enhance learning if it is understood 'how'

individuals with ALI may be compensating for this impairment in familiarity using their enhanced visual perceptual and discrimination skills. It would be interesting to devise tests of familiarity in the future that make use of auditory, gustatory, tactile and/or olfactory stimuli to examine ALI vs. ALN and TD performance on such tasks. It would also be useful to devise tests that examine success on a range of forced choice quartets with varying levels of similarity between target and foils to further examine the issues discussed above.

### *ALN*

In the ALN group, performance on familiarity was also not entirely in line with predictions, ALN participants performing at a similar level to the TD group on FCC but significantly worse than the TD group on SR. The FCC result is consistent with the ASD literature where familiarity is largely preserved in ALN (Beversdorf et al., 2000; Hillier et al., 2007; Salmond et al., 2005; Boucher et al., 2005; Bowler et al., 2000; 2000b; Williams et al., 2006; Ambery et al., 2006; Buitelaar et al., 1999; Bigham et al., 2010; Boucher et al., 2008). However, it was surprising that the scores were relatively low for SR, with ALN participants being impaired relative to the TD group. This finding is particularly surprising considering that a similar test was used previously with similar aged children with ALN (Bigham, Boucher, Mayes & Anns, 2010) and no differences were observed between the TD and ALN groups. It would be possible to conclude that this result may have been obtained by chance but the group size was relatively large. It is possible also that the TD group performed better in the previous study but as there were a few minor changes to the stimuli it is not possible to directly compare results across both experiments.

It is also worth questioning why the ALN group did not perform as well as the ALI group? If the arguments above regarding the similarity of foils holds, then perhaps if WCC is less

pronounced in ALN (see Chapter 5, Table 5.1) and enhanced discriminability is slightly reduced compared to ALI, then it is possible that in ALN, their preserved language may interfere with visual perceptual tasks (Williams et al., 2006; Williams & Jarrold, 2010). This would be consistent with existing findings where verbal skills play a role when people try to remember pictures of objects (Williams & Jarrold, 2010). In ALI, visual perceptual skills are enhanced relative to their language ability whereas in ALN that is not the case. Therefore preserved language may hinder visual perceptual skills in the context of the SR familiarity task used here.

### *Comment*

Whilst there may be instances where performance on tests of familiarity is facilitated by enhanced discrimination ability in people with ASD (as in performance on the FCC test), this may not translate to more ‘real life’ situations. This has been shown in an interesting study where small-scale search skills were extended to a larger-scale environment in a test comparing 20 school-age children with ASD and 20 age and ability-matched typically developing children (Pellicano, Smith, Cristino, Hood, Briscoe & Gilchrist, 2010). In this experiment, a ‘foraging room’ in a purpose built laboratory was created where numerous green and red search options were embedded into the floor. Children were instructed to search an array of 16 (green) locations in order to find the hidden (red) target as quickly as possible. The distribution of target locations was manipulated to appear on one side of the midline for 80% of the trials. Baron-Cohen’s “systemising theory” should predict that children with ASD would have superior visual skills even in more true-to-life settings (Baron-Cohen, 2008; Baron-Cohen, Ashwin, Ashwin, Tavassoli & Chakrabarti, 2009). However this was not the case as their visual search behaviour was much less efficient, and their search patterns were significantly less systematic and optimal than those of the TD

children. The authors (Pellicano et al., 2010) propose that children with ASD have difficulties in inferring a probabilistic rule within a larger-scale environment because it requires constant updating of navigational skills involving egocentric and allocentric representations of space. Although these are not tasks of familiarity, their ecological validity may give a more accurate cognitive representation that is more true to real life. If familiarity was tested in more naturalistic settings where enhanced discriminability can less easily be employed, then it is likely that ALI's may struggle relatively more. The vast majority of familiarity data has been collected within same-day presentation and testing. This would be when familiarity is likely to be at a temporary maximum. Recognition in natural settings produces familiarity responses after months and years (Mandler, 2008). In some natural settings children with ASD may not always be able to rely on their superior visuo-spatial skills therefore this may explain why findings are mixed. Given the possibility that individuals with ASD compensate for reduced abilities in declarative memory it would be useful to obtain data from more realistic settings rather than solely rely on tests that employ small-scale uncontextualised stimuli.

## **Recollection**

Experiment 1 employed a recognition test (Forced-choice non-corresponding; FCNC) and Experiment 2 a cued recall test (Action Recall; AR) to probe processes of recollection. Cued recall tests would be considered a 'truer' test of recollection because familiarity processes contribute little if anything to tests of recall whereas they can play a role on tests of recognition (Bastin, Van der Linden, Schnakers, Montaldi & Mayes, 2010).

## *ALN and ALI*

Both groups were impaired relative to the TD group on the FCNC task, consistent with the predictions and with the literature (e.g. Bowler et al., 2008a; Bigham et al., 2010; Smith et al., 2007; Botting & Conti-Ramsden, 2003; Salmond et al., 2005; Williams et al., 2006a). The ALI group were also significantly impaired on the AR test, consistent with the predictions.

However, on the AR test the ALN group were unimpaired relative to the TD group, which was not predicted, and which is also inconsistent with past results on this specific test (Bigham et al., 2010). The AR test is a source memory test that encourages intentional learning between previously seen cueing item (a shape) and its associated action. The groups in the current study were larger in size than in the Bigham et al, (2010) study, making it unlikely that the current study was underpowered to detect the previously reported group differences. In addition some of the actions were changed in the AR test of the current compared to the previous study to make them more stimulus-directed. Although a minor change this may have contributed to the differences in findings by minimising demands on the imitation of self-directed actions, which has previously been shown to be a source of difficulty for ASD individuals (see Hobson & Lee, 1999). More generally it is also worth noting that the AR test involved cued-recall, which has shown mixed results in ALN (Bowler et al., 2000; 2004; Bigham et al., 2010; Ring et al., 2015). Individuals with ALN tend to do well on recall tests when contextual information (implicating recollection skills) is not part of the test (Ambery et al., 2006; Bowler, Gaigg & Gardiner 2008a; Bowler et al., 2007; Minsheu et al., 1992; Mottron et al., 2001; Renner et al., 2000; Smith et al., 2007; Williams et al., 2006a). It may be the case that AR, although a source memory test, was also relying on a lower level of contextually rich detail due to the fact that the shapes and actions were non-



meaningful. Otherwise cued recall has generally been shown to be intact in ALN and so this performance in the ALN group on AR is not surprising (Mottron et al., 2001; Bowler et al., 1997; Gardiner et al., 2003; Ambery et al., 2006; Bowler et al., 2000). This is also consistent with the Task Support Hypothesis which suggests that cued recall should be preserved over free recall in ASD. However, when cued recall probes specific contextual details the findings become more mixed and therefore further studies will be needed to establish under which circumstances cued recall is and isn't impaired in ALN.

### **Declarative memory and semantic knowledge**

There is little research in ASD that has investigated the possibility that declarative memory impairments contribute to semantic knowledge impairments in this disorder. Ullman's hypothesis (2004), that declarative memory underpins the mental lexicon component of structural language (as set out in Chapter Three), may help explain the impairments of semantic knowledge in ALI as compared to ALN. A clear link was found in Experiment 1 between semantic knowledge and familiarity as predicted but this was less obvious in Experiment 2. This was due to the collinearity of the measure of familiarity with the measures of fluid intelligence and visuo-perceptual skills, which correlated very highly with one another in the ASD groups particularly. Therefore it is difficult to infer that the SR measure of familiarity measured a different construct to the measures of fluid intelligence and visuo-perceptual ability. However, the presence of collinearity does not necessarily affect the efficacy of extrapolating the fitted model to new data provided that the predictor variables follow the same pattern of collinearity in the new data (Gujarati, 2004). This would be the case because individuals with ASD rely on their visuo-perceptual and non-verbal skills and

so the performance on CEFT and Ravens are always likely to correlate, therefore this model was accepted. However, the findings from Experiment 1 clearly demonstrate that the familiarity measures contribute to semantic knowledge over and above any contribution from fluid intelligence or WCC.

Ullman (2001, 2004) states that any form of memory impairment is likely to result in impoverished language. In addition, if language provides a basis for thought, impoverished language may in turn create limited and/or anomalous memories. This cyclical process can be seen in the cognitive profile of ALI and is likely not uni-directional. Ullman's hypothesis states that grammar and vocabulary employ distinct neural systems (Ullman 2001, 2004; Ullman et al. 1997). The fundamental distinction is set up between the mental lexicon, a store of information about phonological forms and their associated meanings, and the grammatical system, which computes the meanings of complex forms using the rules of grammar. According to the declarative/procedural (DP) model of language as described in Chapter Three, these two kinds of processing are most efficiently handled by different systems: the declarative system for the lexicon and the procedural system for grammar.

However, there are several instances of these processes overlapping and also interacting. This can occur at a neurophysiological level where brain structures overlap in the systems that they support as well as on an anatomical level (see Chapter Three for a full account). In addition there is evidence that interactions between Procedural and Declarative systems operate in both a competitive and complementary way (Ullman, 2004). This is important because whilst the focus of this research is on declarative memory, these interactions may explain some of the anomalies in cognitive profiles.

Ullman's hypothesis has motivated substantial research in relation to Specific Language Impairment (SLI) where deficits are more often seen in procedural memory and where declarative memory is relatively intact, almost the reverse of the memory profile in ASD (Boucher et al., 2012; Dewey & Wall, 1997; Lum & Conti-Ramsden, 2013; Ullman & Pierpoint, 2005). This, amongst evidence from other neurodevelopmental disorders, has led to the formulation of the 'Procedural Deficit Hypothesis' (PDH, Ullman & Pierpoint, 2005). The current research on ASD has shown a range of declarative memory with overall quantitative impairments in recollection and more qualitative anomalies in processes of familiarity where visuo-perceptual skills seem to play a disproportionate role. The PDH states that in disorders such as Dyslexia, SLI, Obsessive Compulsive Disorder (OCD) and ASD, declarative memory may be compensating for a deficit in procedural memory (Ullman & Pullman, 2015). Although the work in this thesis focused exclusively on measures of declarative and not procedural memory processes, it seems unlikely that declarative memory would compensate for a procedural deficit in ASD. The current thesis demonstrated anomalies in declarative memory in ASD, which is in line with the extant literature, and studies of procedural memory generally reveal no or only minimal anomalies in ASD. However, the interaction of declarative and procedural memory has not often been considered carefully in ASD, at least not empirically. Ullman's model provides some interesting arguments in this context and it is important to appreciate their significance in relation to the development of ASD in some more detail.

In earlier work, Ullman refers to a see-saw effect between the two systems and how they may compensate for one another (Ullman, 2004, 2008). Therefore this may have implications for the current findings. In order to appreciate the broader significance of the current findings, it is important to broaden the scope of this discussion briefly and consider the role of

declarative memory in language and how procedural memory may also be implicated due to its interaction with declarative memory.

It has been proposed that the declarative system initially acquires knowledge through rapid learning processes whilst the procedural system learns more gradually through repetition (Poldrack & Packard, 2003). In addition, in the early stages of learning new information, the declarative system will dominate and over time shift towards the procedural system. This time shift can be modulated pharmacologically (Packard, 1999) evidencing this possible interaction and therefore if individuals with ASD have declarative memory impairments this may lead to subsequent procedural memory impairments such as implicitly learning underlying principles relating to social situations (Klinger et al., 2007).

Ullman and Pullman (2015) have recently proposed several ways that declarative memory could compensate for procedural deficits in ASD, at least as far as memory processes are concerned in the context of language function. First formulaic speech (Dobbinson et al., 2003; Tager-Flusberg et al., 1990) can be learnt in rote chunks to allow for linguistic deficits in social situations. In addition, individuals with ASD are able to memorise rules and schemas relating to social instances where they may not be able to use their social skills to decipher what type of speech or behaviour is appropriate. This type of explicit learning on which ASD individuals seem to rely is evident of a compensatory declarative role (Ullman & Pullman, 2015). This may be the case but if there are elements of declarative memory that are impaired in ASD such as memory for relational and contextual information, then this may produce a very narrow store of contextually-rich memories from which individuals can subsequently retrieve, whether it is for declarative or procedural purposes. For example, if social understanding and learning is attenuated from the start, it is unlikely to be consolidated

in procedural memory, which would then allow for implicit application in social situations. There is some neurological evidence from studies of ASD on such compensatory action where increased activation in the hippocampus (Dichter et al., 2012) and parahippocampal gyrus (Vaidya et al., 2011) on a reward anticipation task and a social stimuli processing task respectively. Both tasks would not normally employ hippocampally-related areas of the brain for such tasks, which is usually associated with declarative memory and the authors tentatively point towards a compensatory role of declarative memory in ASD here (Ullman & Pullman, 2015).

Recently an interesting study addressing a similar relationship between declarative and procedural systems, but in SLI, found that although there were some clear declarative memory impairments in vocabulary learning in SLI, these impairments could be attributed to procedural deficits (Bishop & Hsu, 2015). Specifically, forming associations between visual and auditory stimuli as well as remembering them over time was intact in SLI. However, relative to an age-matched comparison group the SLI group had difficulties with learning on a vocabulary-learning task. Bishop and Hsu (2015) propose that although vocabulary-learning may often be considered to employ declarative skills, this task utilized procedural skills of remembering novel phonological strings. Therefore this difficulty was attributed to a deficit in the procedural system rather than the declarative system. This is an excellent example of how these memory systems are capable of compensating for one another in specific ways but Ullman and Pullman's PDH hypothesis may not easily be mapped onto ASD. It may be the case instead, that this flexibility of system compensation and competitiveness is present in ASD but more reliant on procedural memory to compensate for a declarative memory impairment. It is well known that individuals with ASD have good rote memory skills, grammar is largely intact but as is evident from this current research and

existing literature their lexical semantic ability is relatively compromised. Given the flexibility of these two systems (declarative and procedural) it is difficult to identify where strengths and weaknesses originate from in ASD.

Therefore, this flexibility between these two systems is interesting and relevant in the case of ASD. There is a substantial body of evidence pointing towards declarative memory anomalies in ASD rather than a procedural deficit (again, see Chapter Three) and this will have a direct effect on language. Individuals with ALI tend to be better at grammar (supported by procedural memory) than lexical semantic ability (supported by declarative memory). This latter association is supported in ALI by the findings in both experiments of the current thesis and has addressed a salient gap in the literature. Important questions remain, however, about how declarative and procedural memory processes interact in ASD and in this context, Ullman's original DP model (2001, 2004) may provide a more fruitful frame of reference than the slightly later PDH model (Ullman & Pierpoint, 2005; Ullman & Pullman, 2015).

## **Implications for Intellectual Disability**

The aim of this research in relation to intellectual disability was to obtain data on possible causes of language impairment in children with ID (without ASD). Performance by the ID group on declarative memory was predicted to fall between the ALI and ALN levels.

However, on all tests excluding verbal IQ and semantic knowledge, the ID group performed significantly poorer. These include two familiarity and two recollection tests as well as tests of visuo-perceptual abilities (CEFT) and fluid intelligence (Ravens). This is a striking

finding and is consistent with a government report on educational needs, which states that children with ID are more impaired than expected and that they struggle more globally (Dockrell et al., 2012a; 2012b). It may be that their relatively high VIQ enables them to cope in every day situations. A study by Carpentieri and Morgan (1996) showed that children with ID who are equated on IQ with children with ASD will show better adaptive behaviours than children with ASD. This is a key advantage; however in an educational setting it is important that these adaptive skills do not mask relatively severe cognitive impairments that could be overlooked or misunderstood.

Despite the impairments in the ID group, they did show a different pattern to the ASD groups in terms of the predictors of semantic knowledge. Low visuo-perceptual skills, as demonstrated by their low performance on CEFT, were significantly associated in the regression analysis to their semantic knowledge. Their performance on PPT was not predicted by either familiarity or fluid intelligence, which paints a very different picture to the ASD groups. This is not consistent with some existing literature. In children with language impairment (not strictly equivalent to an ID group as they included children with SLI), findings have shown that there is a domain specificity of memory impairment that affects verbal processing but not visual processing (Baird, Dworzynski, Slonims & Simonoff, 2010). The authors found that children with a language impairment had an impairment on all verbal memory measures compared to children who had never had language impairment but also that these impairments were still present in children whose learning impairment had resolved. By contrast, visual memory and learning were not impaired relative to children without language impairment. The severity of verbal memory and language impairments correlated with one another. This may be further evidence for Ullman's original model that memory impairment is implicated in language impairment, which may follow in individuals

with ID. However, as mentioned, this link was not shown in this current research. More research is required in intellectual disability to establish factors that may contribute to semantic knowledge and more broadly, language impairment.

## **Limitations**

It was unfortunate that it was not possible to fully pursue testing on the implicit mindreading test in this study as it is important to recognise that mindreading ability and language ability are strongly correlated (Bloom, 2000; Ahktar & Tomasello, 2000). However, the focus on declarative memory in children with ALI, ALN and ID is under researched and had to take priority. It was difficult to collect complete datasets in these populations as testing on a high number of tests across four different diagnostic groups took time and there were often absentees at schools resulting in some missing data. This happened across all groups so it has unlikely caused a sampling bias. Also, there were no participants that elected to no further testing. Similarly, it was also extremely difficult to obtain a separate measure to confirm ASD status. The SRS was administered for 26.3% of the sample and although these individuals performed accordingly in relation to their group status it is nevertheless disappointing. All children were diagnosed by educational or clinical psychologists and extra measures were taken by the experimenter as mentioned in Chapter 5 to attempt to reduce this weakness.

The PPT test had ceiling effects from the TD group which made it problematic for drawing conclusions regarding the role of declarative memory in semantic knowledge in their group. A more sensitive test of semantic ability could have been used; however the priority of this current research was to use a non-verbal test with minimal memory load thus enabling



research to be conducted with language impaired individuals. The Clinical Evaluation of Language Fundamentals – 4th Edition (CELF-4; Semel, Wiig, & Secord, 2003) was initially trialled with children with very low verbal abilities (bordering on non-verbal) with ASD and ID but they were unable to do a significant amount of the tests. An alternative would have been to exclude children with lower verbal abilities and use a wider battery of language tests. However this would not have been in line with the main aim of the study which was to test a very under researched area of individuals with ASD and ID with low verbal abilities. Future research, on the other hand, could benefit from a more comprehensive examination of language abilities and it might be worth compromising the group inclusion criteria to do this. Another factor particular to this current research was that some of the subtests of the CELF were considered to incorporate a memory load which needed to be avoided. This was because not only was this research testing declarative memory but it was also important to identify the language ability of participants without having to rely on other skills such as memory which may have made the task too challenging. In the Bigham et al., (2010) study the British Picture Vocabulary Scale (BPVS) was used but there is evidence to show that this test can overestimate verbal abilities which would also be counter-productive here (Norbury, 2005). Therefore the PPT fulfilled these criteria and it was still sensitive enough to flag interesting associations in individual groups.

The effect of visuo-spatial skills in the ASD group was anticipated to bias results to a certain extent but not as dramatically as they did. Finding a suitable declarative memory test for language-impaired children is challenging for similar reason as mentioned above. To ensure that verbal skills were not being used that could either advantage children with better language and/or interfere with memory performance, the FCC and FCNC recognition tests were advantageous. However, the disadvantage that they may have relied on superior visuo-

perceptual skills may also be seen as a point of learning. At a methodological level this type of test may not be suitable for testing in ASD populations, which is a valuable finding.

It is also possible that instead of having separate ALI and ALN groups that are defined by VIQ cut offs that a single ASD group with a wide and continuous range of language impairments could have been used. There were children that scored a VIQ between 75-90 because there needed to be a clear division between the ALN and ALI groups. It may be the case that this would be underrepresenting the range of ASD abilities. However, whilst a continuous range could be advantageous, it is not necessarily going to address differences at the opposite ends of the spectrum but rather only levels of impairments or abilities. There were also clear difficulties with group matching and direct comparisons cannot be made between the low (ALI and ID) and high functioning (ALN and TD) groups. Again, the aim of working with children with low VIQ's meant that their verbal age equivalent ability needed to be sufficient to understand test instructions. Therefore an older cohort of children were recruited in contrast to their higher VIQ counterparts. It is clear however from the findings, that regardless of age and VIQ, there were different relations and patterns of ability of declarative memory, visuo-perceptual ability, semantic knowledge and fluid intelligence in the different clinical groups. This is an important finding.

It was beyond the scope of this research to measure procedural memory which was regrettable. However, the primary aim was to investigate language impairment in lower functioning children with ASD and although the hypothesis was led Ullman's DP theory, its investigation was secondary. Notwithstanding, it would be advantageous for future research to measure procedural and declarative memory simultaneously in conjunction with a comprehensive range of structural language measures in order to make direct comparisons.

Here however, it was relied upon that there is sufficient evidence that points towards intact procedural memory skills in ASD (see Chapter 3) and the focus of this research was to explore any possible links between declarative memory and semantic knowledge.

What has been learnt through analysing these shortcomings is that the main aim of this research (attention to lower abilities) significantly limited the use of measures and complicated the analysis. No doubt this may be one explanation as to why there is relatively little research with children with lower verbal abilities. Future work would need to prudently weigh up the cost and benefits of working with lower ability children. Larger groups are advantageous and perhaps a better strategy and use of resources would involve exploring heterogeneity within larger groups rather than against a control group. Addressing these limitations as discussed above would involve further substantial work; yet the novel findings from this research should support, justify and consolidate more research activity in this direction.

## **Conclusion**

What these current findings reveal is the importance of investigating performance of ALI and ALN separately. There is now neurological evidence of differences between these groups (see Trontel et al., 2015) as well as behavioural evidence pointing towards different developmental trajectories in language skills (Tek et al., 2014). If these groups had been combined into a mixed group here the lack of familiarity impairment in the ALI group on FCC may not have shown up as a discrete feature in a large group score. These findings in familiarity require careful interpretation because they are still mixed and inconclusive.

However, given the heterogeneous cognitive profile and its varying manifestations in ASD this is not surprising. These anomalies in performance can reveal significant factors regarding methods used in the ASD population as well as inconsistencies in the autistic cognitive profile at both language-impaired and normal language levels.

Whether or not the memory, language and/or visuo-perceptual anomalies in ASD reported in this thesis are conceptualised as skills or deficits has far reaching implications at an interventional level. It is important for educators to value and use the 'skills' present in ASD to help children to maximise their learning capacity by using pre-existing abilities. This can also contribute to a more positive interpretation of ASD, which is useful amongst peers in a social context. However, the danger of this is that pervasive deficits are potentially overlooked and not addressed, either at an individual level (in an interventional context) or at a conceptual level by researchers. There is little known about how children with ALI differ from children with ALN, and the work in this thesis demonstrates that careful comparisons can shed light on this.

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## References

- Aggleton, J. P., & Brown, M. W. (1999). Episodic memory, amnesia, and the hippocampal–anterior thalamic axis. *Behavioral and brain sciences*, 22(03), 425-444.
- Aggleton, J. P., & Brown, M. W. (2006). Interleaving brain systems for episodic and recognition memory. *Trends in Cognitive Sciences*, 10 (10), 455 - 463.
- Aljunied, M., & Frederickson, N. (2013). Does central coherence relate to the cognitive performance of children with autism in dynamic assessments?. *Autism*, 17(2), 172-183.
- Akhtar, N., & Tomasello, M. (2000). The social nature of words and word learning. In R.M. Golinkoff, K. Hirsh-Pasek, L. Bloom, L.B. Smith, A.L. Woodward, et al. (Eds.), *Becoming a word learner: A debate on lexical acquisition*. New York: Oxford University Press.
- Ambery, F Z., Russell, A., Perry, K., Morris, R., & Murphy, D. (2006). Neuropsychological functioning in adults with Asperger syndrome. *Autism*, 10, 551–564.
- American Psychiatric Association. (1987). Diagnostic and Statistical Manual of Mental Disorders, -revised (DSM-III-R) American Psychiatric Association. *Washington, DC*.
- American Psychiatric Association (2000). Diagnostic and statistical manual: 4th edition test revised (DSM IV-TR). New York: Author.
- Andreasen, N. C., O'Leary, D. S., Arndt, S., Cizadlo, T., Rezai, K., Watkins, G. L., ... & Hichwa, R. D. (1995b). I. PET studies of memory: novel and practiced free recall of complex narratives. *Neuroimage*, 2(4), 284-295.
- Andreasen, N. C., O'Leary, D. S., Cizadlo, T., Arndt, S., Rezai, K., Watkins, G. L., ... & Hichwa, R. D. (1995a). II. PET studies of memory: novel versus practiced free recall of word lists. *Neuroimage*, 2(4), 296-305.
- Arias, R. G. (1998). Automatic and effortful processing: A meta analysis.
- Asperger, H.. (1944/1991). 'Autistic psychopathy' in childhood. Translated in U. Frith (Ed.), *Autism and asperger syndrome* (pp. 37–92). Cambridge: CUP.
- Astington, J. W. E., & Baird, J. A. (2005). Why language matters for theory of mind. In *Why Language Matters for Theory of Mind, Apr, 2002, University of Toronto, Toronto, ON, Canada; This volume originated from the aforementioned conference..* Oxford University Press.

- Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. *The psychology of learning and motivation*, 2, 89-195.
- Bäckman, L., Almkvist, O., Andersson, J., Nordberg, A., Winblad, B., Reineck, R., & Långström, B. (1997). Brain activation in young and older adults during implicit and explicit retrieval. *Cognitive Neuroscience, Journal of*, 9(3), 378-391.
- Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology: Section A*, 49(1), 5-28.
- Baddeley, A. (2002). Is working memory still working? *European Psychologist*, 7, 85–97.
- Baddeley, A. D., & Hitch, G. J. (1974). Working memory. *The psychology of learning and motivation*, 8, 47-89.
- Baddeley, A. D., & Lewis, V. J. (1981). Inner active processes in reading: The inner voice, the inner ear and the inner eye. *Interactive processes in reading*, 107-129.
- Baird, G., Dworzynski, K., Slonims, V., & Simonoff, E. (2010). Memory impairment in children with language impairment. *Dev Med Child Neurol*. June; 52, (6), 535-540.
- Baranek, G. (1999). Autism during infancy: A retrospective video analysis of sensory-motor and social behaviours at 9– 12 months of age. *Journal of Autism and Developmental Disorders*, 29, 213–224.
- Barnes, K. A., Howard Jr, J. H., Howard, D. V., Gilotty, L., Kenworthy, L., Gaillard, W. D., & Vaidya, C. J. (2008). Intact implicit learning of spatial context and temporal sequences in childhood autism spectrum disorder. *Neuropsychology*, 22(5), 563.
- Baron-Cohen S, Leslie AM, Frith U (1985). "Does the autistic child have a "theory of mind"?". *Cognition* 21 (1): 37–46.
- Baron-Cohen, S. (2008). Autism, hypersystemizing, and truth. *The Quarterly Journal of Experimental Psychology*, 61(1), 64-75.
- Baron-Cohen, S., & Belmonte, M. K. (2005). Autism: a window onto the development of the social and the analytic brain. *Annu. Rev. Neurosci.*, 28, 109-126.
- Baron-Cohen, S., Ashwin, E., Ashwin, C., Tavassoli, T., & Chakrabarti, B. (2009). Talent in autism: hyper-systemizing, hyper-attention to detail and sensory hypersensitivity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1522), 1377-1383.
- Baron-Cohen, S., Baldwin, D. A., & Crowson, M. (2007). I Cannot Tell a Lie: What People

with Autism Can Tell Us about Honesty. *Character: A journal of everyday virtues*.

Baron-Cohen, S., Knickmeyer, R. C., & Belmonte, M. K. (2005). Sex differences in the brain: implications for explaining autism. *Science*, *310*(5749), 819-823.

Baron-Cohen, S., Leslie, A. M. & Frith, U. (1985). Does the autistic child have a 'theory of mind'? *Cognition*, *21*, 37-46.

Bartak, L., Rutter, M., & Cox, A. (1975). Comparative study of infantile autism and specific developmental receptive language disorder 1: Children. *British Journal of Psychiatry*, *126*, 127-145.

Bartak, L., Rutter, M., & Cox, A. (1977). A comparative study of infantile autism and specific developmental receptive language disorders III. Discriminant function analysis. *Journal of Autism and Childhood Schizophrenia*, *7*(4), 383-396.

Bartolucci, G., Pierce, S., & Streiner, D. (1980). Cross-sectional studies of grammatical morphemes in autistic and mentally retarded children. *Journal of Autism and Developmental Disorders*, *10*, 39-50.

Bartolucci, G., Pierce, S., Streiner, D., & Eppel, P. (1976). Phonological investigation of verbal autistic and mentally retarded subjects. *Journal of Autism and Developmental Disorders*, *6*, 303-316.

Bastin, C., Van der Linden, M., Schnakers, C., Montaldi, D., & Mayes, A. R. (2010). The contribution of familiarity to within-and between-domain associative recognition memory: Use of a modified remember/know procedure. *European Journal of Cognitive Psychology*, *22*(6), 922-943.

Bennett, T., Szatmari, P., Bryson, S., Volden, J., Zwaigenbaum, L., Vaccarella, L., Duku, E., & Boyle, M. (2008). Differentiating autism and Asperger syndrome on the basis of language delay or impairment. *Journal of Autism and Developmental Disorders*, *38*, 616-625.

Bennetto, L., Pennington, B., & Rogers, S. (1996). Intact and impaired memory functions in autism. *Child Development*, *67*, 1816-1835.

Bernier, R., Dawson, G., Panagiotides, H., & Webb, S. (2005). Individuals with autism spectrum disorder show normal responses to a fear potential startle paradigm. *Journal of Autism and Developmental Disorders*, *35*(5), 575-583.

Beversdorf, D. Q., Smith, B. W., Crucian, G. P., Anderson, J. M., Keillor, J. M., Barrett, A. M., ... & Heilman, K. M. (2000). Increased discrimination of "false memories" in autism spectrum disorder. *Proceedings of the National Academy of Sciences*, *97*(15), 8734-8737.



- Bigham, S., Boucher, J., Mayes, A., & Anns, S. (2010). Assessing recollection and familiarity in autistic spectrum disorders: Methods and findings. *Journal of Autism*
- Bishop, D.V.M. (2010). Overlaps between autism and language impairment: Phenomimicry or shared etiology? *Behaviour Genetics*, *40*, 618–629.
- Bishop, D. V., & Hsu, H. J. (2015). The declarative system in children with specific language impairment: a comparison of meaningful and meaningless auditory-visual paired associate learning. *BMC psychology*, *3*(1), 3.
- Bishop, D.V.M., & Norbury, C.F. (2002). Exploring the borderlands of autistic disorder and specific language impairment: A study using standardised diagnostic instruments. *Journal of Child Psychology and Psychiatry*, *43*, 917–929.
- Bitterman, M. E. (1965). Phyletic differences in learning. *American Psychologist*, *20*(6), 396.
- Bloom, P. (2000). *How children learn the meanings of words*. Cambridge, MA: MIT Press.
- Bott, L., Brock, J., Brockdorff, N., Boucher, J., & Lamberts, K. (2006). Perceptual similarity in autism. *The Quarterly Journal of Experimental Psychology*, *59*, 1237–1254.  
doi:10.1080/02724980543000196
- Botting, N., & Conti-Ramsden, G. (1999). Pragmatic language impairment without autism: The children in question. *Autism*, *3*, 371–396.
- Botting, N., & Conti-Ramsden, G. (2003). Autism, primary pragmatic difficulties, and specific language impairment: Can we distinguish them using psycholinguistic markers? *Developmental Medicine and Child Neurology*, *45*, 515–524.
- Boucher, J. (1976). Articulation in early childhood autism. *Journal of Autism and Developmental Disorders*, *6*, 297–302.
- Boucher, J. (1978). Echoic memory capacity in autistic children. *Journal of Child Psychology and Psychiatry*, *19*, 161–166.
- Boucher, J. (1981a). Memory for recent events in autistic children. *Journal of Autism and Developmental Disorders*, *11*(3), 293-301.
- Boucher, J. (1981b). Immediate free recall in early childhood autism: Another point of behavioral similarity with the amnesic syndrome. *British Journal of Psychology*.
- Boucher, J. (2008). *The autistic spectrum: Characteristics, causes and practical issues*. Sage.
- Boucher, J. (2011b). Redefining the Concept of Autism as a Unitary Disorder: Multiple

Causal Deficits of a Single Kind?. *The neuropsychology of autism*, 469.

Boucher, J., (2011). Language in Autism Spectrum Disorders: Characteristics and Causes; in Roth & Rezaie (Eds.). *Researching the Autism Spectrum*. The Open University, Milton Keynes.

Boucher, J., & Bowler, D. M. (Eds.). (2008). *Memory in autism*. Cambridge, England: Cambridge University Press.

Boucher, J., & Lewis, V. (1989). Memory impairments and communication in relatively able autistic children. *Journal of Child Psychology and Psychiatry*, 30, 99–122.

Boucher, J., & Lewis, V. (1992). Unfamiliar face recognition in relatively able autistic children. *Journal of Child Psychology and Psychiatry*, 33, 843–859.

Boucher, J., & Mayes, A. (2011). Memory. In D. Fein, (Ed.), *The neuropsychology of autism* (pp. 139–160). Oxford: OUP.

Boucher, J., & Warrington, E. (1976). Memory deficits in early infantile autism: Some similarities to the amnesic syndrome. *British Journal of Psychology*, 67, 73–87.

Boucher, J., Bigham, S., Mayes, A., & Muskett, T. (2008). Recognition and language in lower functioning autism. *Journal of Autism and Developmental Disorders*, 38, 1259–1269.

Boucher, J., Cowell, P., Howard, M., Broks, P., Farrant, A., Roberts, N., & Mayes, A. (2005). A combined clinical, neuropsychological, and neuroanatomical study of adults with high functioning autism. *Cognitive Neuropsychiatry*, 10(3), 165-213.

Boucher, J., Mayes, A., & Bigham, S. (2012). Memory in Autistic Spectrum Disorder. *Psychological Bulletin*, 138, 458-496.

Bowler, D. M., Gaigg, S. B., & Gardiner, J. M. (2008a). Effects of related and unrelated context on recall and recognition by adults with high-functioning autism spectrum disorder. *Neuropsychologia*, 46(4), 993-999.

Bowler, D. M., Gaigg, S. B., & Gardiner, J. M. (2008b). Subjective organisation in the free recall learning of adults with Asperger's syndrome. *Journal of Autism and Developmental Disorders*, 38(1), 104-113.

Bowler, D. M., Gaigg, S. B., & Gardiner, J. M. (2009). Free recall learning of hierarchically organized lists by adults with Asperger's syndrome: Additional evidence for diminished relational processing. *Journal of Autism and Developmental Disorders*, 39, 589–595.

Bowler, D. M., Gaigg, S. B., & Gardiner, J. M. (2010). Multiple list learning in adults with

autism spectrum disorder: parallels with frontal lobe damage or further evidence of diminished relational processing?. *Journal of autism and developmental disorders*, 40(2), 179-187.

Bowler, D. M., Gaigg, S. B., & Gardiner, J. M. (2014). Binding of multiple features in memory by high-functioning adults with autism spectrum disorder. *Journal of autism and developmental disorders*, 44(9), 2355-2362.

Bowler, D., Gaigg, S., & Lind, S. (2011). Memory in autism: binding, self, and brain; in Roth & Rezaie (Eds.). *Researching the Autism Spectrum*. The Open University, Milton Keynes. Pp 316-346

Bowler, D. M., Gardiner, J. M., & Berthollier, N. (2004). Source memory in adolescents and adults with Asperger syndrome. *Journal of Autism and Developmental Disorders*, 34, 533–542.

Bowler, D. M., Gardiner, J. M., & Grice, S. (2000). Episodic memory and remembering in adults with Asperger syndrome. *Journal of Autism and Developmental Disorders*, 30, 295–304.

Bowler, D. M., Gardiner, J. M., Grice, S., & Saavalainen, P. (2000). Memory illusions: False recall and recognition in high functioning adults with autism. *Journal of Abnormal Psychology*, 109, 663–672.

Bowler, D. M., Limoges, E., & Mottron, L. (2009). Different verbal learning strategies in high-functioning autism: Evidence from the Rey Auditory Verbal Learning Test. *Journal of Autism and Developmental Disorders*, 39, 910–915.

Bowler, D. M., Matthews, N. J., & Gardiner, J. M. (1997). Asperger's syndrome and memory: Similarity to autism but not amnesia. *Neuropsychologia*, 35, 65–70.

Bowler, D.M. and Gaigg, S.B. (2008). Memory in ASD: Emerging themes and future prospects. Boucher, J. and Bowler, D.M. (Ed.), *Memory in Autism: Theory and Evidence* (pp. 330-349) Cambridge University Press.

Brandimonte, M. A., Hitch, G. J., & Bishop, D. V. (1992). Verbal recoding of visual stimuli impairs mentalimagetransformations. *Memory & Cognition*, 20(4), 449-455.

Brock, J., Norbury, C., Einav, S., & Nation, K. (2008). Do individuals with autism process words in context? Evidence from language-mediated eye-movements. *Cognition*, 108(3), 896-904.

Brown, J., Aczel, B., Jimenez, L., Kaufman, S. B., & Grant, K. P. (2010). Intact implicit learning in autism spectrum conditions. *The Quarterly Journal of Experimental Psychology*,

63, 1789–1812.

Brown, M. W., & Aggleton, J. P. (2001). Recognition memory: what are the roles of the perirhinal cortex and hippocampus?. *Nature Reviews Neuroscience*, 2(1), 51-61.

Buckner, R. L., & Wheeler, M. E. (2001). The cognitive neuroscience of remembering. *Nature Reviews Neuroscience*, 2(9), 624-634.

Buitelaar, J., van der Wees, M., Swaab-Barneveld, H., & van der Gaag, R. (1999). Verbal memory and performance IQ predict theory of mind and emotion recognition ability in children with autistic spectrum disorders and in psychiatric control children. *Journal of Child Psychology and Psychiatry*, 40, 869–881.

Burack, J. A., Iarocci, G., Flanagan, T. D., & Bowler, D. M. (2004). On mosaics and melting pots: Conceptual considerations of comparison and matching strategies. *Journal of autism and developmental disorders*, 34(1), 65-73.

Cabeza, R., Mangels, J., Nyberg, L., Habib, R., Houle, S., McIntosh, A. R., & Tulving, E. (1997). Brain regions differentially involved in remembering what and when: a PET study. *Neuron*, 19(4), 863-870.

Cantwell, D., Baker, L., & Rutter, M. (1978). Comparative study of infantile autism and specific developmental receptive language disorder 4: Analysis of syntax and language function. *Journal of Child Psychology and Psychiatry*, 19, 351–362.

Carpenter, M., Tomasello, M., & Striano, T. (2005). Role reversal imitation and language in typically developing infants and children with autism. *Infancy*, 8, 253–278.

Carter, A. S., Volkmar, F. R., Sparrow, S. S., Wang, J. J., Lord, C., Dawson, G., & Schopler, E. (1998). The Vineland Adaptive Behavior Scales: supplementary norms for individuals with autism. *Journal of autism and developmental disorders*, 28(4), 287-302.

Cattell, R. B. (1961). Fluid and crystallized intelligence. *Studies in individual differences: The search for intelligence*, 738-746.

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive development*, 15(4), 481-498.

Charman, T., Drew, A., Baird, C., & Baird, G. (2003). Measuring early language development in preschool children with autism spectrum disorder using the MacArthur Communicative Development Inventory (Infant Form). *Journal of Child Language*, 30, 213–236.

- Charman, T., Pickles, A., Simonoff, E., Chandler, S., Loucas, T., & Baird, G. (2011). IQ in children with autism spectrum disorders: data from the Special Needs and Autism Project (SNAP). *Psychological medicine*, *41*(03), 619-627.
- Charman, T., Swettenham, J., Baron-Cohen, S., Cox, A., Baird, G., & Drew, A. (1997). Infants with autism: an investigation of empathy, pretend play, joint attention, and imitation. *Developmental psychology*, *33*(5), 781.
- Chomsky, N. (1965). Aspects of the theory of syntax Cambridge. *Multilingual Matters: MIT Press*.
- Churchill, D. (1972). The relation of infantile autism and early childhood schizophrenia to developmental language disorders of childhood. *Journal of Autism and Childhood Schizophrenia*, *2*, 182-197.
- Cleland, J., Gibbon, F., Peppe, S., O'Hare, A., & Rutherford, M. (2010). Phonetic and phonological errors in children with high functioning autism and Asperger syndrome. *International Journal of Speech and Language Pathology*, *12*, 69-76.
- Condouris, K., Meyer, E., & Tager-Flusberg, H. (2003). The relationship between standardized measures of language and measures of spontaneous speech in children with autism. *American Journal of Speech-Language Pathology*, *12*, 349-358.
- Constantino, J. N., & Gruber, C. P. (2002). The social responsiveness scale. *Los Angeles: Western Psychological Services*.
- Cook, J. L., Blakemore, S. J., & Press, C. (2013). Atypical basic movement kinematics in autism spectrum conditions. *Brain*, *136*(9), 2816-2824.
- Corkin, S. (1984, January). Lasting consequences of bilateral medial temporal lobectomy: Clinical course and experimental findings in HM. In *Seminars in Neurology* (Vol. 4, No. 2, pp. 249-259).
- Corkin, S. (2002). What's new with the amnesic patient HM?. *Nature Reviews Neuroscience*, *3*(2), 153-160.
- Craik, F. I., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of experimental Psychology: general*, *104*(3), 268.
- Crystal, D., (1987). *The Cambridge Encyclopedia of Language*. Cambridge: Cambridge University Press.
- Curtiss, S., Fromkin, V., Krashen, S., Rigler, D., & Rigler, M. (1974). The linguistic development of Genie. *Language*, 528-554.

- Dawson, G., Meltzoff, A., Osterling, J., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. *Journal of Autism and Developmental Disorders*, 28, 479–485.
- Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: social orienting, joint attention, and attention to distress. *Developmental psychology*, 40(2), 271.
- DeLong, G. R. (1978). A neuropsychological interpretation of infantile autism. In M. Rutter & E. Schopler (Eds.), *Autism* (pp. 207–218). New York, NY: Plenum.
- Desmond, J. E., & Fiez, J. A. (1998). Neuroimaging studies of the cerebellum: language, learning and memory. *Trends in cognitive sciences*, 2(9), 355-362.
- Desmond, J. E., Gabrieli, J. D., & Glover, G. H. (1998). Dissociation of frontal and cerebellar activity in a cognitive task: evidence for a distinction between selection and search. *Neuroimage*, 7(4), 368-376.
- Dewey, D., & Wall, K. (1997). Praxis and memory deficits in language- impaired children. *Developmental Neuropsychology*, 13(4), 507-512.
- Dichter, G. S., Felder, J. N., Green, S. R., Rittenberg, A. M., Sasson, N. J., & Bodfish, J. W. (2012). Reward circuitry function in autism spectrum disorders. *Social cognitive and affective neuroscience*, 7(2), 160-172.
- Diehl, J., Bennetto, L., Watson, D., Gunlogson, C., & McDonough, J. (2008). Resolving ambiguity: A psycholinguistic approach to understanding prosody processing in high-functioning autism. *Brain and Language*, 106, 144–152.
- Dobbinson, S.. (2000). *Repetitiveness and productivity in the language of adults with autism*. Unpublished PhD thesis, University of Sheffield, UK.
- Dockrell, J. E., & Marshall, C. R. (In press). Measurement Issues: Assessing language skills in young children. *Child and Adolescent Mental Health*, 20(2), 116-125.
- Dockrell, J., Lindsay, G., Roulstone, S., & Law, J. (2012a). Supporting children with speech, language and communication needs: an overview of the results of the Better Communication Research Programme. *International Journal of Language & Communication Disorders*, 49(5), 543-557.
- Dockrell, J., Ricketts, J., & Lindsay, G. (2012b). Understanding speech, language and communication needs: Profiles of need and provision. *London: Department for Education (DfE)*(available at: <https://www.gov.uk/government/collection/better-communication->

*research-programme*).

Dunn, M., & Bates, J. (2005). Developmental change in neural processing of words by children with autism. *Journal of Autism and Developmental Disorders*, 35, 361–376.

Dunn, L. M., Dunn, L. M., Whetton, C., & Burley, J. (1997). *The British Picture Vocabulary Scale*, 2nd edn (Windsor: NFER-Nelson).

Dunn, M., Gomes, H., & Sebastian, M. (1996). Prototypicality of responses of autistic, language disordered, and normal children in a word fluency task. *Child Neuropsychology*, 2, 99–108.

Eichenbaum, H. (2000). A cortical–hippocampal system for declarative memory. *Nature Reviews Neuroscience*, 1(1), 41-50.

Eichenbaum, H. (2004). Hippocampus: cognitive processes and neural representations that underlie declarative memory. *Neuron*, 44(1), 109-120.

Eichenbaum, H., & Cohen, N. J. (2001). *From conditioning to conscious recollection: Memory systems of the brain*. Oxford University Press.

Eigsti, I. M., de Marchena, A. B., Schuh, J. M., & Kelley, E. (2011). Language acquisition in autism spectrum disorders: A developmental review. *Research in Autism Spectrum Disorders*, 5(2), 681-691.

Eigsti, I.M., & Bennetto, L. (2009). Grammaticality judgments in autism: Deviance or delay? *Journal of Child Language*, 36, 999–1021.

Eigsti, I.M., Bennetto, L., & Dadlani, M.B. (2007). Beyond pragmatics: morphosyntactic development in autism. *Journal of Autism and Developmental Disorders*, 37, 1007–1023.

Farrant, A., Boucher, J., & Blades, M. (1999). Metamemory in children with autism. *Child Development*, 70, 107–131.

Fay, W., & Schuler, A. (1980). *Emerging language in autistic children*. Baltimore: Edward Arnold.

Fink, G. R., Markowitsch, H. J., Reinkemeier, M., Bruckbauer, T., Kessler, J., & Heiss, W. D. (1996). Cerebral representation of one's own past: neural networks involved in autobiographical memory. *The Journal of Neuroscience*, 16(13), 4275-4282.

Fitch, A., Fein, D. A., & Eigsti, I. M. (2015). Detail and Gestalt Focus in Individuals with Optimal Outcomes from Autism Spectrum Disorders. *Journal of autism and developmental disorders*, 45(6), 1887-1896.

- Fournier, K. A., Hass, C. J., Naik, S. K., Lodha, N., & Cauraugh, J. H. (2010). Motor coordination in autism spectrum disorders: a synthesis and meta-analysis. *Journal of autism and developmental disorders*, 40(10), 1227-1240.
- Franklin, S. (2005, March). Perceptual memory and learning: Recognizing, categorizing, and relating. In *Proc. Developmental Robotics AAAI Spring Symp.*
- Friston, K. J., Lawson, R., & Frith, C. D. (2013). On hyperpriors and hypopriors: comment on Pellicano and Burr. *Trends Cogn. Sci*, 17(1), 10-1016.
- Frith, U. (1970). Studies in pattern detection in normal and autistic children: I. Immediate recall of auditory sequences. *Journal of abnormal psychology*, 76(3 pt 1), 413-20.
- Frith, U. (1970). Studies in pattern detection in normal and autistic children. *Journal of Abnormal Psychology*, 76, 413–420.
- Frith, U. (1989). A new look at language and communication in autism. *International Journal of Language & Communication Disorders*, 24(2), 123-150.
- Frith, U. (1989). Autism: Explaining the enigma.
- Frith, U., & Happe´, F. (1994). Language and communication in autistic spectrum disorders. *Philosophical Transactions of the Royal Society of London B.*, 346, 97–104.
- Fyffe, C., & Prior, M. (1978). Evidence for language recoding in autistic, retarded and normal children: A re-examination. *British Journal of Psychology*, 69, 393–402.
- Fyffe, C., & Prior, M. (1978). Evidence for language recoding in autistic, retarded and normal children: A re- examination. *British Journal of Psychology*, 69(3), 393-402.
- Gaigg, S. B. (2012). The interplay between emotion and cognition in autism spectrum disorder: implications for developmental theory. *Frontiers in integrative neuroscience*, 6.
- Gaigg, S. B., & Bowler, D. M. (2007). Differential fear conditioning in Asperger’s syndrome: Implications for an amygdala theory of autism. *Neuropsychologia*, 45, 2125–2134.
- Gaigg, S. B., & Bowler, D. M. (2013). Relational memory difficulties in Autism Spectrum Disorder: Implications for education. *BJEP Monograph Series II, Number 9-Psychology and antisocial behaviour in school*, 1(1), 34-52.
- Gaigg, S. B., Bowler, D. M., Ecker, C., Calvo- Merino, B., & Murphy, D. G. (2015). Episodic Recollection Difficulties in ASD Result from Atypical Relational Encoding: Behavioral and Neural Evidence. *Autism Research*.



Gaigg, S. B., Gardiner, J. M., & Bowler, D. M. (2008). Free recall in autism spectrum disorder: The role of relational and item-specific encoding. *Neuropsychologia*, *46*, 986–992.

Gardiner, J. M., Bowler, D. M., & Grice, S. (2003). Perceptual and conceptual priming in autism: An extension and replication. *Journal of Autism and Developmental Disorders*, *33*, 259–269.

Gernsbacher, M.A., Sazuer, E., Geye, H., Schweigert, E., & Goldsmith, H.H. (2008). Infant and toddler oral- and manual-motor skills predict later speech fluency in autism. *Journal of Child Psychology and Psychiatry*, *49*, 43–50.

Geurts, H., & Embrechts, M. (2008). Language profiles in ASD, SLI, and ADHD. *Journal of Autism and Developmental Disorders*, *38*, 1931–1943.

Goldberg, A. D., Allis, C. D., & Bernstein, E. (2007). Epigenetics: a landscape takes shape. *Cell*, *128*(4), 635–638.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *11*(3), 501.

Grzadzinski R, Huerta, M, & Lord, C. (2013) DSM-5 and autism spectrum disorders (ASDs): an opportunity for identifying ASD subtypes. *Mol Autism*, 4:12.

Gujarati, D., (2004) "Multicollinearity: what happens if the regressors are correlated?" *Basic Econometrics*, (4th ed.). McGraw–Hill. Pp. 363–363

Happé, F. G. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of autism and Developmental disorders*, *24*(2), 129–154.

Happé, F. (1999). Autism: cognitive deficit or cognitive style?. *Trends in cognitive sciences*, *3*(6), 216–222.

Happé, F., & Frith, U. (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *36*, 5–23.

Happé, F., Ronald, A., & Plomin, R. (2006). Time to give up on a single explanation for autism. *Nature neuroscience*, *9*(10), 1218–1220.

Hare, D. J., Mellor, C., & Azmi, S. (2007). Episodic memory in adults with autistic spectrum disorders: Recall for self- versus other-experienced events. *Research in Developmental*

*Disabilities*, 28, 317–329.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of experimental psychology: General*, 108(3), 356.

Hauck, M., Fein, D., Maltby, N., Waterhouse, L., & Feinstein, C. (1998). Memory for faces in children with autism. *Child Neuropsychology*, 4, 187–198.

Hauser, S., DeLong, G. R., & Rosman, N. (1975). Pneumographic findings in the infantile autism syndrome. *Brain*, 98, 667–688.

Hayes, B. K., & Taplin, J. E. (1993a). Development of conceptual knowledge in children with mental retardation. *American Journal on Mental Retardation*.

Hayes, B. K., & Taplin, J. E. (1993b). Developmental differences in the use of prototype and exemplar-specific information. *Journal of Experimental Child Psychology*, 55(3), 329–352.

Henderson, H. A., Zahka, N. E., Kojkowski, N. M., Inge, A. P., Schwartz, C. B., Hileman, C. M., ... & Mundy, P. C. (2009). Self-referenced memory, social cognition, and symptom presentation in autism. *Journal of Child Psychology and Psychiatry*, 50(7), 853–861.

Hermelin, B., & O'Connor, N. (1967). Remembering of words by psychotic and subnormal children. *British Journal of Psychology*, 58, 213–218.

Hermelin, B., & O'Connor, N. (1970). *Psychological experiments with autistic children*. Oxford: Plenum Press.

Hill, E., & Russell, J. (2002). Action memory and self-monitoring. *Infant and Child Development*, 11, 159–170.

Hillier, A., Campbell, H., Keillor, J., Phillips, N., & Beversdorf, D. Q. (2007). Decreased false memory for visually presented shapes and symbols among adults on the autism spectrum. *Journal of Clinical and Experimental Neuropsychology*, 29, 610 – 616.

Hobson, R.P. (1993). *Autism and the development of mind*. Hove: Lawrence Erlbaum Associates.

Hobson, R.P., & Lee, A. (1989). Emotion-related and abstract concepts in autistic people: Evidence from the British Picture Vocabulary Scale 1. *Journal of Autism and Developmental Disorders*, 19, 601–623.

Hobson, R. P., & Lee, A. (1999). Imitation and identification in autism. *Journal of Child Psychology and Psychiatry*, 40(04), 649–659.

- Hobson, R.P., García-Pérez, R., & Lee, A. (2010). Personcentred (deictic) expressions in autism. *Journal of Autism and Developmental Disorders*, *40*, 403–415.
- Holdstock, J. S., Mayes, A. R., Gong, Q. Y., Roberts, N., & Kapur, N. (2005). Item recognition is less impaired than recall and associative recognition in a patient with selective hippocampal damage. *Hippocampus*, *15*(2), 203-215.
- Holdstock, J. S., Mayes, A. R., Roberts, N., Cezayirli, E., Isaac, C. L., O'reilly, R. C., & Norman, K. A. (2002). Under what conditions is recognition spared relative to recall after selective hippocampal damage in humans?. *Hippocampus*, *12*(3), 341-351.
- Holt, R., & Monaco, A. P. (2011). Links between genetics and pathophysiology in the autism spectrum disorders. *EMBO molecular medicine*, *3*(8), 438-450.
- Howard, D. V., & Howard Jr, J. H. (2012). Dissociable forms of implicit learning in aging. *Memory and Aging: Current Issues and Future Directions*, 125-151.
- Howard, D., & Patterson, K. E. (1992). *The Pyramids and Palm Trees Test: A test of semantic access from words and pictures*. Thames Valley Test Company.
- Howlin, P. (2003). Outcome in high-functioning adults with autism with and without early language delays: Implications for the differentiation between autism and Asperger syndrome. *Journal of Autism and Developmental Disorders*, *33*, 3–13
- Hudry, K., Leadbitter, K., Temple, K., Slonims, V., McConachie, H., Aldred, C., Howlin, P., & Charman, T. (2010). Preschoolers with autism show greater impairment in receptive compared with expressive language abilities. *International Journal of Language and Communication Disorders*, *45*, 681–690.
- Hunt, R. R., & Einstein, G. O. (1981). Relational and item-specific information in memory. *Journal of Verbal Learning and Verbal Behavior*, *20*(5), 497-514.
- Hunt, R. R., & Seta, C. E. (1984). Category size effects in recall: The roles of relational and individual item information. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *10*(3), 454.
- Ivry, R. B., & Fiez, J. A. (2000). Cerebellar contributions to cognition and imagery. *The new cognitive neurosciences*, *2*, 999-1011.
- Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of memory and language*, *30*(5), 513-541.
- Jarrold, C., Boucher, J., & Russell, J. (1997). Language Profiles in Children with Autism Theoretical and Methodological Implications. *Autism*, *1*(1), 57-76.

- Jarrold, C., Gilchrist, I. D., & Bender, A. (2005). Embedded figures detection in autism and typical development: Preliminary evidence of a double dissociation in relationships with visual search. *Developmental science*, 8(4), 344-351.
- Järvinen- Pasley, A., Wallace, G. L., Ramus, F., Happé, F., & Heaton, P. (2008). Enhanced perceptual processing of speech in autism. *Developmental science*, 11(1), 109-121.
- Jonides, J., Lewis, R. L., Nee, D. E., Lustig, C. A., Berman, M. G., & Moore, K. S. (2008). The mind and brain of short-term memory. *Annual review of psychology*, 59, 193.
- Joseph, R. M., Keehn, B., Connolly, C., Wolfe, J. M., & Horowitz, T. S. (2009). Why is visual search superior in autism spectrum disorder?. *Developmental science*, 12(6), 1083-1096.
- Joseph, R., Steele, S., Meyer, E., & Tager-Flusberg, H. (2005). Self- ordered pointing in children with autism: Failure to use verbal mediation in the service of working memory? *Neuropsychologia*, 43, 1400–1411.
- Kamio, Y., & Toichi, M. (2007). Memory illusion in high-functioning autism and Asperger's disorder. *Journal of Autism and Developmental Disorders*, 37, 867–876.
- Kanner, L. (1946). Irrelevant and metaphorical language in early infantile autism. *Journal of Pediatrics*, 25, 211–217.
- Karp, S. A., & Konstadt, N. L. (1963). Manual for the Children's Embedded Figures Test.
- Kelley, E., Paul, J., Fein, D., & Naigles, L. (2006). Residual language deficits in optimal outcome children with a history of autism. *Journal of Autism and Developmental Disorders*, 36, 807–828.
- Kjelgaard, M.M., & Tager-Flusberg, H. (2001). An investigation of language impairment in autism: Implications for genetic subgroups. *Language and Cognitive Processes*, 16, 287–308.
- Klin, A. (1991). Young autistic children's listening preferences in regard to speech: A possible characterization of the symptom of social withdrawal. *Journal of Autism and Developmental Disorders*, 21, 29–42.
- Klin, A., Sparrow, S., de Bildt, A., Cicchetti, D. V., Cohen, D., & Volkmar, F. (1999). A normed study of face recognition in autism and related disorders. *Journal of Autism and Developmental Disorders*, 29, 499– 508.
- Kraijer, D. (2000). Review of adaptive behavior studies in mentally retarded persons with

autism/pervasive developmental disorder. *Journal of Autism and Developmental Disorders*, 30, 39 – 47.

Kuhl, P. (2004). Early language acquisition: Cracking the speech code. *Nature Reviews Neuroscience*, 5, 831–843.

Kuhl, P., Coffey-Corina, S., Padden, D., & Dawson, G. (2005). Links between social and linguistic processing of speech in preschool children with autism: Behavioural and electrophysiological measures. *Developmental Science*, 8, F9–F20.

Leonard, L.B. (2000). *Children with specific language impairment*. Cambridge, MA: MIT Press.

Lepistö, T., Kajander, M., Vanhala, R., Alku, P., Huotilainen, M., Näätänen, R., & Kujala, T. (2008). The perception of invariant speech features in children with autism. *Biological psychology*, 77(1), 25-31.

Lezak, M. D., Howieson, D. B., Bigler, E. D., & Tranel, D. *Neuropsychological Assessment*. 2012.

Lind, S. (2008). Episodic memory, theory of mind, and temporally extended self-awareness in autism spectrum disorder. Unpublished doctoral thesis, Department of Psychology, City University, London, England.

Lind, S. (2010). Memory and the self in autism spectrum disorder: A review and theoretical framework. *Autism*, 14, 430 – 456.

Lombardo, M. V., Barnes, J. L., Wheelwright, S. J., & Baron-Cohen, S. (2007). Self-referential cognition and empathy in autism. *PLoS ONE*, 2, e883.

Loukusa, S., & Moilanen, I. (2009). Pragmatic inference abilities in individuals with Asperger syndrome or high-functioning autism. A review. *Research in Autism Spectrum Disorders*, 3(4), 890-904.

Lord, C., & Paul, R.. (1997). Language and communication in autism. In D. Cohen, & F. Volkmar (Eds.), *Handbook of autism and pervasive developmental disorders*, 1st edn (pp. 195–225). New York: Wiley & Sons

Loucas, T., Charman, T., Pickles, A., Simonoff, E., Chandler, S., Meldrum, D., & Baird, G. (2008). Autistic symptomatology and language ability in autism spectrum disorder and specific language impairment. *Journal of Child Psychology and Psychiatry*, 49, 1184–1192.

Loucas, T., Riches, N., Baird, G., Pickles, A., Simonoff, E., Chandler, S., & Charman, T. (2013). Spoken word recognition in adolescents with autism spectrum disorders and specific

language impairment. *Applied Psycholinguistics*, 34(02), 301-322.

Lum, J. A., & Conti-Ramsden, G. (2013). Long-term memory: A review and meta-analysis of studies of declarative and procedural memory in Specific Language Impairment. *Topics in language disorders*, 33(4), 282.

Luyster, R., Lopez, K., & Lord, C. (2007). Characterising communicative development in children referred for autism spectrum disorders using the MacArthur-Bates Communicative Development Inventory (CDI). *Journal of Child Language*, 34, 623–654.

MacNeil, L. K., & Mostofsky, S. H. (2012). Specificity of dyspraxia in children with autism. *Neuropsychology*, 26(2), 165.

Maister, L., Simons, J. S., & Plaisted-Grant, K. (2013). Executive functions are employed to process episodic and relational memories in children with autism spectrum disorders. *Neuropsychology*, 27(6), 615.

Mandler, G. (2008). Familiarity breeds attempts: A critical review of dual-process theories of recognition. *Perspectives on Psychological Science*, 3(5), 390-399.

Manolitsi, M., & Botting, N. (2011). Language abilities in children with autism and language impairment: using narrative as a additional source of clinical information. *Child Language Teaching and Therapy*, 27(1), 39-55.

Maras, K. L., & Bowler, D. M. (2010). The cognitive interview for eyewitnesses with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 40(11), 1350-1360.

Mayes, A. R., Montaldi, D., Spencer, T. J., & Roberts, N. (2004). Recalling spatial information as a component of recently and remotely acquired episodic or semantic memories: an fMRI study. *Neuropsychology*, 18(3), 426.

Mayes, A., Montaldi, D., & Migo, E. (2007). Associative memory and the medial temporal lobes. *Trends in cognitive sciences*, 11(3), 126-135.

Mayes, S.D., & Calhoun, S. (2001). Non-significance of early speech delay in children with autism and normal language and implications for DSM-IV Asperger disorder. *Autism*, 5, 81–94.

McCrorry, E., Henry, L., & Happé, F. (2007). Eye-witness memory and suggestibility in children with Asperger syndrome. *Journal of Child Psychology and Psychiatry*, 48, 482–489.

McDonald, R. J., & White, N. M. (1993). A triple dissociation of memory systems: hippocampus, amygdala, and dorsal striatum. *Behavioral neuroscience*, 107(1), 3.

- McLennan, D., Barnes, H., Noble, M., Davies, J., Garratt, E., & Dibben, C. (2011). The English indices of deprivation 2010. *London: Department for Communities and Local Government.*
- McLeod, P. (1977). A dual task response modality effect: Support for multiprocessor models of attention. *The Quarterly Journal of Experimental Psychology*, 29(4), 651-667.
- Migo, E. M., Mayes, A. R., & Montaldi, D. (2012). Measuring recollection and familiarity: Improving the remember/know procedure. *Consciousness and cognition*, 21(3), 1435-1455.
- Migo, E. M., Montaldi, D., & Mayes, A. R. (2013). A visual object stimulus database with standardized similarity information. *Behavior research methods*, 45(2), 344-354.
- Migo, E., Montaldi, D., Norman, K. A., Quamme, J., & Mayes, A. (2009). The contribution of familiarity to recognition memory is a function of test format when using similar foils. *The Quarterly Journal of Experimental Psychology*, 62(6), 1198-1215.
- Migo, E., Montaldi, D., Norman, K. A., Quamme, J., & Mayes, A. (2009). The contribution of familiarity to recognition memory is a function of test format when using similar foils. *The Quarterly Journal of Experimental Psychology*, 62(6), 1198-1215.
- Miller, G. A. (1956). Human memory and the storage of information. *Information Theory, IRE Transactions on*, 2(3), 129-137.
- Miller, L. K. (1999). The savant syndrome: Intellectual impairment and exceptional skill. *Psychological Bulletin*, 125, 31-46.
- Millward, C., Powell, S., Messer, D., & Jordan, R. (2000). Recall for self and other in autism: Children's memory for events experienced by themselves and their peers. *Journal of Autism and Developmental Disorders*, 30, 15-28.
- Minshew, N., & Goldstein, G. (2001). The pattern of intact and impaired memory functions in autism. *Journal of Child Psychology and Psychiatry*, 42, 1095-1101.
- Minshew, N., & Goldstein, G., (1993) Is autism an amnesic disorder? Evidence from the California Verbal Learning Test. *Neuropsychology*, 7, 209-216.
- Minshew, N., Goldstein, G., Muenz, L. R., & Payton, J. (1992). Neuro- psychological functioning in nonmentally retarded autistic individuals. *Journal of Clinical and Experimental Neuropsychology*, 14, 749-761.
- Mishkin, M., Malamut, B., & Bachevalier, J. (1984). Memories and habits: Two neural systems. *Neurobiology of learning and memory*, 65-77.

- Mitchell, J. A., & Hall, G. (1988). Caudate-putamen lesions in the rat may impair or potentiate maze learning depending upon availability of stimulus cues and relevance of response cues. *The Quarterly Journal of Experimental Psychology*, *40*(3), 243-258.
- Molesworth, C., Bowler, D., & Hampton, J. (2005). The prototype effect in recognition memory: Intact in autism? *Journal of Child Psychology and Psychiatry*, *46*, 661–672.
- Molinari, M., Leggio, M. G., Solida, A., Ciorra, R., Misciagna, S., Silveri, M. C., & Petrosini, L. (1997). Cerebellum and procedural learning: evidence from focal cerebellar lesions. *Brain*, *120*(10), 1753-1762.
- Montaldi, D., & Mayes, A. R. (2010). The role of recollection and familiarity in the functional differentiation of the medial temporal lobes. *Hippocampus*, *20*, 1291–1314.
- Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of verbal learning and verbal behavior*, *16*(5), 519-533.
- Mottron, L., & Burack, J. (2006). Editorial preface. *Journal of Autism and Developmental Disorders*, *36*, 1–3.
- Mottron, L., & Burack, J. A. (2001). Enhanced perceptual functioning in the development of autism.
- Mottron, L., Morasse, K., & Belleville, S. (2001). A study of memory functioning in individuals with autism. *Journal of Child Psychology and Psychiatry*, *42*, 253–260.
- Moyle, M., & Long, S. (2013). Index of Productive Syntax (IPSyn). In *Encyclopedia of Autism Spectrum Disorders* (pp. 1566-1568). Springer New York.
- Nemeth, D., Janacsek, K., Balogh, V., Londe, Z., Mingesz, R., Fazekas, M., Vetro, A. (2010). Learning in autism: Implicitly superb. *PLoS ONE*, *5*, e11731.
- Norbury, C. F. (2005). The relationship between theory of mind and metaphor: Evidence from children with language impairment and autistic spectrum disorder. *British Journal of Developmental Psychology*, *23*(3), 383-399.
- Norman, K. A., & O'Reilly, R. C. (2003). Modeling hippocampal and neocortical contributions to recognition memory: a complementary-learning-systems approach. *Psychological review*, *110*(4), 611.
- Nyberg, L., Tulving, E., Habib, R., Nilsson, L. G., Kapur, S., Houle, S. & McIntosh, A. R. (1995). Functional brain maps of retrieval mode and recovery of episodic information. *NeuroReport*, *7*(1), 249-252.



- Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry*, 32(7), 1081-1105.
- Packard, M. G. (1999). Glutamate infused posttraining into the hippocampus or caudate-putamen differentially strengthens place and response learning. *Proceedings of the National Academy of Sciences*, 96(22), 12881-12886.
- Parish-Morris, J., Hennon, E.A., Hirsch-Pasek, K., Golinkoff, R.M., & Tager-Flusberg, H. (2007). Children with autism illuminate the role of social intention in word learning. *Child Development*, 78, 1265–1287.
- Park, C. J., Yelland, G. W., Taffe, J. R., & Gray, K. M. (2012). Brief report: The relationship between language skills, adaptive behavior, and emotional and behavior problems in pre-schoolers with autism. *Journal of autism and developmental disorders*, 42(12), 2761-2766.
- Parkin, A. J., Yeomans, J., & Bindschaedler, C. (1994). Further characterization of the executive memory impairment following frontal lobe lesions. *Brain and Cognition*, 26(1), 23-42.
- Pellicano, E., & Burr, D. (2012). When the world becomes ‘too real’: a Bayesian explanation of autistic perception. *Trends in cognitive sciences*, 16(10), 504-510.
- Pellicano, E., Smith, A. D., Cristino, F., Hood, B. M., Briscoe, J., & Gilchrist, I. D. (2011). Children with autism are neither systematic nor optimal foragers. *Proceedings of the National Academy of Sciences*, 108(1), 421-426.
- Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of child psychology and psychiatry*, 37(1), 51-87.
- Perkins, M., Dobbins, S., Boucher, J., Bol, S., & Bloom, P. (2006). Lexical knowledge and lexical use in autism. *Journal of Autism and Developmental Disorders*, 36, 795–805.
- Peterson, L., & Peterson, M. J. (1959). Short-term retention of individual verbal items. *Journal of experimental psychology*, 58(3), 193.
- Pierce, S., & Bartolucci, G. (1977). A syntactic investigation of verbal autistic, mentally retarded, and normal children. *Journal of Autism and Childhood Schizophrenia*, 7(2), 121-134.
- Pinker, S. (1994). How could a child use verb syntax to learn verb semantics?. *Lingua*, 92, 377-410.

Pinker, S. (1999). How the mind works. *Annals of the New York Academy of Sciences*, 882(1), 119-127.

Pinker, S., & Ullman, M. T. (2002). The past and future of the past tense. *Trends in cognitive sciences*, 6(11), 456-463.

Plaisted, K. (2001). Reduced generalisation in autism: An alternative to weak central coherence. In J. Burack, A. Charman, N. Yirmiya, & P.R. Zelazo (Eds.). *Development and autism: Perspectives from theory and research* (pp. 149–169). Lawrence Erlbaum Associates: Mahwah, NJ.

Plaisted, K. C. (2001). Reduced generalization in autism: An alternative to weak central coherence.

Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. *Journal of Child Psychology and Psychiatry*, 39(5), 765-775.

Poldrack, R. A., & Packard, M. G. (2003). Competition among multiple memory systems: converging evidence from animal and human brain studies. *Neuropsychologia*, 41(3), 245-251.

Poldrack, R. A., Clark, J., Pare-Blagoev, E. J., Shohamy, D., Moyano, J. C., Myers, C., & Gluck, M. A. (2001). Interactive memory systems in the human brain. *Nature*, 414(6863), 546-550.

Poldrack, R. A., Prabhakaran, V., Seger, C. A., & Gabrieli, J. D. (1999). Striatal activation during acquisition of a cognitive skill. *Neuropsychology*, 13(4), 564.

Pring, L. (2008). Memory characteristics in individuals with savant skills. In J. gto & D. M. Bowler (Eds.), *Memory in autism* (pp. 210 –230). Cambridge. England: Cambridge University Press.

Prior, M. R., & Hall, L. C. (1979). Comprehension of transitive and intransitive phrases by autistic, retarded, and normal children. *Journal of Communication Disorders*, 12(2), 103-111.

Prizant, B. M. (1983). Language Acquisition and Communicative Behavior in Autism Toward an Understanding of the Whole of It. *Journal of speech and hearing disorders*, 48(3), 296-307.

Prizant, B., & Duchan, J. (1981). The functions of immediate echolalia in autism children. *Journal of Speech and Hearing Disorder*, 46, 241–249.

Quinn, J. G. (2008). Movement and visual coding: The structure of visuo-spatial working

memory. *Cognitive Processing*, 9(1), 35-43.

Rajendran, G., & Mitchell, P. (2007). Cognitive theories of autism. *Developmental Review*, 27(2), 224-260.

Rapin, I. (1991). Autistic children: Diagnosis and clinical features. *Pediatrics*, 87(5), 751-760.

Rapin, I. (1996). Practitioner review: Developmental language disorders: A clinical update. *Journal of Child Psychology and Psychiatry*, 37(6), 643-655.

Rapin, I., & Allen, D. (1983). Developmental language disorders: Nosologic considerations. *Neuropsychology of language, reading, and spelling*, 155-184.

Rapin, I., & Dunn, M. (2003). Update on the language disorders of individuals on the autistic spectrum. *Brain and Development*, 25, 166-172.

Rapin, I., Dunn, M., Allen, D., Stevens, M., & Fein, D. (2009). Subtypes of language disorders in school-age children with autism. *Developmental Neuropsychology*, 34, 66-84.

Raven, J. C. (1976). Raven's coloured progressive matrices. *Karami A. Tehran: Ravansanji*, 1388.

Redman, S., Downie, M., Rennison, R. and Batten, A. (2009). Don't Write Me Off: Make the System Fair for People with Autism, London: *National Autistic Society*. 14.

Renner, P., Klinger, L., & Klinger, M. (2000). Implicit and explicit memory in autism: Is autism an amnesic disorder? *Journal of Autism and Developmental Disorders*, 30, 3-14.

Richardson, J. T. E., & Baddeley, A. D. (1975). The effect of articulatory suppression in free recall. *Journal of Verbal Learning and Verbal Behavior*, 14(6), 623-629.

Riches, N. G., Loucas, T., Baird, G., Charman, T., & Simonoff, E. (2012). Interpretation of compound nouns by adolescents with specific language impairment and autism spectrum disorders: An investigation of phenotypic overlap. *International journal of speech-language pathology*, 14(4), 307-317.

Riches, N., Loucas, T., Baird, G., Charman, T., & Simonoff, E. (2010). Sentence repetition in adolescents with specific language impairments and autism: An investigation of complex syntax. *International Journal of Language and Communication Disorders*, 45, 47-60.

Rimland, B. (1964). *Infantile autism*. New York, NY: Appleton-Century-Crofts.

Ring, M., Gaigg, S. B., & Bowler, D. M. (2015). Object- location memory in adults with autism spectrum disorder. *Autism Research*.

Roberts, J.A., Rice, M.L., & Tager-Flusberg, H. (2004). Tense marking in children with autism. *Applied Psycholinguistics*, 29, 429–448.

Robinson, R. J. (1991). Causes and associations of severe and persistent specific speech and language disorders in children. *Developmental Medicine & Child Neurology*, 33(11), 943-962.

Romero-Munguía, M. (2008). Mnestic imbalance: A cognitive theory about autistic spectrum disorders. *Annals of General Psychiatry*, 7, 20–27.

Rosenblatt, M. (2008) 'I exist. The message from adults with autism in England' London: *National Autistic Society*.

Rosenhall, U., Nordin, V., Sandström, M., Ahlsen, G., & Gillberg, C. (1999). Autism and hearing loss. *Journal of autism and developmental disorders*, 29(5), 349-357.

Ruble, L., McDuffie, A., King, A. S., & Lorenz, D. (2008). Caregiver responsiveness and social interaction behaviors of young children with autism. *Topics in Early Childhood Special Education*.

Russell, J., & Jarrold, C. (1999). Memory for actions in children with autism: Self versus other. *Cognitive Neuropsychiatry*, 4(4), 303-331.

Rutter, M. (1981). Stress, Coping and Development: Some Issues and Some Questions. *Journal of Child Psychology and Psychiatry*, 22(4), 323-356.

Rutter, M. (1998). Developmental catch-up, and deficit, following adoption after severe global early privation. *Journal of Child Psychology and Psychiatry*, 39(04), 465-476.

Rutter, M. (1999). Resilience concepts and findings: implications for family therapy. *Journal of family therapy*, 21(2), 119-144.

Rutter, M., Bailey, A., & Lord, C. (2003). *The social communication questionnaire: Manual*. Western Psychological Services.

Rutter, M., Bartak, L., & Newman, S. (1971). Autism – a central disorder of cognition and language? In M. Rutter (Ed.), *Infantile autism: Concepts, characteristics, and treatment* (pp. 148–171). London: Churchill Livingstone.

Saalasti, S., Lepistö, T., Toppila, E., Kujala, T., Laakso, M., Nieminen-von Wendt, T., ... & Jansson-Verkasalo, E. (2008). Language abilities of children with Asperger syndrome.

*Journal of Autism and Developmental Disorders*, 38(8), 1574-1580.

Salmond, C., Ashburner, J., Connelly, A., Friston, K., Gadian, D., & Vargha-Khadem, F. (2005). The role of the medial temporal lobe in autistic spectrum disorders. *The European Journal of Neuroscience*, 22, 764–772.

Sameroff, A. J., & Chandler, M. J. (1975). Reproductive risk and the continuum of caretaking casualty. *Review of child development research*, 4, 187-244.

Scarborough, H. (1990). Index of Productive Syntax. *Applied Psycholinguistics*, 11, 1–22.

Schacter, D. L., Alpert, N. M., Savage, C. R., Rauch, S. L., & Albert, M. S. (1996). Conscious recollection and the human hippocampal formation: evidence from positron emission tomography. *Proceedings of the National Academy of Sciences*, 93(1), 321-325.

Schacter, D., & Tulving, E. (1994). What are the memory systems of 1994? In D. Schacter & E. Tulving (Eds.), *Memory systems 1994* (pp. 1–38). Cambridge, MA: MIT Press.

Schroeder, J. P., Wingard, J. C., & Packard, M. G. (2002). Post- training reversible inactivation of hippocampus reveals interference between memory systems. *Hippocampus*, 12(2), 280-284.

Sears, L. L., Finn, P., & Steinmetz, J. (1994). Abnormal classical eye-blink conditioning in autism. *Journal of Autism and Developmental Disorders*, 24, 737–751.

Semel, E. M., Wiig, E. H., & Secord, W. (1996). *CELF 3, Clinical Evaluation of Language Fundamentals: Observational Rating Scales*. Psychological Corporation.

Semel, E., Wiig, E. H., & Secord, W. A. *Clinical Evaluation of Language Fundamentals (CELF-4)*, (2003). Toronto, Canada: The Psychological Corporation/A Harcourt Assessment Company.

Shriberg, L., Paul, R., McSweeny, J., Klin, A., & Cohen, D. (2001). Speech and prosody characteristics of adolescents and adults with high-functioning autism and Asperger syndrome. *Journal of Speech, Language, and Hearing Research*, 44, 1097–1115.

Shulman, C., & Guberman, A. (2007). Acquisition of verb meaning through syntactic cues: A comparison of children with autism, children with specific language impairment, and children with normal language development. *Journal of Child Language*, 34, 411–423.

Siegel, D., Minshew, N., & Goldstein, G. (1996). Wechsler IQ profiles in diagnosis of high-functioning autism. *Journal of Autism and Developmental Disorders*, 26, 389–406.

Sigman, M.D., Kasari, C., Kwon, J., & Yirmiya, N. (1992). Responses to the negative

emotions of others by autistic, mentally retarded, and normal children. *Child Development*, 63, 796–807.

Siller, M., & Sigman, M. (2002). The behaviors of parents of children with autism predict the subsequent development of their children's communication. *Journal of autism and developmental disorders*, 32(2), 77-89.

Siller, M., & Sigman, M. (2008). Modeling longitudinal change in the language abilities of children with autism: Parent behaviors and child characteristics as predictors of change. *Developmental Psychology*, 44, 1691–1704.

Smith, B., Gardiner, J., & Bowler, D. M. (2007). Deficits in free recall persist in Asperger syndrome despite training in the use of list- appropriate learning strategies. *Journal of Autism and Developmental Disorders*, 37, 445–454.

Soulières, I., Mottron, L., Giguère, G., & Larochelle, S. (2011). Category induction in autism: Slower, perhaps different, but perfectly possible. *The Quarterly Journal of Experimental Psychology*, 64, 311–327.

Soulières, I., Zeffiro, T. A., Girard, M. L., & Mottron, L. (2011). Enhanced mental image mapping in autism. *Neuropsychologia*, 49(5), 848-857.

South, M., Larson, M. J., White, S. E., Dana, J., & Crowley, M. J. (2011). Better fear conditioning is associated with reduced symptom severity in autism spectrum disorders. *Autism Research*, 4(6), 412-421.

Sperber, D., & Wilson, D. (2002). Pragmatics, modularity and mind- reading. *Mind & Language*, 17(1- 2), 3-23.

Squire, L. R., & Knowlton, B. J. (1995). Memory, hippocampus, and brain systems.

Squire, L. R., & Knowlton, B. J. (2000). The medial temporal lobe, the hippocampus, and the memory systems of the brain. *The new cognitive neurosciences*, 2, 756-776.

Squire, L. R., Wixted, J., & Clark, R. (2007). Recognition memory and the medial temporal lobe: A new perspective. *Nature Reviews Neuroscience*, 8, 872–883.

Stevens, M., Fein, D., Dunn, M., Allen, D., Waterhouse, L., Feinstein, C., & Rapin, I. (2000). Subgroups of children with autism by cluster analysis: A longitudinal examination. *Journal of the American Academy of Child and Adolescent Psychiatry*, 39, 346–352.

Stockbridge, M. D., Happé, F. G., & White, S. J. (2014). Impaired comprehension of alternating syntactic constructions in autism. *Autism Research*, 7(3), 314-321. *spelling*, (pp. 155–184). New York: Academic Press.

- Strathearn, L. (2009). The elusive etiology of autism: nature and nurture?. *Frontiers in behavioral neuroscience*, 3.
- Summers, J., & Craik, F. (1994). The effect of subject-performed tasks on the memory performance of verbal autistic children. *Journal of Autism and Developmental Disorders*, 24, 773–783.
- Sun, X., Allison, C., Auyeung, B., Matthews, F. E., Zhang, Z., Baron-Cohen, S., & Brayne, C. (2014). Comparison between a mandarin Chinese version of the childhood autism spectrum test and the Clancy autism behaviour scale in mainland China. *Research in developmental disabilities*, 35(7), 1599-1608.
- Surian, L., Baron-Cohen, S., & Van der Lely, H. (1996). Are children with autism deaf to Gricean maxims? *Cognitive Neuropsychiatry*, 1, 55–71.
- Szatmari, P. (2011). New recommendations on autism spectrum disorder. *BMJ*, 342.
- Tager-Flusberg, H. (1981). Sentence comprehension in autistic children. *Applied Psycholinguistics*, 2, 5–24.
- Tager-Flusberg, H. (1991). Semantic processing in the free recall of autistic children: Further evidence of a cognitive deficit. *British Journal of Developmental Psychology*, 9, 417– 430.
- Tager-Flusberg, H. (1991). Semantic processing in the free recall of autistic children: Further evidence of a cognitive deficit. In G. Dawson (Ed.), *Autism: Nature, diagnosis, and treatment*. (pp. 92–109). New York, NY: Guilford Press.
- Tager-Flusberg, H. (2006). Defining language phenotypes in autism. *Clinical Neuroscience Research*, 6(3), 219-224.
- Tager-Flusberg, H., Calkins, S., Nolin, T., Baumberger, T., Anderson, M., & Chadwick-Dias, A. (1990). A longitudinal study of language acquisition in autistic and Down syndrome children. *Journal of Autism and Developmental Disorders*, 20, 1–2
- Tager-Flusberg, H.. (2000). Language and understanding other minds: Connections in autism. In S. Baron-Cohen, H. TagerFlusberg, & D. Cohen (Eds.), *Understanding other minds*, 2nd edn (pp. 124–149). Oxford: OUP.
- Tek, S., Mesite, L., Fein, D., & Naigles, L. (2014). Longitudinal analyses of expressive language development reveal two distinct language profiles among young children with autism spectrum disorders. *Journal of autism and developmental disorders*, 44(1), 75-89.
- Thompson-Schill, S. L., D’Esposito, M., Aguirre, G. K., & Farah, M. J. (1997). Role of left

inferior prefrontal cortex in retrieval of semantic knowledge: A reevaluation. *Proceedings of the National Academy of Sciences*, 94(26), 14792-14797.

Thorndike, E. L. (1914). Communications and discussion. Repetition versus recall in memorizing vocabularies; The effect of continuous exercise and of rest upon difficult mental multiplication. *Journal of Educational Psychology*, 5(10), 596.

Thurm, A., Lord, C., Li-Ching Lee, A., & Newschaffer, C. (2007). Predictors of language acquisition in preschool children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 37, 1721–1734.

Toal, F., Murphy, D., & Murphy, K. (2005). Autistic spectrum disorders: Lessons from neuroimaging. *British Journal of Psychiatry*, 187, 395– 397.

Toichi, M. (2008). Episodic memory, semantic memory, and self- awareness in high-functioning autism. In J. Boucher & D. Bowler (Eds.), *Memory in autism: Theory and evidence* (pp. 143–165). Cambridge, England: Cambridge University Press.

Toichi, M., & Kamio, Y. (2002). Long-term memory and levels of-processing in autism. *Neuropsychologia*, 40, 964–969.

Toichi, M., Kamio, Y., Okada, T., Sakihama, M., Youngstrom, E. A., Findling, R. L., & Yamamoto, K. (2002). A lack of self-consciousness in autism. *American Journal of Psychiatry*.

Tomblin, B. (2011). Co- morbidity of autism and SLI: kinds, kin and complexity. *International Journal of Language & Communication Disorders*, 46(2), 127-137.

Travers, B., Klinger, M., Mussey, J., & Klinger, L. (2010). Motor-linked implicit learning in persons with autistic spectrum disorders. *Autism Research*, 3, 68–77.

Trontel, H. G., Duffield, T. C., Bigler, E. D., Abildskov, T. J., Froehlich, A., Prigge, M. B., ... & Lainhart, J. E. (2015). Mesial temporal lobe and memory function in autism spectrum disorder: An exploration of volumetric findings. *Journal of clinical and experimental neuropsychology*, 37(2), 178-192.

Tulving, E. (1972). Episodic and semantic memory 1. *Organization of Memory*. London: Academic, 381(e402), 4.

Tulving, E. (1983). *Elements of episodic memory*. Clarendon.

Tulving, E. (1985). How many memory systems are there? *American Psychologist*, 40, 385–398.



Tyson, K., Kelley, E., Fein, D., Orinstein, A., Troyb, E., Barton, M., Eigsti, I-M., Naigles, L., Schultz, R., Stevens, M., Helt, M., & Rosenthal, M. (2014). Language and verbal memory in individuals with a history of autism spectrum disorders who have achieved optimal outcomes. *Journal of Autism and Developmental Disorders*, *44*(3), 648-663.

Ullman, M. (2001). The declarative/procedural model of lexicon and grammar. *Journal of Psycholinguistic Research*, *3*, 37–69.

Ullman, M. T. (2004). Contributions of memory circuits to language: The declarative/procedural model. *Cognition*, *92*(1), 231-270.

Ullman, M. T., & Pierpont, E. I. (2005). Specific language impairment is not specific to language: The procedural deficit hypothesis. *Cortex*, *41*(3), 399-433.

Ullman, M. T., & Pullman, M. Y. (2015). A compensatory role for declarative memory in neurodevelopmental disorders. *Neuroscience & Biobehavioral Reviews*, *51*, 205-222.

Vaidya, C. J., Foss-Feig, J., Shook, D., Kaplan, L., Kenworthy, L., & Gaillard, W. D. (2011). Controlling attention to gaze and arrows in childhood: an fMRI study of typical development and Autism Spectrum Disorders. *Developmental Science*, *14*(4), 911-924.

van Buijssen, M., Hendriks, A., Ketelaars, M., & Verhoeven, L. (2011). Assessment of theory of mind in children with communication disorders: Role of presentation mode. *Research in Developmental Disabilities*, *32*(3), 1038-1045.

Volden, J., & Lord, C. (1991). Neologisms and idiosyncratic language in autistic speakers. *Journal of Autism and Developmental Disorders*, *21*, 109–130.

Wagner, A. D., Schacter, D. L., Rotte, M., Koutstaal, W., Maril, A., Dale, A. M., ... &

Buckner, R. L. (1998). Building memories: remembering and forgetting of verbal experiences as predicted by brain activity. *Science*, *281*(5380), 1188-1191.

Walenski, M., Mostofsky, S., Gidley-Larson, J., & Ullman, M. (2008). Brief report: Enhanced picture naming in autism. *Journal of Autism and Developmental Disorders*, *38*, 1395– 1399.

Walenski, M., Tager-Flusberg, H., & Ullman, M. (2006). Language in autism. In S. Moldin & J. Rubenstein (Eds.), *Understanding autism: From basic neuroscience to treatment* (pp. 175–203). Boca Raton, FL: Taylor and Francis.

Warren, S., Gilkerson, J., Richards, J., Oller, D.K., Xu, D., Yapanel, U., & Gray, S. (2010). What automated vocal analysis reveals about the vocal production and language learning environment of young children with autism. *Journal of Autism and Developmental Disorders*,

40, 555–569.

Waterhouse L (2013) Rethinking autism: variation and complexity. London: Academic Press.

Waterhouse, L., & Fein, D. (1982). Language skills in developmentally disabled children. *Brain and Language*, 15, 307– 333.

Weschler, D. (1999). Wechsler abbreviated scale of intelligence. *New York: Psychological Corporation*.

Weschler, D. (1997). Wechsler adult intelligence scale. *The Psychological Corporation, San Antonio*.

Whitehouse, A., Maybery, M., & Durkin, K. (2007). Evidence against poor semantic encoding in individuals with autism. *Autism*, 11, 241–254.

Wilkins, D. (2012). Ethical Dilemmas in Social Work Practice with Disabled People: Young Adults with Autism. *Ethics and Social Welfare*, 6(1), 97-105.

Williams, D. M., & Jarrold, C. (2010). Brief report: Predicting inner speech use amongst children with autism spectrum disorder (ASD): The roles of verbal ability and cognitive profile. *Journal of autism and developmental disorders*, 40(7), 907-913.

Williams, D. L., Goldstein, G., & Minshew, N. J. (2005). Impaired memory for faces and social scenes in autism: Clinical implications of memory dysfunction. *Archives of Clinical Neuropsychology*, 20, 1–15.

Williams, D. L., Goldstein, G., & Minshew, N. J. (2006a). Neuropsychologic functioning in children with autism: Further evidence for disordered complex information-processing. *Child Neuropsychology*, 12(4-5), 279-298.

Williams, D. L., Goldstein, G., & Minshew, N. J. (2006b). The profile of memory function in children with autism. *Neuropsychology*, 20(1), 21.

Williams, D., Botting, N., & Boucher, J. (2008). Language in autism and specific language impairment: Where are the links?. *Psychological bulletin*, 134(6), 944.

Williams, D. L., Minshew, N. J., & Goldstein, G. (2015). Further understanding of complex information processing in verbal adolescents and adults with autism spectrum disorders. *Autism*, 1362361315586171.

Willingham, D. B. (1998). A neuropsychological theory of motor skill learning. *Psychological review*, 105(3), 558.

- Wimpory, D., Nicholas, B., & Nash, S. (2002). Social timing, clock genes and autism: A new hypothesis. *Journal of Intellectual Disability Research, 46*, 352–358.
- Wing, L. (1981). Asperger's syndrome: a clinical account. *Psychological medicine, 11*(01), 115-129.
- Wing, L., & Gould, J. (1979). Severe impairments of social interaction and associated abnormalities in children: Epidemiology and classification. *Journal of autism and developmental disorders, 9*(1), 11-29.
- Wing, L., Gould, J., & Gillberg, C. (2011). Autism spectrum disorders in the DSM-V: better or worse than the DSM-IV?. *Research in developmental disabilities, 32*(2), 768-773.
- Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). Manual for embedded figures test, children's embedded figures test, and group embedded figures test. *Palo Alto, CA: Consulting Psychologists Press, Inc. Related constructs and measures from beyond the field of ethics, 365*.
- Wixted, J. T. (2005). A theory about why we forget what we once knew. *Current Directions in Psychological Science, 14*(1), 6-9.
- Wodka, E. L., Mathy, P., & Kalb, L. (2013). Predictors of phrase and fluent speech in children with autism and severe language delay. *Pediatrics, 131*(4), e1128-e1134.
- Wolk, L., & Giesen, J. (2000). A phonological investigation of four siblings with childhood autism. *Journal of Communication Disorders, 33*, 371–389.
- Yonelinas, A. P. (2002). The Nature of Recollection and Familiarity: A review of 30 Years of Research. *Journal of Memory and Language, 46*, 441-517
- Yonelinas, A. P., Otten, L. J., Shaw, K. N., & Rugg, M. D. (2005). Separating the brain regions involved in recollection and familiarity in recognition memory. *The Journal of Neuroscience, 25*(11), 3002-3008.
- Younger, B. A. (1985). The segregation of items into categories by ten-month-old infants. *Child Development, 1574-1583*.

## Appendix

### Summary Table of Memory Studies

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#### Non-declarative Memory

Non-declarative memory in ALI		
Author	Task	Main findings
Miller (1999)	Implicit perceptual skills	Unimpaired
Pring (2008)	Implicit perceptual skills	Unimpaired
Toal et al. (2005)	Habit formation	Unimpaired
Carter et al. (1998)	Daily living skills	Unimpaired
Kraijer (2000)	Daily living skills	Unimpaired
Non-declarative memory in ALN		
Barnes et al. (2008)	Implicit sequence learning	Unimpaired
Nemeth et al. (2010)	Alternating serial reaction time task	Unimpaired
Bowler et al. (1997)	Perceptual/conceptual Priming	Unimpaired
Gardiner et al. (2003)	Conceptual Priming	Unimpaired
Toichi (2008)	Semantic priming	Unimpaired
Molesworth et al. (2005)	Implicit category formation	Unimpaired
Bott et al. (2006)	Implicit category formation	Unimpaired
Soulieres et al. (2011)	Implicit category formation	Unimpaired
Sears et al. (1994)	Classical conditioning	Unimpaired
Gaigg & Bowler (2007)	Fear conditioning	Impaired
Brown et al. (2010)	Contextual cueing, Motor sequence learning	Unimpaired

## Declarative Memory

Recognition in ALI		
Boucher et al. (2008)	Pictures of coloured shapes	Impaired
Boucher & Warrington (1976)	Pictures of common objects- Delayed	Impaired
Lind (2008)	Pictures of common objects- Delayed	Impaired
Summers & Craik (1994)	Spoken words- Delayed	Impaired
Boucher & Lewis (1992)	Pictures of buildings- Immediate	Unimpaired
	Unfamiliar faces- Immediate	Impaired
Hill & Russell (2002)	Object pairs (unexpected test)- Immediate	Unimpaired
	Spoken words- Delayed	Impaired
Hauck et al. (1998)	Pictures of common objects- Delayed	Unimpaired
	Unfamiliar faces- Delayed (unexpected tests)	Impaired
Recognition in ALN		
Bowler et al. (2004)	Written + spoken words (unrelated; various encoding conditions- Delayed	Impaired
Bowler et al. (2010a)	Objects, locations, colours	Unimpaired
	Separately- Delayed	Impaired
Williams et al (2006a)	Story Content- Delayed	Unimpaired
	Complex scenes- Immediate (Wide range assessment of memory and learning)	Impaired
Toichi & Kamio (2002)	Written words (various encoding conditions; unexpected test)	Superior (phonological encoding) Unimpaired (semantic encoding)
	Immediate	Impaired (self-referential encoding)
Henderson et al. (2009)	Written words (various encoding conditions; unexpected test)-	Unimpaired (physical feature encoding)
	Immediate	Impaired (self-ref. encoding)
Lombardo et al. (2007)	Written words (various encoding conditions; unexpected test)	Unimpaired (physical feature encoding)
	Delayed	Impaired (self-referential encoding)
Bowler et al. (2008a)	Written words (unrelated; in context of semantically related/unrelated words)-	Unimpaired (both conditions)
	Delayed	

Toichi et al. (2002)	Written words (various encoding conditions; unexpected test) Immediate	Superior (phonological encoding) Unimpaired (semantic encoding) Impaired (self-referential encoding)
Hillier et al. (2007)	Geometric shapes- Immediate	Superior
	Spoken words (semantically related- Immediate)	Unimpaired
Buitelaar et al. (1999)	Meaningless patterns - Immediate (Benton Visual Recognition Test)	Unimpaired
Bigham et al. (2010)	Meaningless shapes- Delayed	Unimpaired
Boucher et al. (2008)	Pictures of coloured shapes- Delayed	Unimpaired
Beversdorf et al. (2000)	Spoken words (semantically related)- Immediate	Unimpaired
Salmond et al. (2005)	Spoken words (unrelated)	Unimpaired
Lind (2008)	Pictures (common objects)- Delayed	Unimpaired
Boucher et al. (2005)	Written words (unrelated)- Delayed	Unimpaired
	Pictures of common objects- Delayed	Unimpaired
Joseph et al. (2005)	Pictures (common objects: same category; different categories)	Unimpaired
Ambery et al. (2006)	Pictures of doors	Unimpaired
	Proper names (doors and People test)	Unimpaired
Bowler et al. (2000)	Written words (related)- Immediate	Unimpaired

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### Free recall in ALI

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Boucher (1978)	Others- Delayed	Unimpaired
	Written- Spoken Words (unrelated)- Immediate	Unimpaired
Boucher (1981a)	Spoken words (unrelated)- Immediate	Unimpaired (reduced primacy; enhanced recency)
Fyffe & Prior (1978)	Spoken words (unrelated)	Unimpaired (relative to both groups)
	Free recall - Immediate	
Tager-Flusberg (1991)	Spoken words (unrelated)- Immediate	Unimpaired (relative to both findings) Impaired (relative to both groups; limited clustering)
Frith (1970)	Spoken word strings (structured, non-meaningful)	Impaired (relative to both groups) (Enhanced recency)
Boucher & Warrington (1976)	Spoken words (unrelated)- Delayed	Impaired (relative to both groups)
Boucher & Lewis (1989)	Instructions: spoken- immediate and delayed	Impaired

	Demonstrated- immediate and delayed	Impaired
Boucher (1981b)	Past activities: own- Delayed	Impaired
Millward et al. (2000)	Past activities: Own- Delayed	Impaired
Hare et al. (2007)	Past activities: own- Delayed	Unimpaired (floor effects)
	Others- Delayed	

### Free Recall in ALN

Ambery et al. (2006)	Meaningless shape reproduction (doors and people)	Unimpaired
Bowler, Gaigg & Gardiner (2008a)	Written words (unrelated; in semantically related/unrelated word, texts)- Delayed	Unimpaired (unrelated context) Impaired (related contexts)
Minshew, Goldstein, Muenz & Paynton (1992)	Unrelated words (California verbal learning test)	Unimpaired
Mottron et al. (2001)	Written- spoken words (unrelated; various encoding conditions)- Delayed	Unimpaired (all encoding conditions)
Renner et al. (2000)	Pictures of common objects- Delayed	Unimpaired (reduced primacy)
Smith et al. (2007)	Written- Spoken words	Impaired
Williams et al. (2006a)	Number letter lists	Unimpaired
	Unrelated words	Unimpaired
	Sentence repetition	Impaired
	Story Recall	Impaired
	Figure reproduction	Impaired
	Geometric shape reproduction	
Minshew & Goldstein (2001)	Unrelated words	Impaired
Bowler et al. (2009)	Written words (unrelated)	Unimpaired
Buitelaar et al. (1999)	Written words (unrelated)	Unimpaired
Salmond et al. (2005)	Spoken words (unrelated)	Unimpaired
	Spoken words - Immediate over trials	Impaired
Renner et al. (2000)	Sentence repetition	Impaired
	Pictures of common objects - delayed	Unimpaired (reduced primacy)
Bowler, Limoges et al. (2009)	Written words (unrelated)	Unimpaired
Bowler, Gaigg et al. (2008a)	Written words (unrelated)	Unimpaired

Bowler et al. (2008b)	Written words (unrelated)	Unimpaired but Atypical
Bowler et al. (2000)	Spoken words - semantically related	Impaired
Bowler et al. (2009)	Categorically organised word lists	Unimpaired (reduced organisation)
Gaigg et al. (2008)	Categorically organised written words	Impaired
Botting & Conti-Ramsden (2003)	Sentence repetition	Impaired (relative to norm, not SLI)
Williams et al. (2006a)	Number letter lists	Unimpaired
	Unrelated words	Unimpaired
	Sentence repetition	Impaired
	Story recall	Impaired
	Figure reproduction	Impaired
	Geometric shape reproduction	Impaired
Boucher et al. (2005)	Story recall	Unimpaired
	Figure reproduction	Unimpaired
Williams et al. (2005)	Story recall	Unimpaired

#### Cued recall in ALI

Boucher & Warrington (1976)	Spoken words	Unimpaired
	Pictures of common objects	Unimpaired
Tager-Flusberg (1991)	Spoken words	Unimpaired
Farrant et al. (1999)	Named Pictures of common objects	Unimpaired
Klin et al. (1999)	Common objects on grid location	Unimpaired
Boucher & Lewis (1989)	Own past activities	Unimpaired

#### Cued recall in ALN

Mottron et al. (2001)	Written-spoken words	Unimpaired
Bowler et al. (1997)	Written unrelated words	Unimpaired
Gardiner et al. (2003)	Written unrelated words	Unimpaired
	PAL - delayed	Unimpaired
Ambery et al. (2006)	Proper names	Unimpaired



	PAL	Unimpaired
Minshew & Goldstein (2001)	PAL	Unimpaired
Williams et al. (2005)	PAL	Unimpaired
McCrary et al (2007)	Naturalistic events	Unimpaired
Maras & Bowler (2010)	Naturalistic events	Unimpaired
Bowler et al. (2004)	Recognition of encoding condition	Unimpaired
	Recall of encoding condition	Impaired
Bowler et al. (2000)	Recall of episodic experience	Impaired
Bigham et al. (2010)	Recall of unrelated action	Impaired
Salmond et al. (2005)	Recall of temporal source	Unimpaired
Ring et al. (2015)	Object-location relations	Impaired

