ATYPICAL INFORMATION PROCESSING IN CHILDREN WITH AUTISM: LINKS WITH INNER SPEECH DEFICIT

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ABSTRACT

A number of studies have provided evidence that individuals with autism have poor semantic processing of verbal information, instead gaining greater meaning from pictorial information. The aims of this thesis were, to firstly, investigate the verbal and pictorial encoding abilities of children with autism, and secondly, to determine the extent to which limitations in the use of inner speech may drive any encoding differences.

The first study investigated the notion that children with autism have an atypical verbal processing style, showing poor semantic but enhanced phonological encoding of verbal stimuli. The experiment compared the performance of children with autism and ability-matched controls ($N = 20$ in each group) on a novel explicit verbal recall task that contained 20 word stimuli. Recall performance could be benefited through, in one condition, an understanding of the semantic links between the stimuli, and in another condition, an understanding of the phonological similarities between the stimuli. The design of the recall task controlled for the possibility that children with autism have poor retrieval strategies (by providing either a semantic or phonological retrieval cue) and hence maximized the likelihood that any between-groups differences in performance would be related to problems at the encoding stage. There was no difference between the two groups. Follow up comparisons revealed that the performance of the autism group was consistent with that of typically developing children of the same chronological age.

The idea that individuals with autism have increased facility for processing pictorial information (Kamio & Toichi, 2000) was then investigated. This experiment utilized an explicit verbal recall task that contrasted verbal and pictorial information (picture-superiority task) – an experimental design in which retention typically favours pictures (Paivio, 1991). Prior to an examination of the autistic population, a preliminary investigation into the performance of typically developing children on the picture-superiority task was conducted. Eighty children from middle childhood to adolescence (7 to 16 years of age) were administered the task. There were contrasting expectations based upon firstly, the primacy of pictorial information in childhood, but secondly, the protracted development of a cognitive component thought necessary for the dual-coding underpinning pictorial superiority, namely inner speech. Consistent with the dependency of pictorial superiority on inner speech, there was an increase in the magnitude of the picture superiority effect as chronological age increased. The performances of children with autism

and ability matched controls (N = 20 in each group) were then compared in an additional study. In contrast to the notion that those with autism have increased facility for processing pictorial information, the children with autism demonstrated a reduced picture-superiority effect relative to the control sample. This finding was, however, consistent with reports that individuals with autism have limitations in their use of inner speech (Russell, Jarrold, & Hood, 1999). A follow up experiment sought to examine this idea more closely.

Children with autism were again compared with ability matched controls (N = 23 in each group), this time on their performance on a recall task that used a variant of a well-established verbal memory effect, the word-length effect. Stimulus items were presented as pictures, and hence it was assumed that verbal memory effects would be seen only if inner speech was used to label the pictures. Providing further evidence for inner speech limitations, the autism group demonstrated a reduced word-length effect in a condition that did not obligate verbal encoding.

The final study sought to determine whether inner speech limitations of those with autism affect the performance of these children in experimental paradigms other than those of pictorial memory. The experiment employed a task-switching paradigm (Baddeley, Chincotta, & Adlam, 2001), based on arithmetic, for which performance has been shown to be contingent upon inner-speech. While the addition of articulatory suppression significantly affected the task-switching performance of the ability matched control group, it did not affect the performance of those with autism. This provided further evidence that children with autism have limitations in their use of inner speech.

Together, the studies shed some light on the way the children with autism process verbal and pictorial information. In contrast to expectations, children with autism, firstly, encode verbal information in a manner similar to typically developing controls, and secondly, show reduced elaborative processing of pictorial information relative to ability matched controls. Follow up studies indicate that elaborative pictorial processing is reliant on inner speech and that children with autism have deficits in this cognitive component. The implications of these findings and possible avenues for future research are discussed.

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MANUSCRIPTS AND PUBLICATIONS GENERATED FROM THIS THESIS

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Whitehouse, A. J. O., Maybery, M. T., & Durkin, K. (2005). *Evidence against poor semantic encoding in individuals with autism.* Manuscript in submission to Journal of Autism and Developmental Disorders.

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CONTRIBUTION OF THE CANDIDATE TO PUBLICATIONS

In regard to Regulation 31 (points 2 and 3) from the *Regulations Governing Research Higher Degrees* of the Postgraduate Research School of the University of Western Australia, all study design, task development, participant recruitment and testing, data entry, analysis, interpretation, and preparation and revision of manuscripts was conducted by the candidate.

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Andrew Whitehouse (candidate) Date

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Murray Maybery (co-supervisor) Date

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Kevin Durkin (co-supervisor) Date

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PREAMBLE

Language deficits comprise one third of the well-established behavioural triad of autistic impairments (American Psychiatric Association, 1994). The language abilities of children with autism provide vital diagnostic (Lord & Paul, 1997) and prognostic (Ventnor, Lord, & Schopler, 1992) information and hence are central to our understanding of this population. While six decades of research has formed a solid knowledge base of the language abilities of this population, there is still much to be revealed. This thesis investigated two converging bodies of literature related to the autistic language deficit: (1) that individuals with autism have atypical processing (relative to typically developing participants) of verbal and pictorial information and (2) that these differences are a result of inner speech limitations.

The essence of this thesis is that children with autism have poor use of inner speech and that this limitation creates a cognitive processing style that is different to that of typically developing children. Chapters 2 to 5 report a series of studies that have led to this proposal. Chapter 1 presents a preliminary review of the literature that underpins the current investigations (reviews of specific areas are deferred to later chapters), while Chapter 6 summarizes the results, the implication of these findings and provides directions for future research.

This thesis is presented as a collection of papers in a format suitable for publication. At the time of submission, Chapter 3 is in press, and Chapters 2, 4 and 5 have been submitted for publication (Chapters 4 and 5 have been reviewed by an academic journal, which invited a resubmission). Because of restrictions on the length of the manuscripts imposed by some journals, a detailed treatment of the implications of these findings is not presented in the empirical chapters, but a comprehensive discussion of the implications is presented in Chapter 6.

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INTRODUCTION

Chapter 1

An overview of autism and the language ability of this population

The aim of this chapter is to provide, firstly, a review of the literature on autism and the language abilities of this population, and secondly, the theoretical foundations underpinning the series of studies reported in this thesis. The first section summarizes the current epidemiological, cognitive and clinical features of autism. The second section provides a review of the current literature on the language abilities of those with autism. The third section provides an overview of the key cognitive mechanisms under investigation: pictorial and verbal processing, and inner speech. The fourth and final section presents an outline, and the aims, of the ensuing research.

AUTISM

Autism is often recognized as the most severe of all childhood psychiatric disorders (Baron-Cohen, 2000). A diagnosis of this pervasive developmental disorder is based upon a triad of behavioural manifestations: impairments in social behaviour; restricted, repetitive and stereotyped behaviour; and a significant delay in communication. A diagnosis of autism is given to a child who shows qualitative impairment in each of these behavioural categories prior to three years of age (American Psychiatric Association, 1994).

There is great disparity between the various studies that have estimated the prevalence of autism and hence there is difficulty in attaining an accurate figure (Fombonne, 1998). This variance can be attributed to a number of factors, including different sample sizes and the inclusion of children who have later had their diagnosis removed (Fombonne, 1998). Since the mid 1960's, there have been around 30 epidemiological studies of autism, conducted in several countries (Volkmar, Lord, Bailey, Schultz, & Klin, 2004). Across time, there has been a steady increase in the prevalence of individuals diagnosed with autism. For example, studies published between 1966 and 1991 reported an average rate of 4.4 cases per 10,000, whereas the average rate found in studies published between 1992 and 2001 was 12.7 per 10,000 (Fombonne, 2003a). Fombonne (2003b), however, believes that the increase in the number of individuals with an 'autism' diagnosis (prevalence) is due to the increase in the number of *new* diagnoses (incidence), which can be attributed to factors that increase the likelihood of a diagnosis (i.e., an increase in the awareness of autism; a broadening of the diagnostic phenotype; etc.). Currently, the most commonly offered figure of autism prevalence is 10 cases for every 10, 000 people (Fombonne, 2003a). As with many other developmental disorders, the majority of those diagnosed with autism are male. A male:female ratio of around 4:1 is typically reported (Fombonne, 1998).

Language impairment is central to autism disorder. Often, a delay in the acquisition of overt speech or a lack of response to speech is the first indicator to parents that their child may have atypical development. Language ability is also considered a reliable prognostic indicator of autism, with the early acquisition of functional language (i.e., by 5 years of age) often forecasting more advanced cognitive, linguistic and social development relative to outcomes associated with poor language development (Rutter, 1970). Although language delay is necessary for a diagnosis of autism (American Psychiatry Association, 1994), there is significant heterogeneity in the language skills of those diagnosed (Kjelgaard & Tager-Flusberg, 2001). It is estimated that only around half of individuals with autism develop the ability to use language in any meaningful way (Lord & Paul, 1997). Of these, some will develop age-appropriate language skills over time, while others will remain significantly below what is expected for their age (Kjelgaard & Tager-Flusberg, 2001). Despite widespread language impairments, non-verbal abilities of children with autism are frequently within normal limits (Ehlers, Nyden, Gillberg, Dahlgren, & Sandberg, 1997).

Ever since autism was first described by Kanner in 1943, the language ability of this population has been a strong focus of research. In his original description, Kanner highlighted a range of 'idiosyncratic' language features, such as echolalia and difficulties with non-literal language and pronoun reversal, which were thought to characterize 'autistic' language. Since this description, research investigating the language abilities of those with autism has burgeoned, with very few areas remaining untouched. Yet while this population's language impairment is well-established (Charman, Drew, Baird, & Baird, 2003), the exact nature of the deficit remains unclear.

This thesis aims to contribute to the literature that seeks to unravel the language impairment experienced by those with autism. To place such impairments in context, the following section provides an initial overview of what is known of the aetiology of this disorder.

Aetiology of Autism

The unique and diverse profile of disabilities and abilities in those diagnosed with autism has provided a significant challenge to researchers' attempts to describe the disorder and clinicians' attempts to provide effective therapy. For example, individuals with autism characteristically show motor, attentional, social, planning, emotional, language and intellectual developmental deficits. However, preserved abilities in those skills requiring rote, mechanical or procedural aptitude are widely reported (Prior & Ozonoff, 1998). This varying profile has proven to be a stumbling block in establishing an all-encompassing aetiology of the disorder. Indeed, it is due to this lack of an identifiable, unifying aetiological marker that diagnosis is currently based on an evaluation of the behavioural manifestations.

Hope for a biological marker has been buoyed in recent years by findings suggesting that autism is one of the most heritable of all psychiatric disorders (Rutter, 2000). Family studies provide one source of support for this claim. For example, whereas autism afflicts 0.1% of the general population, 3% of the siblings of individuals with autism will be similarly diagnosed (Bolton et al., 1994). Furthermore, twin studies have shown a 60-91% concordance rate in monozygotic twins, in comparison to the 0-10% concordance rate reported in dizygotic twins (Bailey, Le Couteur, Gottesman & Bolton, 1995).

Further evidence for the genetic origin of autism has come from investigations of the cognitive and behavioural abilities of the family members of probands. Parents of children with autism have been shown to score higher (i.e., show more 'autistic' traits) on the social skills and communication sections of the Autism Spectrum Quotient, an instrument designed to identify mild signs of the disorder (Bishop et al., 2004). Furthermore, when compared to individuals who do not have a family member with autism, family members of those afflicted (who themselves are not diagnosed with autism) are more likely to demonstrate autistic-like traits, such as difficulty in sustaining friendships (Szatmari & Jones, 1998).

There is little doubt that the genetic component of autism manifests itself as a neurobiological abnormality (Poustka, 1998). Due to the vast spectrum of deficits, it is unlikely that the behavioural phenotype of those with autism can be explained by abnormalities in one brain region (McAlonan et al., 2005), indeed there is evidence that both atypical neurochemistry and neuroanatomy are involved (Poustka, 1998). While the exact nature and extent of the neurological abnormality remains unclear, understanding has grown in recent years with the development of more advanced assessment tools.

Possibly the most replicated finding in the neurobiological research of autism is of the enlarged brain volume observed in a significant proportion of the population (see Courchesne, 2004, for a review). In his original description of autism, Kanner (1943) observed that children with autism had enlarged heads. More recent studies have confirmed that around 10% of individuals with autism have a head circumference that is at or above the 98^{th} percentile of the typically developing population (e.g., Aylward, Minshew, Field, Sparks, & Singh, 2002). Post-mortem (Kemper & Bauman, 1998) and magnetic resonance imaging (Courchesne et al., 2001) studies have confirmed that the enlarged head circumference is reflective of an enlarged brain volume. Recent evidence suggests that this abnormality follows a developmental trend, with the brain volume of those with autism, relative to chronological age norms, being greatest in childhood and diminishing as individuals progress into adolescence (Aylward et al., 2002). The decreasing trend appears to reflect a gradual reduction in the proportion of white matter to grey matter (Courchesne et al., 2001; Herbert et al., 2003), however the implications of this finding are yet to be determined (Herbert et al., 2003).

Research has also identified a number of specific neural abnormalities that may be the basis of the behavioural/cognitive impairments seen in individuals with autism. For example, hypoactivity in the fusiform face area is thought to explain the difficulties that individuals with autism experience during face recognition (Schultz, 2005). Furthermore, cell abnormalities in the amygdala and hippocampus, such as reduced cell density and size (Kemper & Bauman, 1998), may be the origin of the deficits of emotion arousal and learning (LeDoux, 1996). Further research has suggested that the frontal lobe abnormalities, such as a thickened cortex (Bailey et al., 1998), increased cell packing density (Kemper & Bauman, 1998), smaller cells (Kemper & Bauman, 1998) as well as atypical metabolic (Zilbovicious et al., 1995) and electrophysiological (Dawson, Klinger, Panagiotides, Lewy, & Castelloe, 1995) activity, may account for the planning and inhibition difficulties of this population.

Atypical neurochemistry is also thought to feature in the pathology of autism. One of the most significant findings in this area is of the reduced synthesis and abnormal distribution of serotonin (Chandana et al., 2005) in about one third of individuals with autism (Volkmar et al., 2004). Dopaminergic systems have also started to receive research attention, due to the effectiveness of dopamine-blocking agents in the treatment of autism (Volkmar et al., 2004). While the exact phenotypic implications of these abnormalities remain unclear, it seems likely that atypical neurochemistry would impact upon cortical development.

Attempts to bridge the explanatory gap between the neurological abnormalities and behavioural manifestations have led psychological research to an examination of the cognitive systems of this population (Dahlgren & Trillingsgaard, 1996). While a number of cognitive theories of autism have emerged (e.g., Minshew & Goldstein, 1998), three cognitive models of autism have become especially dominant within the literature (Volkmar, et al., 2004). The *theory of mind* hypothesis relates to the difficulty that individuals with autism have in attributing mental abilities to others and themselves. This deficit leads to a difficulty in understanding people as intentional beings (see Baron-Cohen, 2000, for a review). *Weak central coherence*, a failure to integrate local details into a global entity, is another cognitive characteristic of those with autism. Within this framework, individuals with autism focus on individual elements rather than the integration of these elements. As a consequence, individuals with autism have difficulty in deriving overall meaning from a situation (see Frith, 2002, for a review). The *executive dysfunction* hypothesis proposes that individuals with autism have difficulty in self organizing cognitive functions toward the attainment of a predetermined goal. According to this viewpoint, individuals with autism have difficulty learning new skills due to a cognitive style that is characterized by perseveration, reduced forward planning and poor self-regulation (see Hill, 2004, for a review).

For many years researchers have looked for one single cognitive factor that could account for the whole triad of autistic symptoms (Bishop & Norbury, 2005a). Currently, however, there is poor agreement on a unifying cognitive theory of autism. While the theories described above are able to explain some of the behavioural manifestations seen in autism, no explanation can account for all of the disorder's characteristics. One alternative to the notion of an all encompassing theory is to view the behavioural impairments in this population as a synthesis of a number of cognitive deficits (Goodman, 1989).

One of the behavioural characteristics of autism that has received intense interest from researchers is the language impairment (e.g., Kjelgaard & Tager-Flusberg, 2001) and as mentioned previously, the primary aim of this thesis is to investigate more closely the language deficits observed in those with autism. Below is a summary of what is currently known of the language abilities of this population.

THE LANGUAGE ABILITIES OF INDIVIDUALS WITH AUTISM

Structural Aspects of Language

The structural aspects of language, namely phonological, grammatical and lexical ability, are three areas of language that have come under particular scrutiny in the autistic population. One of the central objectives of this research has been to determine whether the language ability of those with autism is merely delayed in these areas or whether it deviates from the typical developmental pattern (Kjelgaard & Tager-Flusberg, 2001). Due to this, the bulk of this research has contrasted the language performance of children with autism against populations that are known to be delayed in their language development, but do not diverge from the typical path of acquisition, for example, children with Down syndrome.

Phonological Development

The phonological development of individuals with autism was the focus of much early language research (Bartolucci & Pierce, 1977; Bartolucci, Pierce, Steiner, & Eppel, 1976; Goldfarb, Braunstein, & Lorge, 1956; Goldfarb, Braunstein, & Scholl, 1972; Pronovost, Wakstein, & Wakstein, 1966). The vast majority of these early studies found that children with autism acquired phonemes at a rate and order similar to typically developing children. Pronovost, Wakstein and Wakstein (1966), for example, examined the spontaneous speech of 14 children with autism over a period of two years. These children ranged in age from 5 to 15 years. It was found that, although children with autism were delayed in the onset of the phonemes, the pattern of acquisition did not substantially deviate from that of typically developing children.

In the decade following, Bartolucci, Pierce and colleagues (Bartolucci & Pierce, 1977; Bartolucci et al., 1976) conducted a number of studies that sought to consolidate the early findings. Children with autism were compared with children with mental retardation on tests of phoneme perception (e.g., Wepman Auditory Discrimination Test, Bartolucci & Pierce, 1977) and expression (e.g., Edinburgh Articulation Test, Bartolucci et al., 1976).

Confirming the findings of the early studies, there were little differences between the two groups. Both showed a similar pattern of phoneme acquisition, perception and production/comprehension errors.

Note that early studies of the autistic population were hampered by less rigorous definitions of autism disorder. Currently, a diagnosis of autism is most commonly based upon the criteria of the Diagnostic and Statistical Manual of Mental Disorders – Forth Edition (DSM-IV, APA, 1994), which evolved over five decades of research. Indeed autism did not become a diagnostic entity until the DSM-III was published in 1980 (Tidmarsh & Volkmar, 2003). The criteria utilised in early studies did not have the theoretical foundation of the DSM-IV, and as such, it is likely that some of the participants in the aforementioned studies would not achieve a diagnosis under DSM-IV guidelines (Huessler et al., 2001). For example, participants recruited in the studies by Bartolucci and colleagues (Bartolucci & Pierce, 1977; Bartolucci et al., 1976) were diagnosed along the guidelines of Kanner's (1943) *original* account of autism. While Kanner's description was instrumental in the conception of the autism diagnostic label, subsequent research has revealed clear cognitive and behavioural distinctions between autism and a number of closely related developmental disorders, such as Asperger's Syndrome, Pervasive Developmental Disorder-Not Otherwise Specified and Pragmatic Language Impairment (Volkmar et al., 2004). For this reason, caution must be taken when interpreting the findings of early studies.

One recent study was undertaken by Kjelgaard and Tager-Flusberg (2001) who examined the language functioning of 89 children (DSM-IV) diagnosed with autism. The children, aged between 4 and 14 years of age, were administered a range of language assessments, including the Goldman-Fristoe Test of Articulation – a prominent test of phonological production. The majority of the children displayed phonological abilities that were considered appropriate for their chronological age, leading the authors to conclude that articulation skills are "almost always spared in this population" (p. 303).

Grammatical Development

Studies have also demonstrated the relatively unimpaired development of grammar in children with autism (Bartolucci & Albers, 1974; Bartolucci, Pierce, & Streiner, 1980; Cantwell, Baker, & Rutter, 1978; Jarrold, Boucher, & Russell, 1997; Tager-Flusberg et al., 1990; Whitehouse & Hird, 2004). A number of early cross-sectional studies investigated the syntactical rules underlying the sentences produced by children with autism. Cantwell and colleagues (Cantwell, Baker, & Rutter, 1978), for example, attained language samples from 12 children with autism and 12 'dysphasics'. The two groups were found to be comparable on the rules of morphology, phrase structure and linguistic transformation. Similarly, Bartolucci, Pierce and Streiner (1980) demonstrated, through an analysis of language samples, that children with autism show a similar pattern of grammatical errors as children with mental retardation.

In the past two decades, a number of studies have confirmed the findings of the earlier studies. Tager-Flusberg et al. (1990), for example, conducted a longitudinal study of six children with autism and six controls with Down syndrome. A number of language samples were collected over a period where the children were between 12 and 26 months of age. The language samples of the two groups were then compared on a range of established grammatical measures (e.g., mean length of utterance, lexical diversity, form class distribution). In general, the children with autism acquired grammatical structures in the same order as would be expected of typically developing children. While the longitudinal nature of Tager-Flusberg et al.'s data is informative, it does have the limitation of a small sample size. However, more recent studies such as that conducted by Jarrold, Boucher and Russell (1997) have demonstrated appropriate grammatical development with a larger sample size. Jarrold et al. administered a range of receptive and expressive language assessments to 120 children with autism. The findings indicated that the morphological and syntactical development of the children was in keeping with the other aspects of their linguistic profile (e.g., vocabulary).

Lexical Knowledge

As with the development of grammatical ability, the development of lexical knowledge in the autistic population has been found to be delayed in comparison to that observed in the typically developing population, but not markedly deviant. Tager-Flusberg et al. (1990), for example, found that the lexical acquisition of children with autism followed a very similar path to that of children with Down syndrome. Other studies have demonstrated that the vocabulary level of children with autism is equivalent to their grammatical knowledge (Jarrold et al., 1997; Kjelgaard & Tager-Flusberg, 2001) and that there is no substantial difference between the children's receptive and expressive vocabulary (Kjelgaard & Tager-Flusberg, 2001).

Overview

While phonological, syntactical and lexical development may be delayed in children with autism, there is a large literature that suggests that this pattern of development does not deviate from that of typically developing children. Yet despite the mastery of the structural aspects of language, and often a high level of nonverbal ability, the DSM-IV diagnostic criteria indicate that children with autism remain significantly disordered in their communicative competence (Parisse, 1999). Some have proposed that underlying communicative impairment relates to the pragmatic abilities of children with autism.

Autism as a Disorder of Pragmatics?

The Pragmatic Impairment in Autism

In the past two decades, the bulk of autism language research has focused upon the way that individuals *use* language, or as it is known, the pragmatics of language. During the mid-1980's, language research entered what many have called the 'pragmatic revolution' (Kretschmer & Kretschmer, 1989; Prutting & Kirchner, 1987), where the importance of communication skills outside the realm of 'formal' linguistic skills, was being recognized. This conceptual shift within language research filtered through to the study of autism and the ensuing research identified 'pragmatics' as an appropriate category that could describe many of the language difficulties observed in this population. In fact, despite the heterogeneity of the language abilities in the autistic population, research has shown that all children with autism are atypical in the way they use language to communicate (Rice, Warren, & Betz, 2005; Tager-Flusberg, 2003).

Studies have demonstrated a wide range of pragmatic impairments in the autistic population. For example, individuals with autism have difficulty tailoring their discourse to the needs of an interlocutor (Sabbagh, 1999), failing to alter their communicative style to meet the demands of different interactions (e.g., different contexts and participants) (Baltaxe & Simmons, 1977; Dewey & Everard, 1974; Loveland, McEvoy, Kelley, &

Tunali, 1990; Surian, Baron-Cohen, & Van der Lely, 1996). Individuals with autism also demonstrate inappropriate questioning (Geller, 1998; Hurtig, Ensrud, & Tomblin, 1982), a paucity of questions which gain new information from others (Tager-Flusberg & Sullivan, 1995), and difficulty in providing appropriate responses to interlocutors' requests for clarification (Paul & Cohen, 1994). Furthermore, while individuals with autism generate as many communicative utterances as typically developing participants, they display a limited repertoire of communicative acts (Wetherby & Prutting, 1984; Ziatas, Durkin, & Pratt, 2003), indicating a poor understanding of communicative conventions.

Individuals with autism also have impairments in their use of suprasegmental devices - additional features of the language signal that an interlocutor can use to convey meaning (Paul, Augustyn, Klin, & Volkmar, 2005). For example, individuals with autism have difficulty comprehending emotional prosody (McCann & Peppe, 2003), misassign stress to function words (Baltaxe & Simmons, 1992), misuse stress cues within an utterance (Baltaxe, 1984; Shriberg, Paul, McSweeny, Klin, & Cohen, 2001), make more errors than controls in the grammatical placement of stress, and do not differentiate stress patterns for new and used information (McCaleb & Prizant, 1985). These prosodic atypicalities further highlight the difficulties that those with autism experience in using their language skills to convey meaning.

Beyond the Pragmatic Deficit

At the present time, the pragmatic difficulties of those with autism remain the most prominent language deficit in this population. Indeed the 'qualitative impairments in communication' required for a DSM-IV diagnosis of autism have a strong pragmatic emphasis (APA, 1994). The prominence of a focus on the pragmatic impairment in autism research has, in part, been due to the evidence for relatively intact phonological, grammatical and lexical abilities. Furthermore, while the language abilities of those with autism are highly variable, the pragmatic impairment is one deficit that is observed across the entire spectrum of individuals (Rice et al., 2005). However, arguably the most compelling element of the pragmatic impairment to researchers is that all three prevailing cognitive theories of autism can, at least to some extent, account for these deficits (Parisse, 1999). For example, the inability to take into account a listener's perspective, as advanced by the theory of mind account, would affect the ability to understand intentions behind the utterance of an interlocutor (Hale & Tager-Flusberg, 2005). Similarly, difficulties with planning and inhibition (executive dysfunction) would contribute to a greater degree of pragmatic inappropriateness (Bishop & Norbury, 2005a, 2005b), while a weaker drive for the integration of information (weak central coherence) is likely to reduce the ability to engage in conversation in a sustained and meaningful way (Noens & van Berkalaer-Oones, 2005).

Despite the widespread nature of pragmatic impairments, it is clear that a substantial proportion of the autistic population have significant language impairment that goes beyond difficulties with social communication (Kjelgaard & Tager-Flusberg, 2001; Lord & Paul, 1997). As described earlier, only half of children with autism will develop any form of meaningful language (Lord & Paul, 1997), and only a percentage of those that do, develop age-appropriate linguistic skills (Parisse, 1999). This indicates that the pragmatic impairment is only one element of a much broader language deficit. Although the exact nature of this deficit has proved extremely difficult to characterize, describing the broader language phenotype of the autistic population remains one of the most important goals of autism research. Achieving this would provide a significant contribution to the genetic, neurological and cognitive study of autism as well as increasing the likelihood of designing more effective intervention methods.

That the prevailing cognitive models of autism can go partway to explaining the pragmatic deficits of this population is important when conceptualizing the nature of the broader language deficit experienced by this population. In particular, the links between the cognitive and pragmatic impairments of those with autism lead one to question whether the broader language difficulties experienced by this population may also arise as a consequence of the cognitive deficits, or conversely, if they arise independently of each other. This question taps directly into the uncertain relationship between language and cognition, a conundrum that stands at the core of many prominent developmental theories. Piaget (1952), for example, proposed a strong cognitive model where language is both based on, and determined by, thought. Whorf (1956), on the other hand, maintained that all higher thinking is dependent on language. Vygotsky (1962) proposed a compromise position, where thought initially precedes language but is later influenced by language. Chomsky (1968) argued for the independence of language and thought, where the achievement of language is "relatively independent of intelligence or the particular course of experience" (p.66). Intriguingly, while the exact relationship between cognition and language is still debated, one of the greatest sources of evidence for independent systems comes from the study of developmental disorders.

Developmental disorders provide a key source of evidence informing the debate over whether language impairment can arise independent of cognitive impairment. Children with Williams Syndrome (Bellugi, Sabo, & Vaid, 1988), Turner syndrome (Temple & Carney, 1993), and Spina Bifida with hydrocephalus (Hurley, 1993), for example, typically achieve much better scores on tests of linguistic knowledge in comparison to tests of nonverbal ability. In the opposite direction, individuals with Specific Language Impairment (SLI) have a clinical impairment in language but relatively intact cognition. These findings suggest that the language ability of these individuals is dissociated from cognitive performance (i.e., either significantly more proficient or significantly poorer), which indicates that language impairment may arise independently of cognitive deficits. Whether this is also the case for individuals with autism is less clear.

Importantly, there is a developing literature on the association between the genetic components of autism and SLI. For example, there is a greater prevalence of siblings with autism amongst probands with SLI (Tomblin, Hafeman, & O'Brien, 2003). Similarly, family members of children with autism often exhibit significantly lower verbal than nonverbal intelligence (Bartak, Rutter, & Cox, 1975; Folstein, et al., 1999, Fombonne, Bolton, Prior, Jordan, & Rutter, 1997; Piven & Palmer, 1997). Furthermore, recent studies have identified that a significant proportion of children with autism fail language tests that are sensitive to the deficits of those with SLI, such as nonword repetition (Kjelgaard, & Tager-Flusberg, 2001) and tense marking (Roberts, Rice, & Tager-Flusberg, 2004). This evidence suggests that autism may arise when the child has a combination of adverse risk genes. That is, rather than being inherited as a complex syndrome, autism might consist of a constellation of impairments (Folstein et al., 1999).

From this evidence it seems plausible that, unlike the pragmatic deficits experienced by those with autism (which are seen as a result of cognitive deficits), the broader language deficit of this population may arise independent of disordered cognition (e.g., theory of mind impairment, weak central coherence and executive dysfunction). Accordingly, research that investigates the processes underlying linguistic development may provide a greater understanding of the language impairment experienced by those with autism.

KEY COGNITIVE PROCESSES UNDER INVESTIGATION

While phonology, syntax and lexical ability provide a good framework for examining language ability, these are merely indicators of underlying processing skills. Word learning, for example, requires one to perceive and isolate the appropriate phonological form, hold this in short-term memory while extracting the proper meaning from the learning context, and then placing this information into the lexicon for long-term storage (Brackenbury & Pye, 2005). It is the *result* of this process, lexical ability, not the process itself, which has typically been measured in the autistic population. Similar processes are thought to be responsible for the development of syntax and morphology, where children build a storehouse of multiword utterances that can then be analysed into their component parts (Montgomery, 2002; Plunkett & Marchman, 1993). By investigating the skills that underpin language development, greater insight into this population's language ability can be gleaned. This thesis aims to do just this.

One element of language processing that has received a large amount of research attention is the way that individuals with autism gain meaning from linguistic information (print and auditory words). Typically developing children gain meaning from linguistic information by, firstly, encoding an external signal as a perceptual representation (either a phonetic or phonological sequence) and, secondly, using this representation to activate knowledge stored in semantic memory (Kamio & Toichi, 2000). There is evidence from a number of research paradigms that individuals with autism have difficulty with this process (e.g., Beversdorf et al., 2000; Toichi & Kamio, 2002, 2003, 2005; Toichi et al., 2002). In contrast, there is evidence that this process is facilitated in individuals with autism when presented with pictorial information (e.g., Ameli, Courchesne, Lincoln, Kaufman, & Grillon, 1988; Kamio & Toichi, 2000). In short, this evidence suggests that the autistic population can be characterised as individuals with an atypical information processing 'bias', gaining enhanced meaning from pictorial information but reduced meaning from verbal information.

The nature (and indeed existence) of these processing atypicalities is yet to be confirmed. For example, it is not known whether the limited semantic processing of verbal information observed in those with autism is only poor relative to their processing of pictorial information, or whether it is inferior to that observed in typically developing individuals. Similarly, it is unclear whether individuals with autism simply have enhanced semantic processing of pictorial information in comparison to their processing of verbal information, or whether this is enhanced relative to that observed in the typically developing population. Ascertaining the exact nature of the processing style of this population, as well as the cognitive mechanisms that may underpin a possible processing bias is a goal of this research. One potentially important mechanism, discussed in more detail below, concerns limitations of inner speech.

A brief outline of the literature pertinent to this series of studies is provided below. A more comprehensive review of each particular area has been deferred to the later chapters. As a guide, the chapters that include more thorough literature reviews are included in parentheses.

Verbal and Pictorial Processing

The way children with autism gain meaning from verbal and pictorial information is one area of this population's language that has come under scrutiny. In particular, there have been suggestions that children with autism show an atypical style of information processing, demonstrating increased semantic encoding of pictorial information relative to verbal information. Much of the evidence for this view has come from tasks of verbal recall, where participants are presented with, and asked to remember, a series of verbal and/or pictorial stimuli. In these tasks, it is assumed that the items that the participants recall are processed for meaning to a greater depth than those items that are not recalled.

Evidence that children with autism have difficulty in processing the semantic aspect of verbal information has come from both implicit and explicit recall tasks (see Chapter 2 for a more thorough review; Beversdorf et al., 2000; Toichi & Kamio, 2002, 2003, 2005; Toichi et al., 2002). These tasks manipulate the items within the stimulus list so that recall can be benefited through an understanding of the semantic links between items. Notably, individuals with autism do not exhibit these recall benefits (Frith, 1969; Fyffe & Prior, 1978; O'Connor & Hermelin, 1967; Tager-Flusberg, 1991). Further evidence for atypical verbal encoding has come from studies that have demonstrated that individuals with autism have a bias towards processing the phonological characteristics of words (Boucher & Warrington, 1976; Mottron, Morasse, & Belleville, 2001; Toichi & Kamio, 2003, 2005). For example, whereas typically developing children make recall errors that are predominantly semantically similar to the presented words, individuals with autism make more errors that are phonologically similar (Toichi & Kamio, 2003).

On the whole, these findings have been taken to indicate that individuals with autism have difficulty encoding the meaning of verbal items (e.g., Kamio & Toichi, 2000). This is an appealing interpretation of this pattern of findings, as an ‘atypical verbal encoding’ hypothesis has clear potential to describe many of the language difficulties observed in individuals with autism (e.g., a lexical delay). Research however, is yet to rule out other possibilities for this pattern of results. In particular, it remains possible that this recall pattern is due to atypical retrieval strategies by those with autism (Tager-Flusberg, 1991). Clarifying this issue is central in establishing ‘atypical verbal encoding’ as a distinguishing language deficit within the autistic population.

An extension of the proposal that individuals with autism have atypical verbal encoding is the suggestion that this population has a semantic processing bias towards pictorial information (see Chapter 4). There have been anecdotal reports that people with autism ‘think in pictures’ (Grandin, 1995; Hurlburt, Happe, & Frith, 1994). In addition, numerous studies have demonstrated the beneficial use of pictures in clinical intervention (Bondy & Frost, 2001; Kerr & Durkin, 2004; Wellman et al., 2002). There is, however, only limited experimental evidence to support the notion of a pictorial processing bias in the autistic population (Ameli et al., 1988; Kamio & Toichi, 2000; Pring & Hermelin, 1993). As with proposed deficit in the semantic processing of verbal information, most of the evidence supporting the notion of a bias in processing pictorial information has come from recall tasks. Kamio and Toichi (2000), for example, found that, during a priming task, individuals with autism were more likely to complete a word fragment if the prime had been a picture, rather than a word. The comparison participants, however, completed more word fragments if the prime was a word (see Chapter 4 for a more thorough review of this study). Similarly, while there have been mixed results as to whether individuals with autism can use meaning to enhance their recall of verbal information (Lopez & Leekam, 2003; cf. Minshew & Goldstein, 1993), the literature is unanimous in support of ideas suggesting that this population is able to use meaning to enhance their pictorial memory (Ameli, et al., 1988; Pring & Hermelin, 1993).

In sum, research shows that individuals with autism have difficulty in gaining meaning from verbal information, instead paying greater attention to the phonological attributes of the verbal stimuli. Further literature indicates individuals with autism may have a processing bias towards pictorial information. However, there is little direct experimental evidence to confirm these notions. This thesis seeks to add clarity to this area.

Inner Speech

An extension of establishing *how* individuals with autism process verbal and pictorial information, is determining *why* they may have an atypical processing style. One of the suggestions outlined above is that individuals with autism have poor semantic encoding of verbal information, instead gaining greater semantic meaning from pictorial information. A bias towards processing information in one modality is likely to be reflective of the atypical functioning of an underlying cognitive component. Inner speech is one underlying component that may be atypical in children with autism. This thesis investigated inner speech in terms of two separate, but related components: (1) the generation and rehearsal of a phonological code (see Chapter 4) and (2) internal planning (see Chapter 5).

It is widely recognized that individuals utilise working memory while performing recall tasks (Baddeley, 1986). Working memory is a cognitive storage system that enables one to temporarily store a number of pieces of information, while attending to and processing other information. According to Baddeley (1986), working memory consists of a controlling ‘central executive’ that is divided into two distinct ‘slave’ systems, the articulatory loop and the visuospatial sketchpad. While incoming information is processed in the central executive, previously processed information is stored in the slave systems: verbal information in the articulatory loop and visual information in the visuospatial sketchpad.

By definition, the storage of information within working memory is only temporary and unless the information is continually rehearsed, it will decay at a rapid rate (Baddeley, 1986). Within the articulatory loop, this is completed via subvocal rehearsal (Baddeley, 1986; Papagno, 1996), or as this thesis will term it, inner speech. Importantly, inner speech can also be utilised for the retention of pictorial information, whereby one is able to generate a verbal code for pictorial stimuli, which is then rehearsed. It has been suggested that the ability to code pictorial stimuli through two routes has important implications for how individuals perform in recall tasks that contain both verbal and pictorial information. Paivio (1991), for example, claims that the encoding and subsequent storage of pictorial information through two routes (a pictorial and verbal pathway), leads to a greater strength of encoding, and thus enhanced recall of pictorial information relative to the recall of verbal information. From this perspective, the often observed picture-superiority effect, that is, enhanced recall of pictorial relative to word stimuli (reviewed in Chapters 3 and 4), is contingent upon inner speech. An enhanced ability to generate and rehearse a phonological code for pictorial stimuli, may lead to a greater facility for this type of information, such as that proposed in the autistic population.

Internal planning is the second component of inner speech that this thesis will investigate in children with autism. In typically developing children, as overt language develops, so does the internalizing of language (Winsler, Carlton, & Barry, 2000; Winsler, de Leon, Wallace, Carlton, & Willson-Quayle, 2003). As the proficiency of internal language increases, it becomes an important tool in facilitating the development of skills pertinent to other cognitive components (Winsler, Diaz, & Montero, 1997; Winsler & Naglieri, 2003)[1]. In particular, internal language is known to have links with the development of executive function (Baddeley, Chincotta, & Adlam, 2001), theory of mind (Carlson, Moses, & Claxton, 2004) and behavioural regulation (Vygotsky, 1962). That these three areas are known to be deficit in individuals with autism, provides additional interest in the nature of inner speech in this special population.

The possibility of an inner speech impairment in those with autism has recently been proposed (Russell, Jarrold, & Hood, 1999). Russell et al. provided evidence that when tasks of executive function do not depend on inner speech, no significant differences are observed between autism and control groups. This finding, when taken together with the extensive evidence that children with autism perform poorly on executive tasks thought to depend upon inner speech (see Hill, 2004, for a summary), provides indirect support for poor use of inner speech in individuals with autism. However, while the findings of Russell et al. provide tangential support for the notion of inner speech involvement in tasks of executive function, there is, as yet, no direct evidence to confirm this idea. This thesis will investigate the possibility that an inner speech impairment may contribute to, firstly, the atypical performance of individuals with autism in tasks of verbal and pictorial recall (and

[1] Although this thesis does not aim to add to the debate surrounding the relationship between language and cognition, it is important to note that evidence that inner speech has a facilitative effect in the development of other cognitive components, supports the stance offered by Vygotsky (1962).

hence, language development), and secondly, other cognitive deficits observed in the autistic population.

AIMS AND ORGANIZATION OF THIS THESIS

There were two general aims of this thesis. The first aim was concerned with increasing the understanding of how children with autism gain meaning from verbal and pictorial information. This was investigated through a series of studies that examined, firstly, the verbal processing abilities of children with autism, and secondly, pictorial-verbal modality processing differences in these individuals. The second aim was to investigate the use of inner speech in children with autism and, more specifically, to examine whether inner speech may influence firstly, the verbal and pictorial processing abilities of these individuals, and secondly, the functioning of other cognitive components, specifically, executive function. The individual studies reported in this thesis are outlined below.

The study reported in Chapter 2, sought to determine whether the atypical verbal recall performance, often demonstrated by children with autism (i.e., poor semantic processing but enhanced phonological processing), is due to a semantic encoding deficit. This study employed a novel cued recall task in which performance could be benefited through, in one condition, an understanding of the semantic links between the stimuli, and in another condition, an understanding of the phonological similarities between the stimuli. Results demonstrated no significant differences between the populations, and hence did not support the idea that children with autism have atypical semantic encoding of verbal information.

The focus of this thesis then shifted to an investigation of whether children with autism gain greater meaning from pictorial rather than verbal information. This was examined with the use of an explicit verbal recall task that contained pictures and words (picture-superiority task). An initial study, reported in Chapter 3, utilised this task to investigate the possibility of modality processing differences in typically developing children of a range of ages. Picture-recall dominance increased with chronological age, a pattern proposed to be associated with development of inner speech.

The performance of typically developing children and those with autism on the picture-superiority task was then compared in the first experiment of Chapter 4. The children with autism demonstrated significantly reduced pictorial recall in comparison to the control group. This is consistent with suggestions that individuals with autism have inner speech limitations (Russell et al., 1999). Experiment 2 in Chapter 4 utilised a task of immediate serial recall, in particular, a variant of the typical word-length effect experiment (see Chapter 4), in order to provide further evidence that children with autism have difficulty forming and rehearsing phonological codes of pictorial information. It was proposed that participants would only demonstrate a word-length effect if they utilised inner speech. Children with autism demonstrated a pattern of recall consistent with the proposal of inner speech limitations in this population.

Chapter 5 investigated whether inner speech limitations may contribute to the atypical performance of children with autism in a task that examines one component of executive function, mental switching. The interruption of inner speech through concurrent articulatory suppression negatively affected the switching performance of typically developing participants but not the participants with autism. This indicates that children with autism do not use inner speech during tasks of mental switching. The findings of this thesis and implications for the current cognitive models of autism are discussed in Chapter 6.

SUMMARY

In sum, this thesis aims to shed light on the processes underlying language development in children with autism. In particular, this thesis endeavours, firstly, to increase the understanding of how children with autism gain meaning from verbal and pictorial information, and secondly, to investigate the use of inner speech in children with autism. A series of experimental studies will be reported that are taken to demonstrate that children with autism firstly, have appropriate encoding of verbal information, secondly, have reduced semantic processing of pictorial information, and thirdly, have limitations in their use of inner speech. The ideas and empirical work presented provide a departure from the work that has been carried out in recent years by providing clear evidence that individuals with autism have inner speech deficits and that this affects their performance in a number of experimental paradigms.

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VERBAL PROCESSING IN CHILDREN WITH AUTISM

FOREWORD TO CHAPTER 2

One of the aims of this thesis was to examine the idea that children with autism have atypical encoding of information, gaining greater meaning from pictorial rather than verbal information. The first step in this investigation was to examine the extent to which children with autism gain meaning from verbal information. Evidence from recall tasks suggest that individuals with autism are poor in their semantic processing of verbal information (Beversdorf et al., 2000; Tager-Flusberg, 1991; Toichi & Kamio, 2002, 2003, 2005) and in compensation (Mottron & Burack, 2001) have superior processing of the phonological attributes of verbal stimuli (Boucher & Warrington, 1976; Mottron, Morasse, & Belleville, 2001; Toichi & Kamio, 2003, 2005). What remains unclear, however, is whether this pattern of performance is due to poor semantic encoding of verbal information or atypical retrieval strategies. Chapter 2 sought to provide some clarity to this area.

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Chapter 2

Evidence against poor semantic encoding in individuals with autism

ABSTRACT

A number of studies have provided evidence that individuals with autism poorly encode verbal information to the semantic level of processing, instead paying greater attention to the phonological attributes of verbal stimuli. This possibility was investigated through a novel explicit verbal recall task. In order to establish the validity of the task, the performance of 80 typically developing children of various ages was examined. Following this, 20 children with autism were compared with 20 typically developing children matched on verbal, non-verbal and reading ability. On each trial, 20 words were presented individually on a computer screen. Half of the items were in some way related either through, in one condition, having a common semantic theme or, in the other condition, having a common phonological feature. Following a filler task, the participants were presented with a cue (of the common element) and asked to recall as many items consistent with the cue as possible. No differences between the autism and control groups were found in either the semantic or phonological condition. A follow-up comparison revealed that the participants with autism showed comparable levels of recall to an additional group of children matched on chronological age. The findings do not support the idea of a developmental delay in semantic encoding in children with autism.

Language delay is one of the key diagnostic features of those with autism (American Psychiatric Association, 1994). It is estimated that around half of individuals with autism will not be able to use language in any meaningful way, with the remainder showing, at the very least, significant delays in social communication (Parisse, 1999). Although this population's language delay is well-established, the exact nature of the language disorder remains, at present, poorly understood.

One area of language that has received a large amount of research attention is the way that individuals with autism gain meaning from linguistic information. One common way of investigating semantic processing is through verbal recall tasks, in which participants are asked to remember a list of words for subsequent recall. The findings from the literature on typically developing children suggest that it is particularly the meaning of verbal information that participants attend to during these tasks. For example, during retrieval, participants typically recall the stimuli in clusters of semantically similar items (Minshew & Goldstein, 1993). Furthermore, recall is typically enhanced if the items in a stimulus list share a common semantic trait (Tager-Flusberg, 1991).

Interestingly, children with autism have been found not to show these effects (Hermelin & O'Connor, 1970; Minshew & Goldstein, 1993; Minshew & Goldstein, 2001; Minshew, Goldstein, Muenz, & Payton, 1992; Tager-Flusberg, 1991; Turner, 1999). Tager-Flusberg (1991, Experiment 1), for example, compared the verbal recall performance of children with autism and two control groups (typically developing children and those with mental retardation) on a task that contained, in one condition, a list of semantically related items and, in another condition, a list of semantically unrelated items. While the groups performed comparably in the semantically unrelated condition, the autism group recalled significantly less items than the two control groups in the semantically related condition. The children with autism did not demonstrate the same memory facilitation with semantically related stimuli as did typically developing children.

Although such findings raise the possibility that those with autism have poor semantic knowledge, there is evidence from a range of memory and categorization tasks that suggests that these individuals are able to take into account associations between semantically related items (Tager-Flusberg, 1985a, 1985b; Toichi & Kamio, 2001, 2005). In response to these mixed findings, it has been proposed that the pattern of performance by individuals with autism in verbal recall tasks may be a result of poor semantic encoding

(Toichi & Kamio, 2002). Whereas typically developing children encode the meaning of words, children with autism may instead 'rote-learn' verbal information, ignoring the meaning of words as well as any meaningful relations between items.

Beversdorf et al. (2000), for example, conducted a recall task designed to induce a 'false memory'. Participants were presented with a list of semantically related words. The list omitted one dominant member of the category and it was aimed to induce the recall of this item (e.g., *bed*, *rest*, *night*, *dream*, etc. with the anticipated false memory of *sleep*). After the presentation of each list, participants were given a recognition task and were asked to identify which items were members of the original stimulus list. The individuals with autism were less likely to include false memories than ability-matched controls, indicating that they did not encode the meaning of the verbal information to the same extent as the controls.

Toichi and Kamio (2003) came to a similar conclusion with their findings from a task of concrete and abstract word recall. In the typical population, concrete words are better recalled than abstract words (Vellutino & Scanlan, 1985). This is thought to be a function of the increased meaningfulness and imageability of concrete words (Vellutino & Scanlan, 1985). As expected, the control participants recalled more concrete words than abstract words. In contrast, despite an overall level of recall comparable to the control group, the participants with autism did not show this effect, recalling a similar number of concrete and abstract words. Toichi and Kamio advanced this finding as evidence that individuals with autism do not encode the semantic information of words to the same extent as the controls.

Further evidence for poor semantic encoding in the autistic population has come through tasks examining 'levels of processing' effects. In the typical population, information processing can be advantaged through engaging different 'levels' of the language system (Craik & Tulving, 1975). If processing engages the 'deeper' semantic levels, information is retained better than if only 'shallow' levels, such as perceptual or word recognition levels, are engaged. Mottron, Morasse and Belleville (2001) examined this in typically developing adolescents and those with autism. During encoding, participants were asked questions about each item. In one condition, they were asked questions about the taxonomic category of each word (e.g., 'which word is a vegetable?'). In the other condition, participants were asked questions about the phonological features of each word (i.e., 'which word starts with *NA*?'). Consistent with the levels of processing effect, the control participants recalled more words when they were asked a semantic rather than a phonological question. However, while the overall level of recall performance was comparable between groups, the autism group did not display any recall difference between the different levels of encoding. These findings, which have been replicated in a Japanese population (Toichi & Kamio, 2002), suggest that, during recall tasks, individuals with autism have difficulty encoding the meaning of words.

An important secondary finding from the studies examining the 'levels of processing' effect (Mottron et al., 2001; Toichi & Kamio, 2002), is the greater recall by the autism groups in comparison to the control group, of items in the phonological condition. This finding may indicate that individuals with autism have enhanced encoding of the phonological features of words. A handful of studies have provided support for this idea. For example, whereas typically developing children make recall errors that are predominantly semantically similar to the presented words, individuals with autism make more errors that are phonologically similar (Toichi & Kamio, 2003). Furthermore, individuals with autism are more likely than controls to recall items when given a phonologically related prime (Toichi & Kamio, 2005).

It has been suggested that the inferior semantic performance, yet enhanced phonological performance in recall tasks may be causally related (Mottron & Burack, 2001). In their model of information processing in autism, Mottron and Burack propose that defective processing of higher-order functions results in a developmental compensation mechanism that enhances the processing of lower-level functions. In the case of the performance of children with autism in recall tasks, difficulties with encoding the meaning of words would result in a bias towards encoding the phonological features of words.

Although many studies have attributed the lack of semantic memory effects in the autistic population to poor *encoding*, there remains another possibility for their pattern of performance in these tasks. That is, the impairment may instead relate to difficulties in retrieving information from the storage system. For example, recall of a false item in Beversdorf et al.'s (2000) study is reliant upon the participant firstly identifying that the items have a common theme, and then using this theme as a retrieval strategy. It is possible that the participants with autism were able to encode the semantic information, but had difficulty in using this knowledge to facilitate their recall. Similarly, recalling items in semantic clusters is not simply dependent upon recognizing the semantic content of words, but using the semantic content as a strategy for recall.

The ‘poor retrieval strategy’ account of the semantic processing deficit in the autistic population is consistent with results from studies that have investigated fluency. Fluency is assessed by asking participants to generate as many words as possible that meet a certain criterion. Studies have found that tasks which require participants to generate items from a particular semantic category or starting with a particular letter of the alphabet, fail to show differences between participants with autism and typically developing children (Boucher, 1988). In contrast, tasks where the category is more ambiguous, requiring that participants formulate their own retrieval strategies, do show differences (Bishop & Norbury, 2005; Boucher, 1988; Turner, 1999). For example, when asked to ‘generate any words they can think of’, children with autism recall significantly less words than controls (Boucher, 1988). Similarly, children with autism show impairment on ‘ideational fluency’ tasks, where they are told to generate as many uses for an ambiguous object as possible (Turner, 1999).

Tasks of cued recall provide an ideal method of investigating the notion of poor retrieval strategies. If individuals with autism have difficulties with retrieval and not encoding, they should perform comparably with controls when given assistance with recall in the form of a cue. A handful of studies have provided evidence that individuals with autism can indeed use cues to facilitate their recall.

The studies by Boucher and Warrington (1976) and Tager-Flusberg (1991, Experiment 2), which examined cued recall in children with autism and ability matched controls, adopted a very similar design. Participants in both studies were presented with, and asked to remember, a list of semantically unrelated words. After a filler task, the participants were asked to recall as many words as they could. Following this, the participants received a cue for each word that was not recalled. In one condition, the participants were given phonological cues (the visual presentation of the word’s onset in Boucher and Warrington, e.g., CHA___; the oral presentation of a rhyme in Tager-Flusberg, e.g., ‘I said a word that sounds like____’). In the other condition, the participants received semantic cues (e.g., either functional cues: ‘It is something you sit on’ or taxonomic cues: ‘I said a word that was a kind of____’). In contrast to the findings from studies that manipulated encoding conditions (Mottron et al., 2001; Toichi & Kamio, 2002), individuals with autism in both studies showed the same amount of memory facilitation with both semantic and phonological cues as the ability-matched control groups. That there was no difference in the performance of the two groups when cues were provided, indicates that individuals with autism may have a deficit in retrieval rather than encoding.

While the findings raise the possibility that participants with autism can perform as well as typically developing individuals under certain conditions, they leave open the question of whether limited recall of children with autism, when it is observed, is due to poor retrieval strategies or due to poor encoding. The current study sought to address this issue by examining the encoding abilities of those with autism through a novel cued-recall task.

As with previous cued-recall tasks (Boucher & Warrington, 1976; Tager-Flusberg, 1991, Experiment 2) participants were asked to remember a list of words. However, instead of the stimulus list including unrelated items, in this study half of the items were in some way related. In one condition, half of the items had a common semantic theme, and in the other condition, half of the items had a common phonological feature. Following a filler task, the participants were presented with a cue (highlighting the appropriate commonality) and were required to recall as many items that satisfied the cue as possible. This design allowed an investigation of encoding while controlling for the possibility of poor retrieval strategies by those with autism.

However, prior to an investigation of children with autism, it was necessary to establish the validity of this novel task in an experiment testing the performance of typically developing children of various ages. Verbal encoding is known to follow a developmental trend where the efficiency with which the semantic content of verbal information is processed increases in step with verbal ability (Gitomer, Pellegrino, & Bisanz, 1983; Taylor & Eals, 1996). If, as we assume, the current task examines encoding ability, then it was expected that the performance of typically developing children, especially in the semantic condition, would reveal an increasing developmental trend.

EXPERIMENT 1

Method

Participants

Eighty participants were recruited from one government and two private schools and comprised 20 participants from each of (1) Grades 2 and 3, (2) Grades 4 and 5, (3) Grades 7 and 8, and (4) Grades 10 and 11. Because the main focus of this study was investigating children with autism, a population among which there is a predominance of males, it was decided to enlist only male participants for this study. Teacher reports indicated that all participants were developing typically, with no evidence that any child had a neurological or developmental disorder. The participants' characteristics are reported in Table 1.

Table 1

Descriptive statistics for age (years; months) for the grade 2/3, grade 4/5, grade 7/8 and grade 10/11 groups.

Group	N	Range	Mean	SD
Grade 2/3	20	7;1-8;4	7;7	0;5
Grade 4/5	20	8;5-10;3	9;3	0;6
Grade 7/8	20	12;0-13;9	12;9	0;7
Grade 10/11	20	15;0-16;7	15;8	0;5

Apparatus

The experimental tasks were conducted on a NEC laptop computer and required the Microsoft Powerpoint XP computer program.

Design and Procedure

On each trial, the participant was asked to remember a list of 20 words. These words were presented individually on the laptop computer, in size 80 Arial font, at the rate of one every two seconds. Ten of the words in the stimulus list were in some way related (the subset). The words were presented in random order with the constraint that no more than two items that were part of the subset were presented consecutively. The participant was then asked to complete a one-minute filler task (a ball maze task). Following the filler task, the participant was asked to recall only those stimulus items that belonged to the subset.

In total there were four trials: two trials with a semantically related subset (animals and fruit) and two trials with a phonologically-related subset (words that had 'st' and 'ca' onsets). The stimulus items are included in Appendix A. The number of subset items recalled by each participant served as the dependent variable.

For each trial, the items within the subset were matched with the remaining words on concreteness, word familiarity, imagery and word frequency (MRC psycholinguistic database, Coltheart, 1981). The cued and non-cued words were matched across lists on these same parameters.

Each participant was tested individually in a quiet room at his school. There were two sessions, each containing two trials, one with a semantic subset list and the other with a phonological subset list. The order of the two list types was balanced across sessions. There was approximately 30 minutes between trials within a session, and approximately 6 to 8 days between sessions.

Results and Discussion

A 4 (age group) x 2 (condition) mixed ANOVA was conducted to determine whether the performance of typically developing children followed a developmental trend. The means and standard errors are presented in Figure 1.

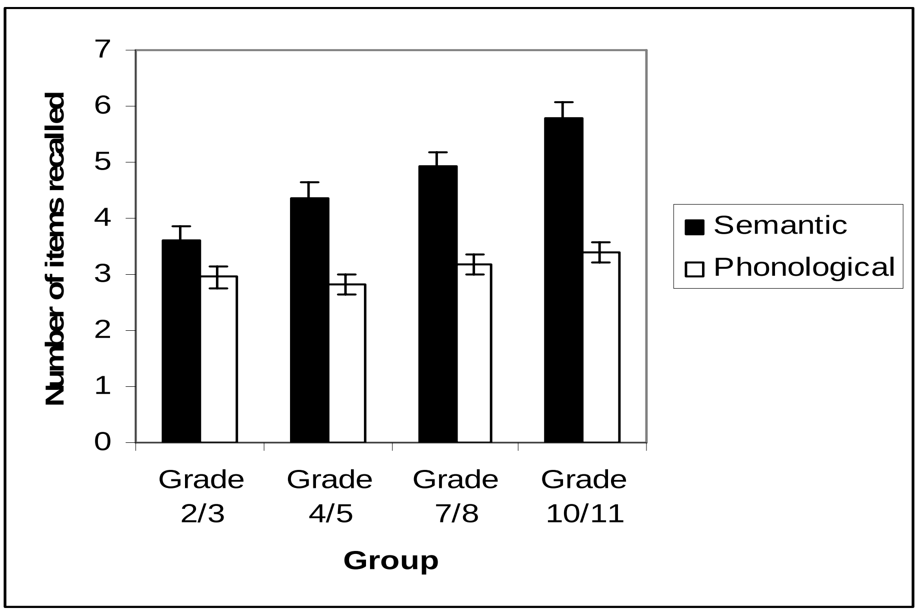

Figure 1.

Mean number of items recalled by the grade 2/3, grade 4/5, grade 7/8 and grade 10/11 groups, in the semantic and phonological conditions. (Error bars represent one SE of the mean.)

There was a main effect for condition, $F(1,76) = 150.15$, $p < 0.001$, indicating that across the four groups more items were recalled in the semantic condition than the phonological condition. There was also a main affect for age, $F(4,76) = 17.49$, $p < 0.001$, indicating that the number of items recalled increased along with chronological age. There was an interaction between condition and age, $F(4,76) = 8.8$, $p < 0.001$. To investigate the nature of the interaction, difference scores were calculated for the two conditions, and trends calculated as a function of age. Only the linear trend was significant, $F(3,76) = 20.39$, $p < .001$, reflecting the more pronounced improvement with age in the semantic condition.

Experiment 1 demonstrated that recall performance in the semantic condition increases with age, and at a more pronounced rate than recall in the phonological condition. This result is consistent with studies of typically developing individuals that have demonstrated an increase in the proficiency of semantic encoding with age (e.g., Taylor & Eals, 1996). Hence, this supports our assumption that the current task serves as a valid assessment of verbal encoding ability. Accordingly, the next experiment used this task to examine the encoding abilities of children with autism.

EXPERIMENT 2

The recall performance of children with autism was compared with that of ability-matched controls. If individuals with autism have poor encoding of semantic information, they will not recall as many items as the control participants, even when they are cued to employ a semantic strategy. If, however, individuals with autism have stronger encoding of the phonological features of words, then under conditions cuing a phonological strategy, they should show increased recall in comparison with the control group. On the other hand, if the participants with autism have appropriate encoding abilities, but have difficulty retrieving information, we would expect the provision of recall cues to ameliorate these difficulties and consequently lead to similar levels of recall for the two groups in both conditions.

Method

Participants

Each of the 20 children with autism had been diagnosed with autism based on DSM-IV guidelines by at least two of a paediatrician, psychologist and a speech pathologist. In addition to this, ten of the group, selected at random, were administered the Autism Diagnostic Interview – Revised (Lord, Rutter, Le Couteur, 1994) to confirm their diagnosis. All diagnoses were confirmed. A control group of 20 typically developing children was recruited from various primary schools. Control participants were included in the study only if their teacher reported no neurological or developmental disorder. All participants were male. The two groups were matched on verbal age, $t(38) = 0.27$, $p = 0.79$, non-verbal age, $t(38) = 1.43$, $p = 0.16$, and reading ability, $t(38) = 1.61$, $p = 0.12$, but not chronological age, $t(38) = 5.85$, $p < 0.001$. The participants' characteristics are reported in Table 2.

Table 2

Participant details for the autism and control group, Experiment 2.

	CA	VA	RSPM Score	Reading Score
Autism				
M	10;11	9;5	38.1	78.3
SD	1;9	2;10	6.7	4.1
Control				
M	8;4	9;2	35.5	75.5
SD	0;10	1;5	4.7	6.8

Note: *CA: Chronological age; VMA: Verbal mental age; RSPM: Raven's standard progressive matrices. Reading Score: Score on the modified Castles word/non-word test.*

Tests

The age-equivalence measure of the Peabody Picture Vocabulary Test – IIIA (Dunn & Dunn, 1997) was used to match the two groups on verbal ability. Non-verbal ability was gauged using Raven's Standard Progressive Matrices (Raven, Court, & Raven, 1992). Reading ability was examined with the use of a modified version of the Castles word/non-word test (Edwards & Hogben, 1999).

Apparatus and Stimuli

The equipment and materials were as for the first experiment.

Procedure

The procedure was as for the first experiment. We did, however, include an additional check in order to verify that participants did not use a retrieval strategy that would confound results. It was possible that participants 'recalled' words that were consistent with the cue but were not part of the previously presented subset (in effect, using the cue to guess items). False recalls were tallied and compared.

Results

A 2 (group) X 2 (condition) mixed ANOVA was performed to compare the mean number of subset items recalled by the autism and control groups in the semantic and phonological conditions. The means and standard deviations are presented in Table 3.

Table 3

Mean number of items recalled by the autism group and the ability matched control group, in the semantic and phonological conditions.

	Semantic condition		**Phonological condition**	
	M	*SD*	*M*	*SD*
Autism	4.33	1.57	3.20	1.38
Control	3.68	1.56	2.85	1.12

There was a main effect for condition, $F(1,38) = 31.02$, $p < 0.001$, indicating that more subset items were recalled in the semantic condition ($M = 4.00$, $SD = 1.20$) than the phonological condition ($M = 3.03$, $SD = 0.96$). There was no statistically significant main effect for group, $F(1, 38) = 2.98$, $p = 0.09$, nor an interaction between condition and group, $F(1, 38) = 0.73$, $p = 0.40$. While there was no significant main effect for group, there was a trend in both conditions for the individuals with autism to recall more items than the control group (see Table 3).

An analysis was also conducted on the mean number of false recalls in each condition. It appeared unlikely that this would influence the results, as both groups made minimal errors in both the semantic (autism: $M = 0.13$, $SD = 0.28$; control: $M = 0.28$, $SD = 0.44$) and phonological conditions (autism: $M = 0.25$, $SD = 0.47$; control: $M = 0.23$, $SD = 0.38$). A 2 (group) x 2 (condition) ANOVA revealed no statistically significant main effect for group, $F(1, 38) = 0.37$, $p = 0.55$, condition, $F(1, 38) = 0.26$, $p = 0.62$, nor an interaction between these factors, $F(1, 38) = 1.39$, $p = 0.25$.

Discussion

A significant main effect of condition reflected the fact that both groups performed better with semantic rather than phonological retrieval cues. With respect to the control group, this is consistent with previous research demonstrating that, during recall tasks, typically developing children attend to the meaning of words rather than their phonological features (Boucher & Warrington, 1976). With respect to the participants with autism, the findings run contrary to the notion that such individuals have poor encoding of semantic information and, in compensation, show enhanced processing of the phonological features of words. Instead, these findings raise the possibility that the processing bias that individuals with autism demonstrate in recall tasks may be due to poor retrieval strategies.

These findings are interesting in the context of recent literature on semantic encoding in autism. A number of recent studies have found that *adolescents* (*M* chronological age = 14 years, Lopez & Leekam, 2003) and *adults* (*M* chronological age > 18 years, Beversdorf et al., 1998) with autism perform comparably with ability-matched controls in tasks thought to be dependent upon semantic encoding abilities. These findings are in direct contrast with similar studies that have demonstrated poor performance by *children* with autism (both Hermelin & O'Connor, 1970 and Tager-Flusberg, 1991, Experiment 1, *M* chronological age = 11 years). Researchers have reconciled these conflicting findings by suggesting that individuals with autism do indeed acquire semantic encoding skills, but on a different developmental time-scale to typically developing children (Lopez & Leekam, 2003; Toichi & Kamio, 2003). That is, individuals with autism develop semantic encoding at a later *developmental* age than typically developing children. The corollary of this notion is that children with autism must undergo a period of 'semantic growth' where their verbal encoding abilities draw level with those of the typically developing population (as demonstrated in the studies by Beversdorf et al., 1998, and Lopez & Leekam, 2003).

The participants in the current study had a considerably lower mean chronological age (*M* = 10; 11) than the participants in the studies by Beversdorf et al. (1998) and Lopez and Leekam (2003). Yet, despite a lower chronological age, the performance of these participants was similar to, if not better than, control children of the same developmental age. Importantly, then, the present findings indicate that if children with autism do indeed acquire semantic encoding abilities on a different developmental time-scale to typically developing individuals, any period of semantic growth has taken place by the time those with autism are in middle to upper elementary school.

ADDITIONAL COMPARISONS

Participants in Experiment 2 were matched on verbal age, non-verbal age and reading ability, but not chronological age. This leaves open the possibility that children with autism experience some other developmental delay in semantic processing to which this study was not sensitive. To address this possibility, we compared the performance of the individuals with autism with *chronological* age-matched controls.

Method

Twenty chronological age controls were compared with the 20 children with autism who participated in Experiment 2. The children in the control group were selected from the grade 4/5 and grade 7/8 groups who participated in the first experiment. Control children were selected and matched individually with each participant with autism, based on their chronological age (no more than two months difference in chronological age was accepted for a matched pair). There was no significant difference between the ages of the autism and control groups (both groups, *M* = 10; 11, *SD* = 1;9), $t(38) = 0.02$, $p = 0.98$.

Results and Discussion

A 2 (group) X 2 (condition) mixed ANOVA was performed to compare the recall performance of the autism and chronologically-age matched control group. The means and standard deviations of the autism and control group are presented in Table 4.

Table 4

Mean number of items recalled by the autism group and the chronological age-matched control group, in the semantic and phonological conditions.

	Semantic condition		**Phonological condition**	
	M	*SD*	*M*	*SD*
Autism	4.33	1.57	3.20	1.38
Control	4.48	1.22	3.10	1.37

There was a main effect for condition, $F(1,38) = 60.98$, $p < .001$, indicating that participants recalled more words in the semantic condition (*M* = 4.40, *SD* = 1.4) than in the phonological condition (*M* = 3.15, *SD* = 1.37). There was no main effect for group, $F(1,38) = 1.21$, $p = 0.28$, nor an interaction between condition and group, $F(1,38) = 2.18$, $p = 0.15$. To investigate the possibility that guessing affected the results, we examined the mean number of errors produced by both groups in each condition. A 2 (group) x 2 (condition) repeated measures ANOVA revealed no statistically significant main effect for group, $F(1, 38) = 0.1$, $p = 0.75$, condition, $F(1, 38) = 1.73$, $p = 0.19$, nor an interaction between these factors, $F(1, 38) = 0.11$, $p = 0.74$.

This comparison extends the findings of Experiment 2 by demonstrating that children with autism encode the semantic and phonological characteristics of words to the same extent as typically developing children of the same chronological age. This finding provides further support against the notion that the atypical processing bias of children with autism is due to poor encoding.

GENERAL DISCUSSION

Individuals with autism have been shown to perform atypically in a range of verbal recall tasks (Beversdorf et al., 2000; Toichi & Kamio, 2002, 2003). Specifically, individuals with autism appear to ignore the meaning of verbal information, instead demonstrating a processing bias for the phonological features of words. What remains unclear, however, is whether this pattern of performance is a product of poor semantic encoding of verbal information or a function of poor retrieval strategies. The current study sought to provide clarity to this issue.

Participants were asked to memorize twenty words, half of which were members of a certain semantic or phonological category. Following a filler task, they were presented with a cue (i.e., the semantic or phonological category) and were required to recall as many items as possible that satisfied the cue. Cuing participants to particular retrieval strategies maximizes the likelihood that any between-groups differences in performance would be related to problems at the encoding stage. Under these conditions, participants with autism performed as well as typically developing participants on both semantically and phonologically focused recall tasks. This finding provides evidence against the notion that the atypical processing bias observed in this population is due to poor semantic encoding.

We sought to extend the findings of the second experiment by determining whether the performance of the children with autism was consistent with typically developing children of the same *chronological* age. No between group differences were observed, providing evidence that children with autism encode semantic and phonological information to the same extent as typically developing children of the same chronological age.

While the results of this study do not support the ‘poor semantic encoding’ account of autism, they are consistent with the notion that children with autism have poor retrieval strategies during recall tasks (i.e., the atypical processing bias that other studies have demonstrated was not obtained when retrieval strategies were controlled between populations). In future research, it would be useful to investigate directly the retrieval strategies of this population. Just as the current task controlled retrieval strategies to investigate encoding ability, a possible means of investigating retrieval methods is to conduct a recall task that controls the encoding methods of both groups. In such an experiment, any between-groups variance could be attributed to different retrieval methods. Some evidence is already available which speaks to this issue. Mottron et al.'s (2001) and Toichi and Kamio's (2002) investigations of 'levels of processing' effects employ this kind of procedure. In both of these studies, the autism group demonstrated a reduced processing advantage for semantic information and an enhanced processing advantage for the phonological condition, relative to the control group. Toichi and Kamio (2002) interpreted this atypical processing bias as representing an "impaired relationship between semantic memory and episodic memory" (p. 28). In the present experiment, however, we found no verbal encoding differences between the autism and control groups. An alternative possibility for why those with autism do not show levels of processing effects may be related to the proposed atypical retrieval strategies of this population. That is, the participants with autism may have indeed achieved 'deeper' encoding with the verbal stimuli in the semantic condition, but they employed retrieval strategies that were unable to capitalize upon this encoding benefit. Future studies examining the retrieval strategies of those with autism could provide clarity to this area.

Future studies could also examine more extensively processing differences *within* the autistic population. It is well-established that there is significant variation in the abilities of individuals with autism and it appears that this is especially relevant to the processing of verbal information (e.g., Hermelin & O'Connor, 1970; cf. Lopez & Leekam, 2003). Research that compares the performance of high and low functioning children with autism in verbal recall tasks, as well as longitudinal studies that examine the developmental trajectory of verbal processing will be important in extending this research.

In summary, this study provides evidence against the notion of poor semantic encoding by those with autism. Specifically, the study showed that participants with autism attend to both the semantic and phonological information of verbal stimuli at similar levels as ability and chronological age-matched controls. Future studies can consolidate and extend these findings through investigations that focus upon how children with autism retrieve items during recall tasks.

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PICTORIAL PROCESSING AND INNER SPEECH IN CHILDREN WITH AUTISM

FOREWORD TO CHAPTERS 3 AND 4

The results of Chapter 2 do not provide evidence that children with autism have atypical encoding of verbal information. The next step in our investigation of the processing abilities of children with autism was to determine whether these individuals gain greater meaning from pictorial rather than verbal information. One task employed in this examination (Chapter 4, Experiment 1) was that of an explicit verbal recall task containing both pictorial and verbal stimuli. For this experimental design, retention typically favours pictures (Paivio, 1991). However, while this 'picture-superiority effect' is well-established in studies of adults (McBride & Dosher, 2002) and the aging population (Winograd, Smith, & Simon, 1982), very little is known of its typical developmental course. Considering that *children* with autism were the focus of this thesis, it was necessary to conduct an initial investigation as to how typically developing children perform in this task. Chapter 3 sought to provide baseline data for the performance of 80 typically developing children of various ages on this recall task, in order for more accurate predictions of the performance of children with autism to be made.

The first experiment of Chapter 4 then compared the performance of children with autism and ability-matched controls on this task of picture and word recall. If children with autism have greater facility with processing pictorial relative to verbal information, it was expected that these participants would show a picture-superiority effect that is equivalent to, or greater than, that of a typically developing comparison group. However, according to Paivio (1991), pictorial recall-superiority results from one's ability to encode pictorial information through two routes: an image pathway and a verbal pathway. From this perspective, the picture-superiority effect is contingent upon the use of inner speech, in particular, one's ability to generate of a phonological code for pictorial information. Evidence that children with autism have inner speech difficulties (Russell, Jarrold, & Hood, 1999) created a competing expectation as to the performance of the autism group, that is, children with autism should show a lesser picture-superiority effect relative to typically developing controls. The second experiment reported in Chapter 4 extended this investigation, by providing a direct examination of the extent to which children with autism generate an internal verbal code for pictorial information.

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Chapter 3

The development of the picture-superiority effect

ABSTRACT

When pictures and words are presented serially in an explicit memory task, recall of the pictures is superior. While this effect is well-established in the adult population, little is known of the development of this picture-superiority effect in typical development. This task was administered to 80 participants from middle childhood to adolescence. The magnitude of the picture superiority effect increased with age. This finding is interpreted as supporting the position that pictorial superiority is contingent upon the encoding of pictorial information through two different routes.

It is widely recognized that information processing can be advantaged by engaging different 'levels' of the cognitive system (Craik & Tulving, 1975). If processing engages the 'deeper' semantic levels, information is retained better than if only 'shallow' levels such as perceptual recognition are activated (Craik & Tulving, 1975). Pictures are one source of information believed to engage deeper levels of processing (McBride & Dosher, 2002). When print and pictorial information are contrasted in an explicit verbal recall task, retention favours pictures. This effect, known as the picture-superiority effect, has been well-replicated and extensively discussed (see McBride & Dosher, 2002, for a review).

A number of theorists have attempted to provide explanations for the picture-superiority effect (see McBride & Dosher, 2002). One account that has been particularly influential is Paivio's dual-coding theory (Paivio, 1991). This theory proposes that pictures hold an advantage over words because they are amenable to semantic encoding through two different routes. Whereas words are processed only through a verbal pathway, Paivio claims that pictures access an image pathway in conjunction with the verbal code. That is, when processing an image, people not only attend to its visual features, but also spontaneously (internally) verbalize its label. The dual-coding of pictorial information facilitates access to the semantic store and hence increases the strength of encoding.

While the picture-superiority effect is well-established in studies of adults, very little is known of its developmental course. This gap in our knowledge is surprising in light of evidence suggesting a dominance of pictorial over print information in childhood (Rosinski, Pelligrino, & Siegal, 1977).

Pictures directly represent features of objects and as such, meaning can be gained from pictorial stimuli even if one has little experience with the objects depicted – such as in the case of the child (Cox, 1992; Hochberg & Brooks, 1962; Rosinski et al., 1977). In comparison to pictures, words are arbitrary symbols, and processing them semantically is contingent upon adequate linguistic and conceptual development (Clark, 1995). As children's language proficiency develops there is likely to be a shift in the facility with which verbal information, relative to pictorial information, invokes deeper levels of coding. Evidence for this shift has come from a number of developmental studies, which have used a variety of psychological and electrophysiological paradigms (Gibson, Barron, & Garber, 1972; Gitomer, Pellegrino, & Bisanz, 1983; Rosinski et al., 1977; Taylor & Eals, 1996).

This evidence could lead to the expectation that the picture-superiority effect would be at its greatest during early to middle childhood, because of the primacy of pictorial information. In due course, increasing skills in language, including rapidly expanding vocabulary knowledge (Clark, 1995), might be expected to reduce the discrepancy (i.e., the scale of the picture superiority effect). So, while pictorial information may retain some advantage, children's improving competencies in the verbal domain should facilitate word recall and narrow that advantage. However, in light of dual coding theory (Paivio, 1991), an alternative possibility emerges.

Paivio's dual coding theory of the picture-superiority effect presupposes that pictures are encoded through two routes, the image pathway and the verbal pathway. A corollary of this proposal is that both pathways must be functioning in order for the effect to be obtained. While not explicitly discussed by Paivio, it may be extrapolated that the use of the verbal route for pictorial stimuli depends on the availability of inner speech, whereby the labels of pictures are spontaneously but covertly articulated. If an individual is unable to spontaneously formulate an inner verbal representation of a given stimulus, then he or she would not engage in dual coding.

Importantly, inner speech is not available from the beginning of life. Vygotsky (1962) proposed that it begins to develop via 'self talk'. Self-talk occurs when one audibly talks to oneself in going about daily activities. Self-talk is generally most frequent around the preschool years (Bivens & Berk, 1986). Through the early elementary school years, children begin to internalize their self-talk via whispers and/or inaudible muttering (Bivens & Berk, 1990). Eventually these verbal activities are completely internalized and the result is 'inner speech' (Winsler & Naglieri, 2003). From this point, the proficiency of inner-speech and the variety of functions it serves increase in step with language development (Winsler & Naglieri, 2003). With regard to the picture-superiority effect, it is possible that the development of inner speech increases the likelihood with which the labels of pictures are spontaneously named, and thus the likelihood of dual coding of pictures. Consistent with this proposal, Cycowicz, Friedman, Rothstein and Snodgrass (1997) found that, when presented with a series of pictures, young children have a higher 'failure to name' rate than young adults.

The purpose of this study was to examine the change, if any, in the picture-superiority effect across childhood and into adolescence. A 'priority of pictorial processing' account leads to the expectation that the picture-superiority effect should be at its strongest in younger age-groups and should decrease as linguistic processing proficiency increases. In contrast, if inner speech is a relatively protracted developmental achievement, then forming a dual representation of a stimulus via image and verbal pathways should be less readily accessible to younger persons but become more natural with the internalization of speech. It follows from this latter perspective that, through childhood, the picture superiority effect should become increasingly pronounced with age.

METHOD

Participants

The 80 participants were recruited from one government and two private schools and comprised 20 participants from each of (1) Grades 2 and 3, (2) Grades 4 and 5, (3) Grades 7 and 8, and (4) Grades 10 and 11. All participants were male. Descriptive statistics for the samples are displayed in Table 1.

In the youngest age group (1), participants were included only if their teacher indicated that their reading skills were adequate for the task demands of the study. To confirm reading competence, each child in this age band was administered the modified version of the Castles word/non-word test (Edwards & Hogben, 1999). Participants were included in the study only if they were able to read at least two-thirds of the 90 words in this test (60 items).

Participants were included in the older age groups (groups 2, 3 and 4) if their teacher indicated that their reading skills were 'not atypical for their age'. Average performance for an 8-year-old (the youngest participant in group 2) on the modified version of the Castles word/nonword reading test is roughly 70 correct items, well above the 60 item threshold for inclusion in this study. For this reason, the older participants were not administered the reading test.

Table 1.

Descriptive statistics for age (years; months) for the four groups.

Group	N	Range	Mean	SD
Grade 2/3	20	7;1-8;4	7;7	0;5
Grade 4/5	20	8;5-10;3	9;3	0;6
Grade 7/8	20	12;0-13;9	12;9	0;7
Grade 10/11	20	15;0-16;7	15;8	0;5

Apparatus and Stimuli

The experimental task was conducted on an ACER TravelMate laptop computer. Snodgrass and Vanderwart's (1980) set of standardized pictures, and the words they commonly connote, were used as stimuli. The pictures are black and white line drawings, and were presented in jpg graphic format. Each item was presented in the middle of the screen. Words were in size 80 Arial font and pictures were 7.08 cm square. Items were presented individually at the rate of one every 2 s.

There were three trials, each using a different 20-item stimulus set, with each set divided into two 10-item subsets. The subsets were used to counterbalance the use of items in print and pictorial form. Thus, half of the participants in each age group received one subset of items as pictures and the other subset as words, whereas the remaining participants received the two item subsets in their alternate modalities. The stimuli were selected so that in each subset there were no more than two semantically or phonologically similar items. The stimulus items were matched, between sets (and also between subsets), on the familiarity and name agreement of the pictures, as normed by Snodgrass and Vanderwart (1980), as well as on measures of concreteness, word familiarity, imagery and word frequency, as reported in the MRC psycholinguistic database (Coltheart, 1981). The stimulus items are included in Appendix B.

Design and Procedure

Participants were tested individually in a quiet room at their school, sitting approximately 80cm from the screen. The task was administered along with several other unrelated tasks in two sessions separated by 6 to 8 days. The first two trials were administered in the first session, separated by approximately 30 minutes of other testing, and the third trial was administered in the second session.

For each trial, participants were asked to remember a stimulus list. Specifically, the participants were told that they would "see a series of pictures and words appear on the screen one after another" and they were to "remember as many of the items as possible". As described above, each list contained 10 picture and 10 print stimuli. The items were presented in random order with the constraint that no more than two stimuli in the same modality were presented consecutively. After the presentation of the stimuli, each participant was given a one minute filler task (a ball maze task). Following the filler task, participants were asked to recall orally as many of the study items as possible. One minute was allowed for recall, and no feedback other than general encouragement was given during this period.

Participants were awarded one point for each stimulus item that was recalled. A point was also awarded for a synonym of the name commonly associated with a picture stimulus. Possible synonyms for the picture stimuli were based on guidelines in Snodgrass and Vanderwart (1980). Synonyms were not accepted for the word stimuli.

RESULTS

A 4 (age group) x 2 (modality: pictures vs. words) mixed ANOVA was performed on the mean number of items recalled, calculated across the three trials (maximum 10). Means and standard errors for recall as a function of age group and modality are presented in Figure 1.

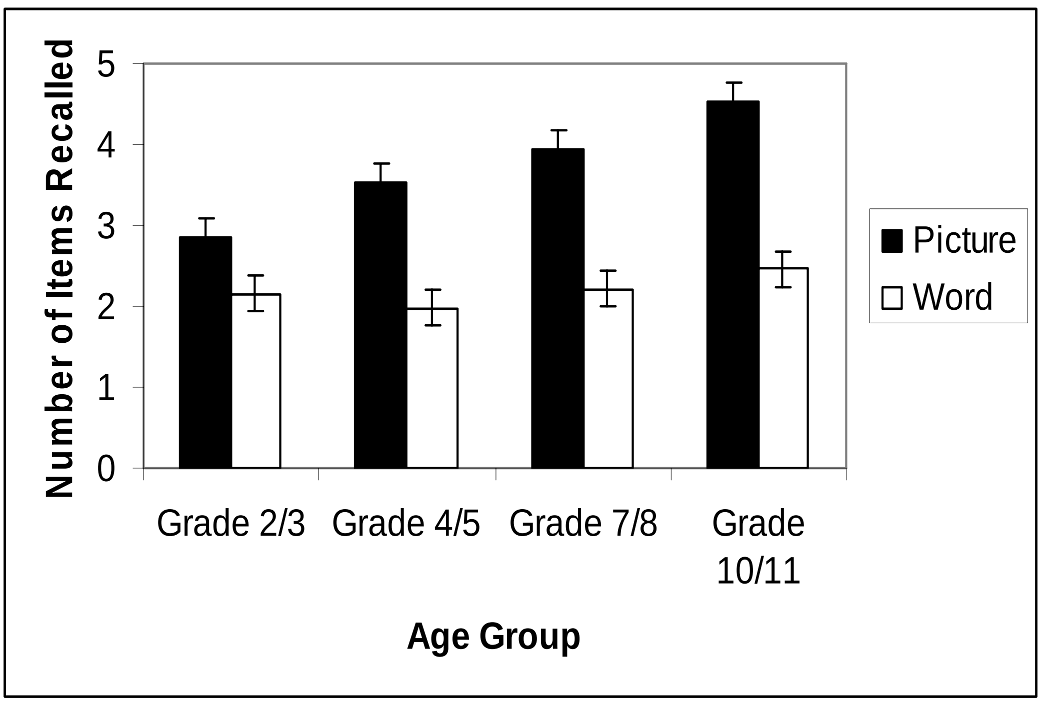

Figure 1.

The mean number of pictures and words recalled for each of the four age groups. (Error bars represent one SE of the mean.)

This analysis revealed a main effect for modality, $F(1, 76) = 118.38$, $p < 0.001$, a main effect for age group, $F(3, 76) = 7.97$, $p < 0.01$, and an interaction between these two factors, $F(3, 76) = 4.54$, $p < 0.001$. When the data were expressed as a difference score (i.e., the difference in recall between the modalities), there was a significant linear trend as a function of age, $F(1, 76) = 2.9$, $p < 0.01$, but the quadratic, $F(1, 76) = 0.63$, $p = 0.45$, and cubic trends, $F(1, 76) = 0.35$, $p = 0.67$, were non-significant.

A related samples t-test was performed for each age group to examine modality differences in recall. Significantly more pictures were recalled in each group: Year 2/3 [$t(19) = 2.60$, $p < 0.05$], Year 4/5 [$t(19) = 4.87$, $p < 0.001$], Year 7/8 [$t(19) = 7.04$, $p < 0.001$] and Year 10/11 [$t(19) = 7.42$, $p < 0.001$].

Those oral responses that the participants gave during the recall phase that were not actually part of the stimulus list were tallied and examined. A one-way between-groups ANOVA was performed to examine differences in the number of these intrusion errors across the four groups. There were no significant differences among the groups, $F(3, 76) = 1.08$, $p = 0.36$.

DISCUSSION

The aim of this experiment was to examine the change in the picture-superiority effect in different age groups from middle childhood to adolescence. While all groups showed better recall of pictorial relative to word stimuli, and hence demonstrated the picture superiority effect, this effect increased in step with chronological age. This finding contrasts with the assumption that the priority in processing pictorial information is at its strongest during childhood, and instead indicates that in explicit memory tasks, picture/word processing differences may be related to the concurrent development of another cognitive factor.

We considered the possibility that our results are due to the younger groups generating atypical names for the pictorial items during either the encoding or the recall phase of the task (perhaps because of poor expressive vocabulary skills). However, there were no differences in the frequencies of recall errors between groups, indicating that picture-labelling errors were unlikely to have influenced the results.

While the increase in the magnitude of the picture-superiority effect across age does not support the ‘priority of pictorial processing’ hypothesis, the results are consistent with the proposal that the picture superiority effect reflects the increasing availability of inner speech and its application to the task of remembering the pictorial stimuli that are encoded via two routes simultaneously (Paivio, 1991). Some inner speech may be available to early school-age children but it is used with increased proficiency among older children and adolescents (Bivens & Berk, 1990). Thus, a relatively small picture superiority effect is obtained at Grades 2/3 and a more substantial effect is obtained by adolescence.

It is important to mention, however, that this study did not include any direct measurement or manipulation of inner speech and thus there may be alternative possibilities for the pattern of findings observed. For example, it is possible that the increase in the magnitude of the picture-superiority effect is due to the development of different recall strategies. With increasing age, strategic behaviour emerges and becomes more efficient and organized (Woody-Dorning, & Miller, 2003). It is plausible that the increasing facility with pictorial stimuli observed in this study is due the protracted development of effective storage and retrieval strategies. Similarly, the observed pattern of results may be due to the development of general semantic processing skills. Consistent with dual route theory (1991), pictures elicit both an image and verbal code, while words elicit a verbal code only. It is possible that a general developmental increase in semantic processing skills would produce an additive effect in the strength of the two codes elicited by pictorial stimuli, resulting in proportionately greater increase in the recall for pictures compared to words.

This notwithstanding, future studies could confirm the proposal advanced in this study by directly examining the change in the use and proficiency of inner speech across development. Some indirect support for the involvement of verbal coding in the development of the effect is that a reduced picture superiority effect has been established for children with autism (Whitehouse, Maybery & Durkin, 2005), a population argued to be characterized by limited development of inner speech (Russell, Jarrold & Hood, 1999).

In summary, the magnitude of the picture-superiority effect increased with age from middle childhood to adolescence. This finding did not support the hypothesis that younger children would show a greater picture-superiority effect due to the primacy of pictorial information. The finding is compatible with the argument that the picture superiority effect is dependent upon dual coding and that this in turn is dependent upon the use of inner speech.

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Chapter 4

Inner speech impairments in autism 1: Evidence from tasks of pictorial memory

ABSTRACT

Background: Inner speech is thought to be a component of executive functioning skills. While deficits in executive functioning in those with autism are well-known, very little research has examined their inner speech capabilities. Two experiments using explicit recall tasks investigated a potential inner-speech limitation and a countervailing advantage for processing pictorial information in this population.

Methods: The first experiment compared children with autism (N = 20) with ability-matched controls (N = 20) on a verbal recall task where the stimulus lists contained pictures and words. The second experiment (N = 23 per group) used pictures for which the typical names were either single syllable (short) or multi-syllable (long), and two encoding conditions were designed to differentially promote the use of verbal encoding.

Results: Children with autism demonstrated a reduced picture-superiority effect compared to controls in Experiment 1. In Experiment 2, relative to the comparison group, the children with autism showed a reduced word-length effect in a condition where pictures were presented alone, but a more substantial word-length effect in a condition where overt labelling was required.

Conclusions: Impairment in the use of inner speech appears to limit the availability of verbal codes for pictorial stimuli in individuals with autism.

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Children with autism demonstrate varying levels of linguistic ability, typically showing late onset of language and major deficits in semantic, pragmatic and conversational performance, but achievement of syntactic and phonological proficiencies (Ziatas, Durkin, & Pratt, 2003). Research focusing on the expressive and receptive language characteristics of children with this disorder has now spanned several decades (Kjelgaard & Tager-Flusberg, 2003). The difficulties that persons with autism appear to experience in representing mental states has led to a particular focus on the relationships among language development, social understanding and social interaction (e.g. Ziatas et al., 2003). Despite the recognition of the integral importance of language in the disorder, however, some aspects of linguistic processing have received much less attention. Inner speech is one component of language that has seldom been the focus of autism research.

It is now well-established that the functions of language are not restricted to external, interpersonal communications (Carruthers, 2002). Covert, self-directed language plays an important role in cognitive processes and in the regulation of behaviour (Carruthers, 2002). Vygotsky (1962) proposed that inner speech serves as a tool for planning, monitoring and guiding behaviour towards the attainment of goals. Luria (1969) elaborated this account by relating inner speech to cognitive meta-awareness. He proposed that inner speech allows a unique type of meta-awareness that facilitates the identification of goals as well as the most relevant course of action.

Recently, researchers have shown renewed interest in the relationship between inner speech and self-guidance. Due to the difficulty in providing an objective measure of ‘internal’ language, investigations have typically focused on a developmental precursor to inner speech: private speech. Private speech – overt speech directed to oneself - is seen as an intermediate link in the process of language internalization (Bivens & Berk, 1990). As such, private speech provides a clear behavioural indicator of a developmental shift, from the use of language primarily as a tool to communicate with others, to a means of regulating one’s own behaviour.

There is evidence of the importance of self-directed speech in behavioural regulation in that the use of private speech typically increases during periods of goal-directed activity (Winsler & Diaz, 1995). Furthermore, the quality of task performance is positively correlated with the frequency (Berk & Spuhl, 1995) and awareness (Winsler & Naglieri, 2003) of private speech. There is considerable evidence to suggest that it is especially the internalization of self-directed speech that is important in behavioural self-regulation (Diaz & Berk, 1992; Winsler, Diaz, McCarthy, Atencio, & Chabay, 1999). This evidence comes particularly from observations of ‘partial internalizations’ - such as inaudible muttering, whispers, and silent verbal lip movements - which are thought to represent an attempt by the child to internalize self-directed speech. While overt self-directed speech is able to guide simple behaviours, as task difficulty increases, the time-consuming process of vocalization does not allow language to be manipulated in a way that can accommodate rapidly changing environmental demands. Without some of the demands of overt speech, inner speech places fewer restrictions on the level of task difficulty that can be accomplished (Vygotsky, 1962). As the child develops and progresses into school, there are also increasing social prohibitions on overt self-directed speech.

In comparison with typically developing children, preschool aged children with behavioural problems (as rated by the children’s teachers based on DSM-III-R diagnostic criteria for Attention Deficit Disorder – Hyperactivity) show a *greater* amount of overt self-directed speech (Barkley, 1997; Winsler, et al., 1999), but lesser use of partially internalized speech (Berk & Potts, 1991; Winsler, 1998). Similarly, in a longitudinal study, Winsler, de Leon, Wallace, Carlton and Willson-Quayle (2003) found that children who demonstrated more partial internalizations presented subsequently with better social skills and fewer behavioural problems, while poorer behavioural outcomes were seen in those children with predominantly overt self-directed speech.

Behavioural regulation is generally understood to be under the control of the collection of cognitive processes known as executive functions. Capabilities thought to be involved in executive control include planning, the ability to shift sets and cognitive flexibility (Hill, 2004). The similarities between the operations of inner speech and executive function are striking and, indeed, recent studies have illuminated the mediating role that inner speech plays in executive control (Baddeley, Chincotta, & Adlam, 2001; Cinan & Tanor, 2002).

Autism is characterized by executive impairments in planning, mental flexibility, and self-monitoring (Hill, 2004). However, despite the accumulating evidence of a relationship between executive function and inner speech, few studies have examined the use of inner speech by individuals with autism. An exception is the work of Russell, Jarrold and Hood (1999). These investigators provided one piece of evidence for an inner speech deficit in the autistic population in showing that, when their use of inner speech is interrupted (through requiring a verbal response), the performance of typically developing children on a task of executive function is comparable to the performance of those with autism. This, of course, is in contrast with the typically superior performance of typically developing children in comparison to children with autism on tasks of executive function when inner speech is not interrupted. However, without a direct measurement of the inner speech capabilities of those with autism, this interpretation remains speculative.

One method of investigating inner speech is through recall tasks that include pictorial information. When print and pictorial information are contrasted in a verbal recall task, retention typically favours pictures. This effect, known as the picture-superiority effect, is well-replicated and has been observed in children as young as 7 years (Whitehouse, Maybery, & Durkin, in press). While a number of theorists have attempted to explain the picture-superiority effect (see McBride & Dosher, 2002, for a review), Paivio's (1991) dual-coding theory has been particularly influential. Paivio proposed that pictures hold an advantage over words because they are amenable to semantic encoding through two different routes. Whereas words are processed only through a verbal pathway, Paivio claims that pictures access an image pathway in conjunction with the verbal route. That is, when processing an image, people not only attend to its visual features, but also spontaneously (internally) verbalize its label. The dual-coding of pictorial information facilitates access to the semantic store and hence increases the strength of encoding. From this perspective, the picture-superiority effect is contingent upon inner speech, and limitation in the use of inner speech, such as that proposed in the autistic population, would lead to a reduced picture-superiority effect.

Intriguingly, however, there is evidence that children with autism have enhanced facility with processing pictorial relative to verbal information. Kamio and Toichi (2000), for example, conducted a cross-modal associative priming study of young adults with autism and an age-matched control group. Target items were word fragments, with half having word primes and the other half picture primes. Whereas control participants showed better priming with verbal rather than pictorial stimuli, individuals with autism were more likely to complete the word fragment if the prime had been a picture. In addition, there are numerous anecdotal reports that people with autism 'think in pictures' (Grandin, 1995; Hurlburt, Happé, & Frith, 1994), and many clinically/experimentally supported intervention methods centre around the use of pictorial stimuli (e.g., Bondy & Frost, 2001).

In respect of the picture superiority effect, evidence of inner speech limitations in those with autism and research into the pictorial processing abilities of this population lead to contrasting expectations. If children with autism have impairments in inner speech, then this would limit the extent to which information is encoded through two pathways, and hence a reduced picture superiority effect (in comparison to a typically developing control group) would be expected. In contrast, if pictures do indeed allow better semantic access than words in the autistic population, we would expect a recall advantage for pictorial compared to word stimuli, and the advantage observed for children with autism should be greater than that observed for typically developing children.

EXPERIMENT 1

Method

Participants

Twenty children with autism were recruited from various sources, such as a state register and private clinics, and 20 typically developing children were drawn from several primary schools. Each child with autism had been diagnosed under DSM-IV guidelines (American Psychiatric Association, 1994). In addition, 50% of the autism sample were randomly selected and administered the Autism Diagnostic Interview – Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994). All of these children had their diagnosis confirmed. Based on teacher report, no control participant had a neurological or developmental disorder. All participants were male. The two groups did not significantly differ on verbal age, $t(38) = 0.27$, $p = 0.79$, nonverbal age, $t(38) = 1.43$, $p = 0.16$, and reading ability, $t(38) = 1.61$, $p = 0.12$, but did differ on chronological age, $t(38) = 5.85$, $p < 0.001$. Participants' characteristics are reported in Table 1.

Tests

Verbal mental age was determined using the Peabody Picture Vocabulary Test – Version IIIA (PPVT; Dunn & Dunn, 1997). Nonverbal ability was gauged using Raven's Standard Progressive Matrices (Raven, Raven, & Court, 2000). Reading ability was examined with the modified Castles word/non-word test (Edwards & Hogben, 1999), which includes regularly spelt words (e.g., drop), irregularly spelt words (e.g., gauge), and non-words (e.g., framp). Participants were included in the study only if they were able to read at least two-thirds of the 90 items in this test.

Table 1.

Participant details, Experiment 1.

	Autism (N = 20)		Control (N = 20)	
	M	*SD*	*M*	*SD*
CA	10;11	1;9	8;4	0;10
VMA	9;5	2;10	9;2	1;5
RSPM Score	38.1	6.7	35.5	4.7
Reading Score	78.3	4.1	75.5	6.8

Note: *CA: Chronological age; VMA: Verbal mental age; RSPM: Raven's standard progressive matrices.*

Apparatus and Stimuli

The experimental task was conducted on an ACER TravelMate laptop computer. Snodgrass and Vanderwart's (1980) set of standardized pictures, and the words they commonly connote, were used as stimuli. The pictures are black and white line drawings, and were presented as 7.08 cm-square jpg images. Words were printed in size 80 Arial font.

There were three trials, each using a different 20-item stimulus set, with each set divided into two 10-item subsets to counterbalance the use of items in print and pictorial form. Thus, half the participants in each group received one subset of items as pictures and the other subset as words; the remaining participants received the two item subsets in their alternate modalities. Stimuli were selected so that in each subset there were no more than two semantically or phonologically similar items. The stimulus items were matched, between sets (and also between subsets), on the familiarity and name agreement of the pictures (Snodgrass & Vanderwart, 1980), as well as on measures of concreteness, word familiarity, imagery and word frequency (Coltheart, 1981). The verbal labels of the stimulus items are included in Appendix B.

Design and Procedure

Participants were tested individually in a quiet room at their school, sitting approximately 80cm from the screen. The task was administered along with several other unrelated tasks in two sessions separated by 6 to 8 days. The first two trials were administered in the first session, separated by approximately 30 minutes of other testing. The third trial was administered in the second session.

For each trial, 10 picture and 10 print stimuli were presented serially (one item every 2 s) in the centre of the screen. Their order was random except that no more than two stimuli in the same modality were presented consecutively. After a one minute ball-maze filler task, the participant was asked to recall orally as many of the study items as possible (i.e., free recall). One minute was allowed for recall, and no feedback other than general encouragement was given.

One point was awarded for each stimulus item recalled. Possible synonyms for the picture stimuli were accepted based on guidelines in Snodgrass and Vanderwart (1980). This same leniency was not given for the word stimuli.

Results

As the autism and control groups were group-matched on the different ability measures, a matching procedure considered less stringent than individual matching, nonverbal ability was included as a covariate in the analyses. Analyses were also conducted without this covariate and the same patterns of significant differences were observed.

A 2 (modality: picture vs. word) x 2 (group: autism vs. control) ANCOVA was performed on the mean number of items recalled, calculated across the three trials (maximum 10). Means and standard errors are presented in Figure 1. There was a significant main effect for modality, $F(1, 38) = 27.30$, $p < 0.001$, but not for group, $F(1, 38) = 0.84$, $p = 0.36$. There was, however, a significant interaction of modality and group, $F(1, 38) = 5.64$, $p < 0.05$.

Exploring this interaction, simple between-groups differences were tested using ANCOVA. The control group recalled significantly more pictures than did the autism group, $F(1, 37) = 9.22$, $p < 0.01$. In contrast, the autism group recalled slightly more words than the control group, although the difference did not approach significance, $F(1, 37) = 0.49$, $p = 0.49$. The control group recalled more pictures than words, $t(19) = 5.36$, $p < 0.001$, whereas there was no significant difference in the recall of pictures and words for those with autism, $t(19) = 2.02$, $p = 0.06$. (It is possible, however, that with a greater sample size, this effect would reach statistical significance).

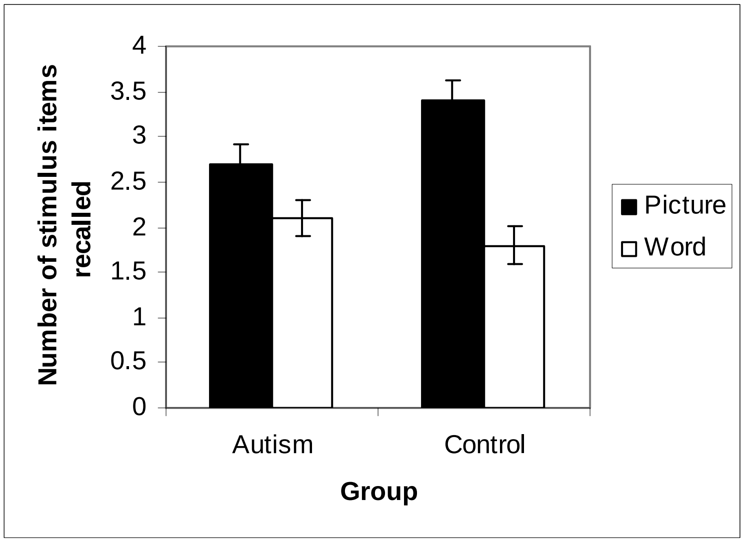

Figure 1.

Mean number of pictures and words recalled by each group. (Error bars represent one SE of the mean.)

We considered the possibility that the recall differences were a result of the different chronological ages between groups. We examined the correlation between the picture-word recall difference and chronological age in each group. While there was no correlation in the autism group ($r = 0.11$, $p = 0.65$), the correlation in the control group approached significance ($r = 0.41$, $p = 0.07$). This near significant correlation supports previous findings of an increase in the magnitude of the picture-superiority, in typically developing individuals, from middle childhood to adolescence (Whitehouse, Maybery, & Durkin, in press). Note that the direction of this trend indicates that it is unlikely that an increase in the magnitude of the picture-superiority effect with age could explain the differences in recall between the two groups. The autism group was considerably *older* than the comparison group, but showed evidence of no more than a marginal picture-superiority effect. As a further check, additional correlational analyses were conducted between the picture-word recall difference and verbal IQ (as determined by the PPVT) in each group. Neither correlation was significant (autism, $r = -0.01$, $p = 0.97$; control, $r = -0.08$, $p = 0.72$). Hence, it seems improbable that verbal IQ differences explain the pictorial advantage restricted to the control group.

Words that the participants provided during the recall phase, but which did not match any stimulus items, were also examined. There was no difference between the autism

($M = 1.2$, $SD = 1.28$) and control group ($M = 1.4$, $SD = 0.99$) in the frequency of these intrusion errors, $t(38) = 0.55$, $p = 0.58$.

Discussion

As expected, and in keeping with the well-established picture-superiority effect, typically developing children recalled significantly more pictures than words. In comparison, the children with autism demonstrated a significantly reduced picture-superiority effect. Furthermore, the children with autism recalled significantly fewer pictures than did the typically developing children, yet recalled more words (though not significantly so) relative to this comparison group. These results are consistent with the hypothesis that, because of a deficit in the use of inner speech, children with autism would not show the clear picture-superiority effect expected (and found) in the control group.

It is unlikely that the group differences could be attributed to one group using atypical names for the pictures. The pictures had high name agreement (93.7%; Snodgrass & Vanderwart, 1980) and, in any case, synonyms were accepted. Also, the two groups were matched on the PPVT, a language measure that requires linking a vocally presented word to its representative picture. Furthermore, we found no group difference in recall errors (intrusions).

The central outcome of the first experiment — that the typically developing control group showed a substantial picture superiority effect but the autism group did not — is consistent with the interpretation (1) that the picture-superiority effect depends on the capacity to exploit dual-route information, a capacity contingent upon access to inner speech, and (2) that individuals with autism have deficient inner speech. However, in the absence of a more direct comparison of the use of inner speech in pictorial processing in the two populations, this proposal remains speculative. For example, it is possible that inner speech was used effectively by the children with autism in labelling the pictures, but the delay between the presentation of the stimuli and the cue for recall (one minute of ball-maze activity) impacted more negatively on their retention of pictorial information (relative to controls), because the children with autism invested greater effort in the filler visuospatial activity. The purpose of the following experiment was to examine the use of inner speech in those with autism and typically developing comparison participants, through a manipulation known to affect the immediate recall of sequences of items when those items are encoded verbally.

EXPERIMENT 2

More words are recalled in an aurally presented verbal recall task if the words are of shorter (e.g., one syllable) rather than longer (e.g., three syllable) spoken duration. This *word-length* effect is extremely robust and has been reported in many populations, including typically developing children of a wide range of reading abilities (Lovatt & Avons, 2001), children with language impairment (Balthazar, 2003), and, significantly, children with autism (Russell, Jarrold, & Henry, 1996).

There is some controversy as to an appropriate explanation for the word-length effect. Various authors have accounted for it as a function of rehearsal time (Baddeley, 1986), output duration (Cowan et al., 1992) and inter-item interference (Hulme, Suprenant, Bireta, Stuart, & Neath, 2004). While the exact basis for the effect remains unclear, that it is dependent on verbal coding is undisputed. For example, when articulatory suppression is used in a recall task with visually presented words, the word-length effect is eliminated, presumably due to the interruption of verbal encoding (Cowan, Baddeley, Elliot, & Norris, 2003).

Several studies have used the word-length effect to investigate inner speech by employing pictures for which there is high name agreement. These studies operate under the assumption that verbal memory effects will be seen only if inner speech is used to label the pictures. Thus, a word-length effect will be evident only if pictorial information is translated into an internal verbal code. Importantly, there is evidence that young children do not spontaneously recode visual information into phonological form. For example, Hitch Halliday, Dodd and Littler (1989) found that children do not demonstrate a word-length effect for pictorial information (which does not obligate one to generate a phonological code) until 7 or 8 years of age, 3 to- 4 years after the effect is observed with aurally presented words (in which the information is already present in a phonological code). This time lag is thought to reflect the delay between children's use of overt language and the development of inner speech.

In Experiment 2, autism and control groups were compared for the serial recall of five-item sequences in which two within-subjects manipulations were encoding condition (silent vs. label) and word length (short vs. long). Pictures were presented for each of the two encoding conditions. The *silent* condition required the participants not to label audibly the pictures during their presentation, and hence there was no obligation to verbally encode the stimuli. In comparison, the *label* condition, which required the participants to overtly label the pictures, encouraged some form of verbal encoding.

It was expected that if children with autism do not spontaneously recruit inner speech to any substantial extent to assist in the processing of pictorial information, they should demonstrate a lesser word-length effect in comparison to ability matched controls in the *silent* condition. They should, however, show an effect more comparable in magnitude to that shown by the comparison group in the *label* condition, which encourages the use of verbal labels.

Method

Participants

The sample of 23 children with autism included 19 of the participants from the first study and 4 additional children who had their DSM-IV autism diagnosis confirmed with the ADI-R. The 23 children in the control group comprised all of the participants from the first study and three additional children with no known neurological or developmental disorder. The two groups did not differ significantly on verbal ability, $t(44) = 0.76$, $p = 0.45$, non-verbal ability, $t(44) = 1.85$, $p = 0.07$, reading ability, $t(44) = 1.37$, $p = 0.19$, and gender (20 males and 3 females in each group), but did differ on chronological age, $t(44) = 6.12$, $p < .001$. The participants' characteristics are reported in Table 2.

Table 2.

Participant details, Experiment 2.

	Autism (N = 23)		**Control (N = 23)**	
	M	**SD**	**M**	**SD**
CA	11;0	1;11	8;4	0;10
VMA	9;9	3;3	9;3	1;3
RSPM Score	38.8	5.58	36.4	3.20
Reading Score	78.87	4.3	76.82	5.64

Note: *CA: Chronological age; VMA: Verbal mental age; RSPM: Raven's standard progressive matrices.*

Apparatus and Stimuli

Tasks were presented on a NEC laptop computer. Stimuli comprised 32 of Snodgrass and Vanderwart's (1980) pictures (4.8 cm-square images), divided into two pools of 16 items based on the number of syllables of the word labels. One pool comprised short (single-syllable) and the other long (3- or 4-syllable) words (see Appendix C). Each trial used five items from one of these pools. Stimulus items were matched across pools and across trial sets on picture familiarity and name agreement (Snodgrass & Vanderwart, 1980). Similarly, the typical verbal labels of these pictures were matched on word familiarity, imagery, concreteness and frequency (Coltheart, 1981).

Procedure

Participants were tested individually in a quiet room in their school or home, seated approximately 80cm from the computer screen. Each trial showed five squares evenly spaced across the screen. Pictures were displayed consecutively (each for 2s) in the squares, working from left to right. In the *silent* condition, the participant was required to remain silent. In the *label* condition, she/he was required to articulate out loud the label of each picture as it was presented. Immediately after presentation of the final picture, the participant was asked to verbally recall the pictures in serial order. That is, immediate serial recall was tested, in contrast to the delayed free recall assessed in Experiment 1.

There were four sets of trials, two for each encoding condition. These sets were administered over two sessions, occurring roughly a week apart. One set for each encoding condition was administered in each session. A set contained six trials, with three trials using short-word items and three using long-word items. These two trial types alternated within each set. The order of presentation of the two encoding conditions was counterbalanced across sessions, as was the order of the short- and long-word trials within each set.

For each trial, one point was awarded for each stimulus item recalled in correct serial position. Possible synonyms for the picture stimuli were accepted based on Snodgrass and Vanderwart (1980). Mislabels were not corrected.

An additional task addressed the possibility that alternative labelling of the pictures (e.g., *rhino* for rhinoceros) could contaminate the manipulation of word length. Following the experimental tasks, the 32 pictures were presented individually and the participant provided the label that she/he "would normally call the picture". For each participant, the mean number of syllables per label was calculated for each of the short- and long-word sets.

Results

The mean number of items recalled per trial was submitted to a 2 (word length) x 2 (encoding condition) x 2 (group) mixed ANCOVA. As with Experiment 1, nonverbal ability was included as a covariate. Unadjusted means and standard errors are presented in Figure 2.

The main effects for word length, $F(1, 43) = 0.01$, $p = 0.94$, encoding condition, $F(1, 43) = 0.05$, $p = 0.82$, and group, $F(1, 43) = 1.09$, $p = 0.30$, were all non-significant. An interaction between group and word length was observed, $F(1, 43) = 35.66$, $p < 0.001$. However, this interaction was qualified by a higher-order interaction among group, word length and encoding condition, $F(1, 43) = 4.14$, $p < 0.05$ (see Figure 2).

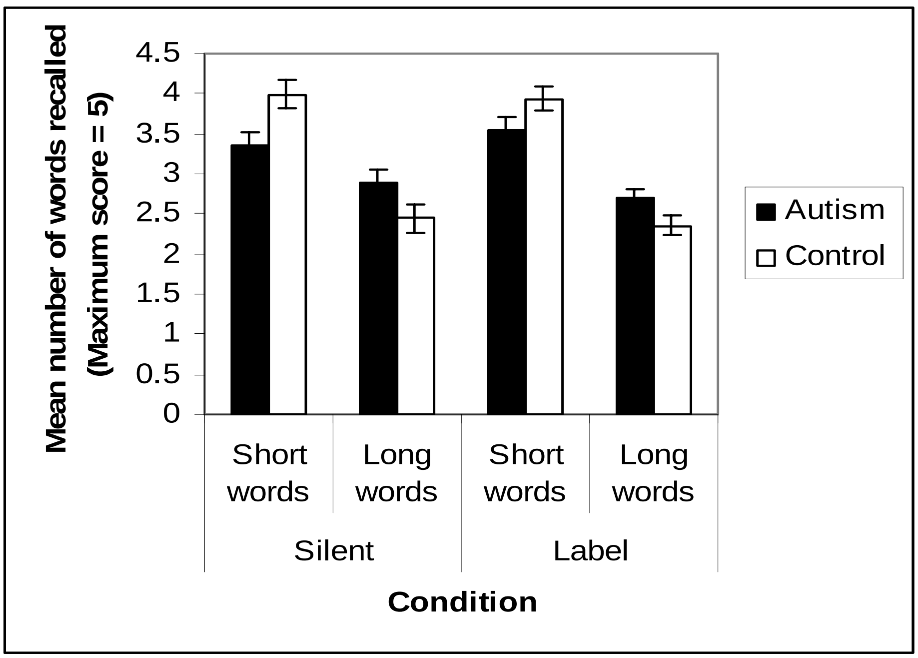

Figure 2.

The mean number of words recalled in each condition, by the autism and control group. (Error bars represent one SE of the mean.)

To follow up the three-way interaction, the group x word length interaction was examined for each encoding condition (using ANCOVA). This interaction was significant for the *silent* condition, $F(1,43) = 33.77$, $p < 0.001$. As expected, the children with autism demonstrated a lesser word-length effect relative to the control children (Figure 2). However, the group x word length interaction was significant for the *label* condition also, $F(1,43) = 12.66$, $p < 0.01$, with the autism group again showing a lesser word-length effect compared to the control group (Figure 2). This is somewhat surprising in that it suggests that, after providing the verbal labels for the pictures, the children with autism did not rely on those labels to the same extent as did the control group in remembering the sequences of items.

To investigate this unexpected outcome, we examined the data from just the autism group to determine if the magnitude of the word-length effect differed for the *silent* and *label* conditions. A 2 (long vs. short) x 2 (silent vs. label) ANOVA revealed a marginally significant interaction, $F(1,22) = 3.80$, $p = 0.05$, reflecting a greater word-length effect in the *label* condition relative to the *silent* condition. When this same analysis was performed for the control group, no interaction was found, $F(1,22) = 0.04$, $p = 0.84$. These outcomes provide some support for our hypotheses because they indicate, firstly, that the participants with autism made less use of verbal encoding in the *silent* condition relative to the *label* condition and, secondly, that the control participants used verbal encoding to a similar extent in these two conditions.

As in Experiment 1, we considered the possibility that the findings were a result of the different chronological ages between groups. We examined the correlation between the short word-long word recall difference and chronological age in each encoding condition (i.e., silent and label) for each group. No correlations achieved significance (silent condition: autism, $r = -0.23$, $p = 0.28$; control, $r = 0.17$, $p = 0.43$; label condition: autism, $r = -0.02$, $p = 0.93$; control, $r = 0.33$, $p = 0.12$). Correlations between the short word-long word recall difference and verbal IQ were also conducted. Once again, there were no significant correlations (silent condition: autism, $r = 0.33$, $p = 0.12$; control, $r = -0.13$, $p = 0.54$; label condition: autism, $r = 0.12$, $p = 0.57$; control, $r = 0.26$, $p = 0.24$).

Finally, to address the possibility that the differences in recall between the groups may be due to differences in syllabic production when naming the stimuli, we conducted a 2 (group) x 2 (stimulus pool: short vs. long) ANCOVA on the mean length (in syllables) of participants' own labels for the pictures. Only the main effect for stimulus pool was significant, $F(1,43) = 119.03$, $p < 0.001$. As expected, participants used a greater number of syllables in labelling the pictures corresponding to the long-word pool ($M = 3.00$; $SD =$

0.04) than in labelling the pictures corresponding to the short-word pool (M = 1.02; SD = 0.15).

Discussion

The findings confirm the hypothesis that during memory tasks involving pictorial stimuli, individuals with autism do not recruit inner speech to the same extent as do typically developing children. This study examined a variant of the typical word-length effect by presenting information in the pictorial rather than the verbal modality. It is assumed that a word-length effect will be seen only if individuals translate the pictorial information into verbal codes. Although the main effect for word-length shows that the participants did recall more short words than long, the three-way interaction among encoding condition, word-length and group indicates that there were important recall differences between the groups.

The instruction for the *label* condition was expected to encourage the use of verbal codes. Hence, it was expected that in these conditions, the two groups would show a comparable word-length effect. The *silent* condition, on the other hand, did not obligate verbal encoding and hence a word-length effect should have been observed only if the participants chose to subvocally name the pictures. Providing support for poor use of inner speech during pictorial processing, the autism group produced a significantly lesser word-length effect compared to the control group in the *silent* condition. This finding contrasts with that of Russell et al. (1996), who demonstrated that children with autism show a word-length effect comparable with that of typically developing children (matched on verbal ability) with aurally presented words.

In contrast to predictions, for the *label* condition, a lesser word-length effect was observed for the autism group relative to the control group. However, further analysis of the data for the autism group did reveal a smaller word-length effect in the *silent* condition relative to the *label* condition. Future research that adapts this task paradigm to examine other verbal recall effects (e.g., the phonological similarity effect; Conrad, 1971) would provide a valuable extension of these findings.

GENERAL DISCUSSION

This study presents some intriguing findings regarding the use of inner speech by individuals with autism in tasks of pictorial memory. The first experiment showed that children with autism demonstrate a significantly reduced picture-superiority effect in comparison to the control group. It was hypothesized that this result was due to impaired inner speech. Using the word-length effect, the second experiment provided further support for the proposal that inner-speech limitations restrict the effectiveness of the verbal encoding route.

Although the findings of the present study do not support the notion of an advantage in pictorial processing in autism, they do not completely exclude the possibility that children with autism are better at encoding and remembering pictures than words. For example, the failure of children with autism to generate a verbal code (in both experiments) may leave them at a disadvantage that more than offsets any pictorial advantage. Furthermore, the tasks in this study required *verbal* recall and hence added a complexity beyond strictly pictorial processing. It is possible that had an exclusively pictorial task been used (e.g., a recognition test), the autism group would have shown a memory advantage.

The notion of an inner-speech deficit characterizing autism was originally advanced by Russell et al. (1999), who believed that this impairment may account for the autistic population's poor performance on tasks of executive function. The current findings extend the implications of the inner speech impairment in the autistic population to pictorial processing. Specifically, the two tasks used in this study offered a processing advantage if the participants generated verbal representations of pictorial stimuli. The reduced memory effect in both tasks indicates that the children with autism did not spontaneously label the pictorial stimuli.

The finding of an inner-speech impairment in the autistic population may have broader implications for understanding this disorder. For example, in the typically developing population, inner speech is known to have strong links with language development, theory of mind and executive dysfunction (Carlson, Moses, & Claxton, 2004; Vygotsky, 1962), which are three well-established areas of deficit in those with autism. Establishing whether inner-speech impairment contributes to these deficits would be a significant addition to the understanding of the cognitive phenotype of autism.

In summary, the possibility of inner speech limitations in individuals with autism was tested. The first experiment showed that children with autism show a substantially lower picture-superiority effect, a finding consistent with the proposal of inner speech deficits (which limits the availability of two routes of encoding for pictorial stimuli). The second experiment examined this proposed limitation more directly using pictures that differed in the syllable length of the names typically assigned to them, and found evidence that children with autism do not spontaneously utilize inner speech to the same extent as typically developing controls when encoding information presented pictorially. Future research should focus on describing the exact nature and extent of the inner speech impairment as well as the possible implications that this impairment may have for the prominent cognitive models of autism.

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INNER SPEECH IN CHILDREN WITH AUTISM

FOREWORD TO CHAPTER 5

The findings of the two experiments reported in Chapter 4 did not support the proposal that children with autism have enhanced facility for pictorial relative to verbal information. Instead, these findings were consistent with the hypothesis that children with autism have limitations in their use of inner speech, in particular, difficulties generating a phonological code for pictorial information. The study reported in Chapter 5 aimed to build upon these findings through an investigation into whether inner speech deficits in the autistic population extend to difficulties with internal planning.

Chapter 5

Inner speech impairments in autism 2: Evidence from a task of mental switching

ABSTRACT

Background: Previous research indicates that children with autism may have a deficit in inner speech, in particular, difficulty generating and rehearsing a phonological code for visual information. This study sought to provide further evidence for an inner speech deficit in those with autism through an investigation of the extent to which these individuals use the internal planning function of inner speech as a tool for behavioural regulation.

Method: Twenty-three children with autism were compared with 23 typically developing children matched on verbal, non-verbal and reading ability. The experiment employed a task-switching paradigm for which performance has been shown to be contingent upon inner speech.

Results: Articulatory suppression affected the task-switching performance of the control participants but not the performance of the individuals with autism.

Conclusions: This result supports previous findings of impaired use of inner speech by those with autism. The implications of this finding are discussed in relation to cognitive models of autism.

The importance of inner speech in social and cognitive development is central to Vygotsky's (1962) theory of development. Whereas Piaget (1952) viewed language as a symptom of the child's underlying cognitive development, Vygotsky saw language, and in particular, the internalization of language, as the force that drives cognitive development. According to Vygotsky, language mediates the child's interaction with the intellectual and social environment, which in turn promotes the development of further skills necessary for self-thought. From this perspective, language is multifunctional, serving as a social-interactive tool and also as an abstract representation for logical reasoning. One corollary is that impairment in the internalization of language is likely to result in significant cognitive and behavioural impairment (Rieber & Carton, 1993).

Although much time has passed since the original publication of Vygotsky's ideas, research has only just started to examine the importance of inner speech in cognitive and behavioural regulation, or as it is known, executive control. With increasing evidence of the mediating role that inner speech plays in executive control (Baddeley, Chincotta, & Adlam, 2001; Cinan & Tanor, 2002), research has started to investigate the inner speech abilities in certain populations known to have executive dysfunction. Autism is one such disorder.

To the authors' knowledge there are two studies that have addressed inner speech deficits in autism. Russell, Jarrold and Hood (1999) examined use of inner speech by individuals with autism in tasks of executive function. According to Russell et al., executive function tasks can be divided into rule bound and non-rule bound tasks. Rule bound tasks contain arbitrary, experimenter-imposed regulations such as 'sort by shape now, instead of colour' (as in the Wisconsin Card Sorting Test: WCST). These experimenter-imposed regulations must be held on-line to guide behaviour and, according to Russell et al., this is achieved through inner speech. In contrast, non-rule bound tasks involve non-arbitrary requirements (e.g., by invoking a prepotent response to look for a hidden object in the place it was last seen). For these tasks, motivation is a 'given', in that it exploits a well-established, natural tendency, and inner speech need not be invoked (Russell et al., 1999). Accordingly, Russell et al. argued that a lack of inner speech in individuals with autism could explain both their limited performance on rule bound executive tasks that require non-verbal responses, such as the WCST (Rumsey & Hamburger, 1988) and their equivalent performance relative to controls on a non-rule bound task (reported by Russell et al. themselves). They further suggested that if a rule bound task requires a verbal response, performance is likely to be negatively affected due to competition between verbalizing the answer and internally maintaining the rules. Thus, a verbal response should interfere with typically developing children's use of inner speech, and this form of rule bound task should not differentiate autism and control groups. This prediction was also confirmed empirically by Russell et al. However, as acknowledged by Russell et al., the interpretation of their null findings is post hoc and in need of additional tests.

In another study, Whitehouse, Maybery and Durkin (2005, Experiment 2) examined verbal and pictorial processing in children with autism and ability matched controls. This experiment investigated the word-length effect – an effect by which words of shorter spoken duration (e.g., monosyllabic words) are better recalled than words of longer spoken duration (e.g., trisyllabic words) – using items presented pictorially. It was assumed that if participants were asked to remain silent, the word-length effect would be seen only if inner speech was used to internally verbalize the labels of the pictures. In contrast, if the participants were asked to label the pictures overtly, the word-length effect would be seen regardless of inner-speech proficiency. The participants with autism demonstrated a significantly reduced word-length effect in the silent condition, both in comparison to their performance in the label condition and also with reference to control-group performance in the silent condition, providing further evidence that those with autism do not utilize inner speech spontaneously.

The purpose of the following experiment was to provide an additional test of the hypothesis of inner-speech deficits in those with autism, using a task-switching paradigm that requires participants to alternate between two simple mental operations. While the individual tasks themselves are not especially difficult, the cognitive shift that one must make between tasks increases the cognitive resources one must recruit and thereby imposes a cost on performance. Inner speech is thought to be a crucial cognitive component that assists performance in these tasks (Miyake, Emerson, Padilla, & Ahn, 2004).

Baddeley, Chincotta and Adlam (2001, Experiment 2) examined the relationship between inner speech and task-switching performance in young adults. Participants were presented with lists of simple mathematical problems, in which the function and equals signs were omitted (e.g., 8 1 _____). They were asked to consider the lists of problems in two ways: *block*, where they were to treat all problems as addition, and *alternate*, where they were to treat the first problem as addition, the next as subtraction, and so on. A further experimental manipulation – verbal output – meant that participants completed the lists either with or without articulatory suppression (AS; concurrently saying the months of the year). Baddeley et al. expected that AS would impede participants' use of inner speech[1]. The participants took longer to complete the alternate lists than the block lists, supporting the assumption of a cost due to task switching. Further, AS had a greater adverse effect on performance for the alternate condition compared to the block condition, indicating that switching is heavily reliant upon inner speech. Baddeley et al. (2001, Experiment 5) also showed that a manual-tapping concurrent task carried a much-reduced performance cost compared to AS, in the alternate condition. These findings (which have been replicated by Emerson & Miyake, 2003) further strengthen the argument that it is indeed inner speech that is important in task switching.

The current experiment adapted Baddeley et al.'s (2001, Experiment 2) procedures to investigate whether there are differences in the performance of typically developing children and those with autism. If, as hypothesized, individuals with autism have deficits in their use of inner speech, then it would be expected that the addition of AS would not significantly affect their performance on the alternating task relative to their performance on the blocked task. However, in comparison, the control group would show a significant time cost in the alternating task with the addition of AS.

METHOD

Participants

Details of background assessments, participant selection and characteristics are summarized in Table 1. Fuller details can be found in Whitehouse et al. (2005, Experiment 2). In brief, two groups were recruited, high functioning children with autism and typically developing comparisons (N = 23, in both groups). All children had English as a first language. There was no difference between the two groups on verbal ability, $t(44) = 0.76$, $p = 0.45$, non-verbal ability, $t(44) = 1.85$, $p = 0.07$, reading ability, $t(44) = 1.37$, $p = 0.19$, and gender (20 males and 3 females in each group). The autism group was, however, significantly older than the comparison group, $t(44) = 6.12$, $p < .001$. Each child with autism had been diagnosed using DSM-IV guidelines by at least two of a paediatrician, psychologist and speech pathologist. In addition, 13 participants, selected at random, were

[1] There is considerable evidence from other task domains that AS disrupts inner speech. For instance, qualitative changes in verbal short-term memory observed when AS is imposed are interpreted with reference to the disruption of subvocal rehearsal (see Baddeley, 1986).

administered the Autism Diagnostic Interview-Revised (Lord, Rutter, & Le Couteur, 1994), and it confirmed their diagnosis. Control participants were included in the study only if their teacher reported no neurological or developmental disorder.

Table 1.

Participant details.

Domain	Assessment	Autism (N = 23)		Control (N = 23)	
		M	SD	M	SD
CA		11;0	1;11	8;4	0;10
VMA	Peabody Picture Vocabulary Test-IIIA (Dunn & Dunn, 1997)	9;9	3;3	9;3	1;3
NVA	Matrices raw score (Raven, Court, & Raven, 1992)	38.8	5.58	36.4	3.20
Reading	Castles word/non-word test-modified (Edwards & Hogben, 1999)	78.87	4.3	76.82	5.64

Note: *CA: Chronological age; VMA: Verbal mental age; NVA: Nonverbal ability; Reading: Single-word reading ability*

Apparatus

Participants were given slips of paper (105mm X 297mm), each containing a list of 20 mathematical ‘equations’. However, the function and equal signs were omitted. For example:

4 1 ________ .

There were eight lists in total. The first digit for each problem was selected at random, with the only limitation that all solutions were single digits. The second digit (to be added or subtracted) was always ‘1’. An example of a stimulus list is included in Appendix D. A metronome set a rhythm to control participants’ articulatory suppression and a stopwatch was used to time the completion of each list of 20 problems.

Design and Procedure

There were three independent variables. G*roup* (autism vs. control) was a between-subjects variable. *Task* (block vs. alternate) and *verbal output* (silent vs. articulatory suppression) were within-subjects variables. As with Baddeley et al.’s (2001) study, the task variable related to how the participants were required to view the mathematical problems. Specifically, the block condition required completing one entire list as if all problems were addition. The alternate condition required completing the problems as if the first was addition, the second subtraction and so on. Turning to the verbal output variable, in the articulatory suppression (AS) condition, participants were asked to say repeatedly 'Monday' in time with the metronome. Prior to the commencement of the trials the participants were given as much time as was necessary to practise their articulation, so that each verbalization was produced to the beat of the metronome. If the participants strayed from this rhythm during the task, they were reminded to verbalize to the beat. In the control condition (*silent*), participants were given no instructions other than to complete the problems as fast and as accurately as possible (as they were also told in the AS condition). The metronome was set to 60 beats per minute and was beating during both verbal output conditions.

There were eight lists in total - two for each combination of the task and verbal output variable. The trials were split over two sessions, with one trial for each cell completed in each session. Sessions were conducted in a quiet room at the participants' school or home. The order of presentation was the same for all participants. Trials for the first session were ordered blocked-silent, alternate-silent, blocked-AS and alternate-AS. In the second session, this order was reversed. The two sessions were separated by 10 to 14 days.

Time taken to complete each list served as the primary dependent variable, although the number of mathematical errors (out of 20) was also recorded. The scoring of trials for the alternate task was designed to avoid extreme penalties accumulating for mistakes in ordering the addition and subtraction operations. For example, one early error, followed by a return to alternating addition/substraction, could result in all post-error responses being scored as mistakes. To pre-empt this, if a mathematical error was made, such that an addition trial was completed with a subtraction, this equation was scored as incorrect but then treated as the start of a new alternating sequence (i.e., as a subtraction), with subsequent problems being marked according to this sequence (i.e., the next trial should be completed with an addition). This was undertaken each time an error occurred.

As an additional check on whether the participants adhered to the task demands in the AS condition, the number of times the participant was reminded to keep verbalizing to the beat of the metronome was recorded (articulation errors).

Statistical Analyses

As the autism and control groups were group-matched on the different ability measures, a matching procedure considered less stringent than individual matching, nonverbal ability was included as a covariate in the analyses. Analyses were also conducted without this covariate and the same patterns of significant differences were observed. Assumptions of homogeneity of variance and sphericity were tested for all analyses. Where an assumption was not met, outcomes of the parametric analysis were checked by running nonparametric analyses.

RESULTS

A 2 (group: autism vs. control) x 2 (task: block vs. alternate) x 2 (verbal output: silent vs. AS) mixed ANCOVA was conducted using each participant's mean latency per list for each experimental cell. Unadjusted means and standard deviations for the latency data are presented in Table 2.

Table 2.

The mean time (in secs) taken by the autism and control groups to complete each task under conditions of silence or articulatory suppression (AS).

		Autism		**Control**	
		M	**SD**	**M**	**SD**
Block	**Silent**	40.11	25.27	43.09	15.39
	AS	43.12	28.00	49.00	15.85
Alternate	**Silent**	74.14	40.52	80.58	25.16
	AS	76.23	41.42	99.76	33.65

The analysis revealed main effects of task, $F(1,43) = 5.53$, $p < 0.05$, and verbal output, $F(1,43) = 4.66$, $p < 0.05$, but not group, $F(1,43) = 0.69$, $p = 0.41$. An interaction between verbal output and group was also obtained, $F(1,43) = 12.28$, $p < 0.01$. However these effects were qualified by a significant three-way interaction among task, verbal output and group, $F(1,43) = 7.30$, $p < 0.02$ (Table 2).

To explore the three-way interaction, a test using ANCOVA of the simple interaction (group x verbal output) was conducted for each task. This interaction was not significant for the block task, $F(1,43) = 0.77$, $p = 0.39$, but was significant for the alternate task, $F(1,43) = 11.72$, $p < 0.01$. Exploring this simple interaction further, the between-groups difference was not significant in the alternate-silent cell, $F(1,43) = 0.23$, $p = 0.63$, but was marginally significant in the alternate-AS cell, $F(1,43) = 3.88$, $p = 0.05$. The control group took longer to complete the alternate task under AS than did the autism group (see Table 2).

Levene's test for heterogeneity of variance was not met for one of the variables in the analyses. Consequently, the between-groups difference was tested using the Mann-Whitney U test for each variable in the analysis. Corroborating the findings of the parametric analyses, the only significant between-groups difference was in the alternate-AS condition ($U = 167$, $p < 0.05$). As indicated above, the control group took significantly *longer* than the autism group to complete the alternate task under AS.

We examined also the effect of AS on the performance of each group on each task. The typically developing children took significantly longer to complete both the block, $t(22) = 4.23$, $p < 0.001$, and alternate, $t(22) = 5.66$, $p < 0.001$, tasks when AS was imposed. In comparison, the addition of AS did not affect the performance of the children with autism for either the block, $t(22) = 1.94$, $p = 0.06$, or alternate task, $t(22) = 0.76$, $p = 0.45$.

Next, a 2 (group) x 2 (task) x 2 (verbal output) repeated measures ANCOVA was conducted on the number of mathematical errors. There was a main effect for task, $F(1,43) = 4.97$, $p < 0.05$, with more errors made in the alternate task ($M = 1.13$, $SD = 1.24$) than in the block task ($M = 0.1$, $SD = 0.33$). There was also a main effect for verbal output, $F(1,43) = 4.53$, $p < 0.05$, with more mathematical errors under AS ($M = 0.7$, $SD = 0.71$) than with silence ($M = 0.62$, $SD = 0.87$). There were no other statistically significant effects. Levene’s test for homogeneity of variance was not met for one of the variables and in order to substantiate the outcomes of the parametric analyses, between-group differences were tested using the Mann-Whitney U test. No between-group differences were found (all *p* values > 0.25) indicating that the two groups made an equivalent amount of mathematical errors in each condition. Unadjusted means and standard deviations for the mathematical errors are presented in Table 3.

We undertook a further analysis of the mathematical errors made in the two alternate conditions by examining arithmetic errors (e.g., adding or subtracting two rather than one) and switching errors (a failure to switch from addition to subtraction or vice versa). Arithmetic errors were too infrequent to permit rigorous analysis. However, the trend was for the children with autism to make fewer errors than the controls (1 vs. 4 errors for the alternate-silent condition, and 0 vs. 5 errors for the alternate-AS condition).

Table 3.

The total number of mathematical errors made by the autism and control groups in each condition.

	Autism		Control	
	M	**SD**	**M**	**SD**
Block-Silent	0.09	0.29	0.09	0.29
Block-AS	0.04	0.21	0.17	0.49
Alternate-Silent	1.13	1.32	1.13	0.92
Alternate-AS	0.91	1.00	1.35	1.64

Note: *AS: Articulatory Suppression*

Switching errors were more frequent and were subjected to a 2 (group) x 2 (verbal output) X 2 (mathematical function: failure to switch for an *addition* problem vs. failure to switch for a *subtraction* problem) repeated measures ANCOVA. There was minimal difference between the amount of errors made on addition (autism: M = 0.41; SD = 0.51; control: M = 0.48, SD = 0.50) and subtraction problems (autism: M = 0.46; SD = 0.68; control: M = 0.35, SD = 0.46). However, there was a trend for more switching errors to be made in the alternate-AS condition (autism: M = 0.47, SD = 0.63; control: M = 0.50, SD = 0.58) than the alternate-silent condition (autism: M = 0.40; SD = 0.55; control: M = 0.33, SD = 0.38). Importantly, however, no statistically significant differences were observed (all p values > 0.1).

We then conducted a 2 (group) x 2 (task) repeated measures ANCOVA on the number of articulation errors made under articulatory suppression. No statistically significant differences were observed (largest F = 1.5).

DISCUSSION

It has been demonstrated that when AS is imposed (and presumably inner speech is interrupted) during a task that involves switching, performance is affected negatively (Baddeley et al., 2001; Emerson & Miyake, 2003; Miyake et al., 2004). This study extends these previous findings reported for young adults, showing that typically developing 8-year-olds are also vulnerable to the intrusion of task requirements which purportedly disrupt internal speech. More importantly, the study demonstrates that, in contrast, the addition of AS does not significantly affect the task-switching performance of children with autism. This study and those previous have indicated that inner speech is important in task switching performance. As such, the finding that blocking inner speech has no effect on the task switching performance of those with autism indicates that this population does not use inner speech to complete such tasks. These findings provide arguably the most compelling empirical evidence so far for the notions originally advanced by Russell et al. (1999).

Two additional measures were taken to address the possibility that the pattern of results for the task latencies may have been influenced by one group not properly adhering to the rules of the tasks or to the AS requirement. Both groups made more mathematical errors in the AS condition compared to the silent condition and more mathematical and articulation errors in the alternate task compared to the block task. There was, however, no significant difference between the groups on either type of error. Hence, it appears unlikely that any difference in speed-accuracy trade-off or in the allocation of cognitive resources to the concurrent tasks influenced the group differences on latencies for the mathematical tasks.

Before we discuss the implications of the findings from this study, it is important to address two methodological issues. Firstly, the autism and control groups were not matched on chronological age. Although the two groups were matched on a range of ability measures (and the analyses included non-verbal ability as a covariate), it is possible that the older autism participants have had increased exposure to simple arithmetic and that this may have influenced between-group differences. In order to determine the effect that differences in chronological age may have had on performance, we calculated the latency and accuracy ‘costs’ of AS for each arithmetic task (i.e., the difference in performance for the AS and silent conditions) for each group. None of these indices of AS cost correlated with chronological age. Thus it is unlikely that the difference in chronological age for the two groups can account for the greater resilience of the children with autism in relation to AS. As an additional check, we conducted correlational analyses between the latency and accuracy costs (as described above) and verbal IQ (as determined by the PPVT) for each group. Once again, no correlations achieved significance.

Secondly, the design of this study did not include a block condition of subtraction problems only. This raises the possibility that the added cost of AS in the alternate task pertains not to the interruption of inner speech during periods of switching, but rather to the interruption of an additional demand on inner speech for subtraction relative to addition, perhaps because substraction is the more difficult operation. Note, however, that there were no between-groups differences in the frequencies of errors made on addition and subtraction problems. Further evidence against this proposal comes from Lee and Kang (2002) who asked college students to complete subtraction problems under either no interference, concurrent AS, or concurrent visuospatial suppression. Subtraction performance was negatively affected by visuospatial suppression but not by AS, suggesting that subtraction operations are not dependent upon the use of inner speech. If Lee and Kang's finding is contrasted with that of Hitch and colleagues (Adams & Hitch, 1997; Hitch, Cundick, Haughey, Pugh, & Wright, 1987), who provided evidence for inner speech involvement in children's addition, then it seems unlikely that the performance cost observed with the addition of AS related to an increased demand of inner speech during subtraction performance. Of course it remains possible that subtraction may make demands on inner speech in children. However these demands would need to exceed those made by addition for our interpretation of the key results to be compromised.

One question raised by this research is how the children with autism were able to switch between addition and subtraction problems without the use of overt or covert speech. One possible explanation comes from evidence that individuals with autism have enhanced spatial planning skills. Caron, Mottron, Rainville and Chouinard (2004) investigated the spatial abilities of individuals with autism using a large-scale labyrinth. Individuals with autism performed comparably with typically developing controls on navigational tasks that relied upon spatial memory (i.e., learning a route through the labyrinth). However, when the participants were required to employ macro-micro mapping (translating knowledge of the labyrinth to a map of this labyrinth) and micro-macro mapping (translating knowledge of the map to the labyrinth), tasks that are heavily reliant upon spatial planning skills, the individuals with autism demonstrated superior performance. From this evidence it is possible that, in the current study, rather than managing task-switching through verbal mediation, the children with autism utilized visuospatial representations as a means of planning their future actions. Future research could employ a visuospatial concurrent task to determine the nature of representations used by individuals with autism in managing task-switching demands.

Although this study has provided evidence consistent with individuals with autism differing from ability-matched controls in their use of inner speech, the exact nature of this difference is still unknown. For example the difference between populations may be due to a *lack* of inner speech in those with autism, a *delay* in the development of inner speech, or simply *poor awareness* of how to use inner speech. This notwithstanding, the findings of the current study have important theoretical implications for cognitive models of autism.

An inner-speech deficit in this population may provide an important link between other cognitive deficits. For example, executive control, a cognitive function for which deficit is well-established in autism, is known to have strong links to inner speech in the typically developing population (Miyake et al., 2004). Baldo, Dronkers, Wilkins, Ludy, Raskin and Kim (2005) reported that the WCST performance of individuals with varying degrees of aphasia was highly correlated with a range of language measures, but not with a measure of visuospatial skill. Baldo et al. also showed that the WCST performance of healthy adults was adversely affected by AS relative to a silent control condition. These findings indicate that performance on the WCST is contingent upon language ability and on the availability of inner speech in particular. This suggests that the typically poor performance of individuals with autism on the WCST (Rumsey & Hamburger, 1988) may be due to limitations in inner speech.

The present findings may also provide important insights into the impairments of those with autism that currently have an unidentifiable cause, in particular, language delays. Inner speech is known to be important in the development of a number of language skills. For example, inner speech assists vocabulary (Bebko, 1998) and syntactical development (Adams & Gathercole, 1995) through the internal rehearsal of information. Similarly, inner speech supports discourse development through internal utterance planning (Levelt, 1989). The atypical development of inner speech may exacerbate language problems by hindering the development of these linguistic skills.

These issues prompt the question of whether therapeutic benefit could be gained by teaching inner speech skills. Once again, establishing the exact nature of the relationship between inner speech and other aspects of cognition is pivotal to achieving this goal. By determining the direction and extent of the relationships, studies can then establish whether inner speech could serve as an important bridge in the development of other aspects of cognition, such as language and executive function.

This study provides perhaps the most direct investigation to date of the utilisation of inner speech by individuals with autism. The results indicate that those with autism do not recruit inner speech in order to assist their performance in tasks involving mental-switching. In the typical population, inner speech is known to be associated with the development and functioning of a number of cognitive capabilities. These relationships are yet to be determined within the autism population and future research should concentrate upon establishing firstly, the exact nature of the inner-speech deficit in autism and secondly, how this deficit relates to other cognitive and behavioural deficits. While clearly there is still much to be known about the inner speech deficit of those with autism, the findings from the current study suggest that it will reward attention.

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GENERAL DISCUSSION

Chapter 6

A discussion of the main findings of this thesis

There were two general aims of this thesis. The first aim was concerned with increasing the understanding of how children with autism gain meaning from verbal and pictorial information. The second aim was to investigate the use of inner speech in children with autism and, more specifically, to examine whether inner speech may influence firstly, the verbal and pictorial processing abilities of these individuals, and secondly, the functioning of other cognitive components, in particular, executive function. These aims were investigated through a series of independent, but related studies.

1) The first study (Chapter 2) investigated the proposition that children with autism poorly encode verbal information at the semantic level of processing, instead paying greater attention to the phonological attributes of verbal stimuli.
2) The next two studies focused on determining whether children with autism have a superior facility for processing pictorial rather than verbal information. This was investigated with the use of the picture-superiority task (i.e., an explicit verbal recall task containing both pictures and words). The performance baseline of typically developing children on the picture-superiority task was examined in the second study of this thesis (Chapter 3). In particular, this study aimed to determine whether there are age related modality processing differences from middle childhood to young adulthood.
3) The third study (Chapter 4, Experiment 1) investigated whether children with autism manifest modality processing differences, specifically, enhanced processing of pictorial relative to verbal information. This was examined with the use of the picture-superiority task.
4) The fourth study (Chapter 4, Experiment 2) investigated whether modality processing differences in children with autism may be due to atypical inner speech, in particular, a difficulty in constructing a phonological code of pictorial stimuli and rehearsing this information.
5) The final study (Chapter 5) investigated whether the inner speech limitations of those with autism demonstrated in the fourth study extend to deficits in internal planning. More specifically, the final study examined the use of internal planning by children with autism during a task of mental switching.

In this chapter, the main findings relevant to each of these studies are reviewed in turn. Following this, a key assumption underpinning the interpretation of the findings is discussed (i.e., that the lesser picture-superiority effect of the autism group is due to inner speech limitations) and an alternative explanation is raised. The final section will discuss the implication of these results and possible directions for future research.

REVIEW OF THE MAIN FINDINGS

How do children with autism gain meaning from verbal information? Explicit recall tasks which manipulate certain features of the verbal stimuli (e.g., word meaning, word form), have been an important means through which this has been investigated. It is assumed that the items that the participants recall are processed for meaning more extensively than are those items which are not recalled (Irwin & Lupker, 1983). As reviewed in Chapter 2, there is evidence to suggest that children with autism have limited semantic processing of verbal information (Beversdorf et al., 2000; Tager-Flusberg, 1991; Toichi & Kamio, 2002, 2003, 2005; Toichi et al., 2002), instead paying greater attention to the phonological attributes of verbal stimuli (Boucher & Warrington, 1976; Mottron, Morasse, & Belleville, 2001; Toichi & Kamio, 2003, 2005). While this processing 'style' is thought to be a product of atypical information encoding (e.g., Toichi & Kamio, 2003), it remains a possibility that children with autism have an atypical retrieval strategy that influences recall performance. Excluding this possibility is an important step in establishing 'atypical verbal encoding' as a distinguishing language deficit within the autistic population. The study reported in Chapter 2 employed a novel cued-recall task as a means of clarifying this issue.

A group of children with autism and a control group of typically developing children were asked to memorize twenty words, half of which were in some way related. In one condition, half of the items had a common semantic theme (e.g., animals), and in the other condition, half of the items had a common phonological feature (e.g., the onset of 'st'). The participants were presented with a cue (of the common element) and required to recall as many items consistent with this cue as possible. All participants were presented with the same recall cue. Hence, this experimental design maximized the likelihood that any between-groups differences in performance would relate to processing differences at the encoding stage. No between-group differences were found in either the semantic or phonological condition. A follow-up comparison demonstrated that the autism group performed as would be expected for typically developing children of the same chronological age. These findings did not support the proposition that individuals with autism have atypical encoding of verbal information.

The dominance of pictorial processing relative to verbal processing is another concept advanced in support of the proposed atypical information encoding of individuals with autism. While anecdotal reports suggest that individuals with autism have enhanced processing of pictorial information (e.g., Grandin, 1995a; Hurlburt, Happé, & Frith, 1994), there is, as yet, only limited empirical evidence to suggest that this is indeed the case (e.g., Kamio & Toichi, 2000). Recall tasks that contrast pictorial and print information provide one method through which pictorial superiority can be examined. Pictures are thought to engage deeper levels of processing and, hence, in such a task, retention typically favours pictures (Weldon, Roedigger, & Challis, 1989). As a preliminary study, the performance of typically developing children was gauged.

As reviewed in Chapter 3, it has been argued that younger children are more dependent upon visual information than verbal information (Simpson, 1995), and further, that this dependency subsides as children's language proficiency develops (Gibson, Barron, & Garber, 1972; Gitomer, Pellegrino, & Bisanz, 1983; Rosinski, Pellegrino, & Siegal, 1977). This developmental trend leads to the expectation that the picture-superiority effect would be at its strongest in younger age-groups and decrease with the development of linguistic processing proficiency. However, in light of an influential account of the picture superiority effect (Paivio, 1991), another possibility emerges.

Paivio's dual route model (1991) presupposes that the strength of pictorial processing is due to the ability to encode this information through two routes, the image pathway and the verbal pathway. As argued in more detail in Chapter 3, the verbal pathway depends on the availability of inner speech, whereby the labels of pictures are converted to a phonological code, which is then covertly rehearsed. From this perspective, inner speech limitations restrict the effectiveness of the verbal encoding route and hence reduce the possibility of encoding pictorial information through two pathways. Importantly, inner speech is known to follow a developmental path akin to the development of overt speech, whereby children's proficiency typically develops across the pre- and primary-school years. The protracted development of inner speech leads to the contrasting expectation that the magnitude of the picture-superiority effect should increase with age.

Eighty typically developing participants, aged between 7 and 16 years, were recruited for the study reported in Chapter 3. In each of three trials, participants were presented with, and asked to remember, a list of 10 pictorial and 10 print stimuli. All groups showed better recall of pictorial relative to word stimuli, and hence demonstrated the picture-superiority effect. However, the magnitude of the effect increased with chronological age. In line with Paivio's (1991) account of the picture-superiority effect, this finding indicates that in explicit memory tasks, picture-word processing differences may be related to the concurrent development of another cognitive factor. It is proposed in this thesis that the critical factor is the development of inner speech proficiency.

The picture-superiority task was then utilised as a means of investigating the largely untested notion that pictorial information provides children with autism better semantic understanding than verbal information. If pictures do indeed provide individuals with autism better semantic access than words, it was expected, firstly, that the autism group would demonstrate a recall advantage for pictorial relative to verbal information, and secondly, for this advantage to be greater than that observed in the control group. The interpretation of the findings reported in Chapter 3, however, provided an alternative hypothesis for the performance of participants with autism on this task. The findings of Chapter 3 were consistent with the proposal that the magnitude of the picture-superiority effect may be influenced by the availability and utility of inner speech (Paivio, 1991), where inner-speech limitations (i.e., difficulty in creating a phonological code of pictorial stimuli, which is then rehearsed) reduce the retention benefits that can be obtained from dual-route processing of pictorial stimuli. Suggestions that those with autism have poor use of inner speech (e.g., Russell, Jarrold, & Hood, 1999) lead to a competing prediction concerning the performance of the autism group in the picture-superiority task. If individuals with autism have less facility with inner speech, it is likely that they would show a comparatively reduced picture-superiority effect in comparison to typically developing children.

Children with autism were compared with an ability matched control group. The children with autism demonstrated a significantly reduced picture-superiority effect in comparison to the typically developing children. This finding provided evidence against the idea (Kamio & Toichi, 2000) that these individuals gain better semantic understanding from pictorial rather than verbal information. Further, it was demonstrated that, within the context of a picture-superiority task, children with autism have reduced recall of pictures in comparison to typically developing controls. One explanation for this reduced pictorial recall by children with autism, and one which provided the basis for the further investigations, relates to Paivio's (1991) dual route theory and the idea that these individuals have limitations in their use of inner speech (the validity of this explanation is addressed later in this Discussion).

The second experiment of Chapter 4 represents a closer examination of the idea that, during recall tasks, children with autism are limited in their ability to generate a phonological code of visual stimuli. As highlighted in Chapter 4, the use of inner speech in pictorial processing has been examined in the typically developing population with the assistance of verbal short-term memory effects (Henry, Turner, Smith, & Leather, 2000; Hitch, Halliday, Dodd, & Littler, 1989). In this research, items are presented pictorially rather than aurally, with the assumption that verbal memory effects will be seen only if inner speech is used to label the pictures. The second experiment in Chapter 4 exploited the word-length effect as a means of gauging the involvement of inner speech in pictorial processing.

In comparison to the control group, the autism group produced a significantly reduced word-length effect in a condition that did not obligate verbal encoding of the pictures (the *silent* condition). Furthermore, relative to their recall performance in the *silent* condition, the autism group showed a more pronounced word-length effect in the *label* condition – a condition that required the participants to generate an overt verbal code for the pictorial stimuli. These findings provide support for the proposal that, during memory tasks, individuals with autism do not spontaneously generate and rehearse a phonological code for pictorial information to the same extent as do typically developing children.

The finding that children with autism demonstrate less inner-speech facility is significant in the context of defining the cognitive phenotype of autism. The studies reported in Chapter 4 demonstrate that children with autism show a reduced propensity to generate and rehearse a phonological code for visual stimuli. Further, these studies show that this limitation is significant enough to undermine the manifestation of two well-established memory effects (the picture-superiority effect and the word-length effect). As described in the Introduction, as overt language develops, the role of inner speech extends beyond that of cognitive rehearsal. In particular, inner speech assumes an internal planning role, which facilitates the development and functioning of a number of cognitive processes. One of these, executive control (Carlson & Moses, 2001), is an established deficit in the autistic population (Hill, 2004). The aim of Chapter 5 was to determine whether poor use of inner speech by children with autism may relate to the executive dysfunction often observed in this population.

The experiment described in Chapter 5 employed a task-switching paradigm, based on arithmetic, for which performance has been shown to be contingent upon inner speech (Baddeley, Chincotta, & Adlam, 2003). It was hypothesized that if individuals with autism have deficits in their use of inner speech, then attempts to obstruct inner speech, through the addition of articulatory suppression, would not significantly affect their performance during a task-switching condition. This hypothesis was confirmed with concurrent articulation affecting the task-switching performance of the typically developing group only. This result extended the findings of Chapter 4, in demonstrating that the inner-speech limitations observed in children with autism also encompass difficulties with inner planning.

Summary

The main findings of this thesis which are relevant to the processing capabilities of children with autism are summarized below.

1. Typical verbal encoding: This thesis found no evidence that children with autism atypically encode verbal information.
2. Reduced pictorial processing: Children with autism demonstrated reduced processing of pictorial information during memory tasks.
3. Inner speech impairment: Children with autism did not use inner speech to the same extent as controls during tasks of pictorial processing and tasks of mental switching.

AN ALTERNATIVE EXPLANATION OF A KEY ASSUMPTION

Reduced Picture Superiority is due to Inner Speech Limitations

A key transition in this thesis stemmed from the performance of the autism group in the picture superiority task (Chapter 4, Experiment 1). As highlighted previously, there is anecdotal and experimental evidence that children with autism have enhanced facility with processing pictorial information. From this perspective, it was expected that the autism group would show a picture superiority effect that would be of equal or greater magnitude than the typically developing comparison group. Instead, however, the reverse was found, with the autism group demonstrating a comparably less picture superiority effect. As highlighted previously, Paivio's (1991) dual route model of pictorial processing provided one possible explanation for this finding. According to Paivio, picture-recall superiority is contingent upon one processing pictorial information through both an image (attending to its visual features) and a verbal (internally verbalizing the picture's label) route. If the processing capability of one of these pathways is compromised then recall performance is likely to be reduced. The possibility that the lesser picture-superiority effect of the children with autism was due to limitations in their use of internal language, formed the basis for the investigations reported in Chapter 4 (Experiment 2) and Chapter 5. Although the findings of the subsequent experiments (i.e., Chapter 4, Experiment 2; Chapter 5) provided solid evidence that children with autism have inner speech limitations, this interpretation is only one possibility for the lesser picture-superiority effect demonstrated by this population. An alternative explanation will now be discussed.

An Alternative Explanation: Different Reading Styles?

It is possible that the reduced picture-superiority effect demonstrated by the autism group relates to differences in the *reading styles* of the autism and control participants. A number of studies have reported that high-functioning people with autism (the population recruited in this thesis) display a reading style indicative of hyperlexia, that is, precocious grapheme decoding skills with poor word comprehension (O'Connor & Klein, 2004, Whitehouse & Harris, 1984). There is evidence to suggest that individuals with autism who show a tendency for hyperlexia have increased retention of words within a memory task (compared to the level of recall that would be expected on the basis of their intelligence) (Whitehouse & Harris, 1984). This processing style may increase the ability of those with autism to remember word stimuli, offsetting any recall limitation that may result from the poor semantic encoding of verbal information. It is possible that the individuals with autism recruited in this thesis may have had a similar reading style, which could explain why the autism group recalled a similar amount of words relative to the ability matched control group. This notwithstanding, the autism group recalled significantly fewer pictures than did the control group and thus the autism group demonstrated a reduced picture-superiority effect despite their comparatively intact recall of word stimuli. Hence, it is unlikely that such a reading style could account for the reduced picture-superiority effect demonstrated by the children with autism.

Note, that while the second experiment of Chapter 4 provides direct evidence for inner speech limitations in children with autism, the findings also provide indirect support for the idea that the developmental increase in the magnitude of the picture-superiority effect in typically developing children (Chapter 3) is due to the development and increasing availability of inner speech. For this reason, I will also consider an alternative possibility for the pattern of performance observed in the typically developing children in the study reported in Chapter 3.

For typically developing children, the increase in the magnitude of the picture-superiority effect with age may be due to the progressive reduction in the amount of cognitive resources required for processing word stimuli. In contrast to pictorial information, which directly represent an object or action, written words are arbitrary codes, and the ability to process these codes for meaning (i.e., reading) follows a developmental course. By around grade 2 to 3 (roughly 7 to 8 years of age), the youngest group of participants recruited for the study reported in Chapter 3, most typically developing children have developed the ability to analyse unknown words using orthographic patterns (Owens, 1996). At this age, however, a child has only modest experience with word processing and as such, reading is an effortful and cognitively-expensive process, relying heavily on sound-spelling correspondence rules (Owens, 1996). Throughout childhood and adolescence, reading becomes more automatic and there is a reduction in the level of cognitive resources that need to be allocated to this process (Owens, 1996). This shift may have influenced the pattern of findings in Chapter 3. That is, children in the younger age groups may have allocated a greater amount of cognitive resources to the word stimuli, which reduced the resources these individuals could allocate to the processing of the pictorial stimuli. This would reduce the recall of pictorial information in the younger groups, a restriction that would decrease with the improvement of reading skills, in this case, with chronological age. Note, however, that the word stimuli utilised in Chapter 3 are simple nouns, and are at a level considered relatively straightforward for an individual with grade 2 reading ability (Owens, 1996). Hence, it seems improbable that differences in reading ability would explain the developmental increase in pictorial superiority.

Nevertheless it would be useful to investigate the precise nature of the development of the picture-superiority effect by presenting word and picture stimuli in separate to-be-remembered lists. This would eliminate the influence of any sharing of resources between word reading and the processing of pictorial stimuli.

How to Attain Further Support for the Involvement of Inner Speech in Pictorial Processing

Further support for the proposal that individuals with autism have difficulty generating and rehearsing a phonological code for pictorial information can be gained through evidence from different memory tasks. One experimental design that has the potential to shed more light on this proposal comes from Laws (2002). In this study, children with Down syndrome and typically developing controls participated in a serial recall task that used colour stimuli. Participants were asked to retrieve (via a nonverbal recognition task) as many items as possible, in each of two conditions, 1) ‘focal’ colours: participants were presented with a series of colours, each considered a prototypical example of one of the 11 basic colour categories for English speakers (e.g., yellow or green), and 2) ‘nonfocal’ colours: participants were presented with a series of colours that were close to the colour-category boundaries (e.g., yellowy-green). It is assumed that if a colour is towards a category boundary it becomes less easy to name. This creates difficulty with verbally coding the items via the phonological loop and, as such, memory performance is expected to be poorer for these colours relative to memory for focal colours. Laws found no difference between children with Down syndrome and typically developing children in the recall performance of nonfocal colours, but a significantly poorer performance by the children with Down syndrome in their recall of focal colours. The children with Down syndrome did not demonstrate the same memory facilitation for colours with easily nameable labels as did the typically developing participants. This finding led Laws (2002) to conclude that children with Down syndrome have “impairment in the phonological loop component of working memory” (p. 360).

An additional manipulation of ‘verbal output’ could also be included in a study of children with autism. In one condition, participants would be required to overtly label the stimuli during encoding (a *label* condition), and in another condition, participants would be required to remain silent during encoding (a *silent* condition). Similar to the experimental assumptions highlighted in the second experiment of Chapter 4, participants should only demonstrate the verbal memory effect (i.e., enhanced recall for focal relative to nonfocal colours) in the silent condition, if they recruit inner speech to verbally code each colour stimuli. If children with autism have inner speech limitations, then it would be expected that these participants would show a lesser memory effect in the silent condition relative to the performance of typically developing controls. In contrast, the label condition obligates verbal encoding, and hence in this condition, the participants with autism would be expected to demonstrate a memory effect comparable to that observed for the control group.

One study with a similar design has recently been conducted with individuals with autism (Joseph, Steele, Meyer, & Tager-Flusberg, 2005)[1]. Children with autism were compared with typically developing controls on their performance on the Self Ordered Pointing Test (Petrides & Milner, 1982). In this task, children are presented with a set of picture stimuli illustrated on a single piece of paper. Participants are repeatedly presented with a stimulus page, each time with the pictures in a different spatial arrangement. The stimulus page is presented to the participants for as many times as the number of stimuli (i.e., if there are 9 pictures, then it is presented 9 times), and the child's task is to point to a different picture on each presentation. Accurate performance therefore requires memory of pictures pointed to on previous presentations. In one condition, the stimulus card contained concrete, nameable objects (e.g., a bird), whereas in the other condition, the stimuli were not easily named or verbally encoded (i.e., abstract designs). As with Laws (2002), it was expected that memory performance would be better for those items that are more easily translated into a verbal code, in this case, the concrete objects. The two groups were equivalent in their memory performance for the abstract designs. Importantly, however, the children with autism performed significantly poorer than the controls in the recall of the concrete objects. This finding provides further evidence that children with autism do not use verbal mediation to enhance their pictorial recall.

[1] This study was published subsequent to the submission of the manuscripts in Chapters 4 and 5 to an academic journal.

IMPLICATIONS FOR FUTURE RESEARCH

Although some uncertainty remains regarding an explanation for the performance of the autism group on the picture superiority task, this thesis offers a number of important findings that may impact upon the broader autism literature. Firstly, there was no evidence that children with autism have verbal encoding deficits. Secondly, children with autism showed reduced elaborative processing of pictorial information during memory tasks. Finally, children with autism demonstrated inner speech limitations. In the final section of the Discussion, I interpret these findings within the context of the broader literature, and offer avenues for further research.

Verbal Encoding in Children with Autism

The findings of Chapter 2 do not support the proposition that individuals with autism have atypical encoding of verbal information. However, they are consistent with the possibility that children with autism employ atypical retrieval strategies. Previous studies have shown that, in comparison to typically developing controls, children with autism show reduced semantic processing (Beversdorf et al., 2000; Toichi & Kamio, 2002, 2003, 2005) and enhanced phonological processing (Toichi & Kamio, 2003, 2005) in a range of recall tasks. Interestingly though, Chapter 2 demonstrated that when retrieval strategies are controlled between populations, this between-group difference is not obtained. Further studies are required in order to provide conclusive evidence that differences in reliance on phonological and semantic information exist for individuals with, versus without, autism.

Chapter 2 outlined two potential extensions of this research. Firstly, studies that examine the retrieval methods that children with autism employ during recall tasks would provide a direct test of the ‘atypical retrieval strategy’ hypothesis (a design of a possible study is outlined in the Discussion of Chapter 2). Secondly, studies that include both high and low functioning children with autism, as well as those that examine the developmental trajectory of verbal processing (through longitudinal studies), would reveal more about the consistency of these deficits across the autism spectrum in addition to their stability over time.

A further consideration for future studies is whether the range of stimuli utilised in the task reported in Chapter 2 may have been too restricted to show any between-group differences. A number of authors have suggested that semantic encoding deficits may be seen only in tasks that utilise stimuli relatively low in familiarity (Lopez & Leekam, 2003; Toichi & Kamio, 2003). The majority of studies that have demonstrated typical encoding capabilities in those with autism have included stimuli from relatively familiar semantic categories, such as animals, fruit and modes of transport (Chapter 2; Lopez & Leekam, 2003; Toichi & Kamio, 2003). It is possible that these semantic categories are so prevalent within a child's environment (e.g., home, school, therapeutic setting, etc.) that children with autism have been afforded sufficient experience to facilitate their ability to process these items. It does, however, seem unlikely that this would account for the current findings, as the stimuli utilised in this study were very similar to those employed by studies that have purported to have found encoding deficits (e.g., Boucher & Warrington, 1976). This notwithstanding, future studies could consolidate and extend the findings of this study by including a greater variety of stimuli.

The findings of the study reported in Chapter 2 may bear particular relevance to the generativity impairment that has been observed in children with autism (Bishop & Norbury, 2005). As reviewed previously, children with autism perform comparably with typically developing controls on tasks of fluency that require one to generate items from a concrete category (e.g., 'animals' or 'letters' that begin with the letter 'p') (Boucher, 1988) but show deficits in tasks that require the generation of items from a more ambiguous category (e.g., "any words that you can think of") (Bishop & Norbury, 2005; Boucher, 1988; Turner, 1999). The study reported in Chapter 2 provided further evidence that, when given an appropriate cue, children with autism are able to generate relevant and appropriate levels of exemplars from a given category. A recent study of children with autism found strong correlations between pragmatic abnormality (i.e., the score on the pragmatic section of two widely utilised autism assessments) and weak generativity (Bishop & Norbury, 2005). Bishop and Norbury suggested that this relationship may be indicative of the difficulty that individuals with autism have in generating ideas that are pragmatically relevant to a particular communicative context. This interpretation in the context of the findings of Chapter 2 may have implications for pragmatic intervention. In particular, intervention that provides appropriate examples of social behaviour *a priori* (through means such as social stories and role plays: Greenway, 2000; Smith & Coleman, 1986; Thieman & Goldstein, 2001; Wolfberg, 2003), and more importantly, *cues* that will prompt the use of these behaviours, may be an effective means through which inappropriate behaviours can be remediated.

Reduced Pictorial Processing in Children with Autism

A central aim of this thesis was to determine whether children with autism have enhanced processing of pictorial relative to verbal information. While there is anecdotal (e.g., Grandin, 1995), clinical (e.g., Bondy & Frost, 2001) and experimental (e.g., Kamio & Toichi, 2000) evidence to suggest that those with autism receive semantic processing benefits with pictorial relative to verbal information, the findings reported in Chapter 4 suggest that, during recall tasks, limitations in the use of inner speech may restrict the extent to which this pictorial dominance is revealed. Nevertheless, it remains possible that individuals with autism do indeed have enhanced facility with processing pictorial information, however the experimental methods that sought to expose this, tap additional skills which are deficit in the autistic population and offset this processing bias. In order to shed more light on the proposition that children with autism have enhanced facility with pictorial information, research could: 1) provide further examinations of how individuals with autism process pictorial information; 2) reveal more about the visuospatial abilities of this population; and 3) gain a better understanding of the internal representations of individuals with autism.

Firstly, research could further examine whether individuals with autism have a processing advantage for pictorial information. This thesis provided experimental evidence that children with autism do not have enhanced facility for processing pictorial information when it is contingent upon inner speech. However, as described in Chapter 4, it remains possible that pictorial information does indeed provide children with autism better semantic understanding than verbal information but their failure to generate a verbal code may leave them at a disadvantage that more than offsets any pictorial advantage. In response to this possibility, future studies could utilise tasks that reduce the involvement of inner speech (e.g., a recognition task). Such an experiment may limit the intrusion of cognitive elements beyond those strictly involved in pictorial processing, and would hence provide a clearer understanding of the pictorial processing capabilities of those with autism.

Secondly, studies could further investigate weak visuospatial coherence, a processing style known to be characteristic of autism. According to the weak central coherence framework (Frith & Happé, 1994), individuals with autism perceive and process information in a piecemeal fashion, demonstrating a weaker drive to integrate information into a coherent gestalt (Joseph, 1999). Consistent with this theory, individuals with autism have superior performance relative to typically developing controls on embedded figures tasks (Joliffe & Baron-Cohen, 1997), the block design task (Ghazziuddin & Mountain-Kimchi, 2004; Goldstein, Beers, Siegal, & Minshew, 2001; Minshew, Turner, & Goldstein, 2005; Shah & Frith, 1993) and copying impossible figures (Mottron, Belleville, & Ménard, 1999). Recent literature has begun to shed light on the possible cortical abnormalities that may contribute to this visuospatial processing style (Bertone, Mottron, Jelenic, & Faubert, 2003; Milne et al., 2002; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005). Pellicano et al., in particular, argue that weak visuospatial coherence in autism may result from abnormal cooperative mechanisms in extra-striate cortical areas. It is possible that this processing style may afford individuals with autism greater attention to detail and better memory for visuospatial information, such as pictures. Future research that seeks to identify how weak visuospatial coherence of those with autism may influence the interactions of these individuals with their environment could determine the extent to which this processing style leads to enhanced facility for pictorial information.

Finally, research could examine whether the supposed ‘pictorial dominance’ of those with autism is a reflection of the way these individuals internally represent the external world. There are anecdotal reports that the inner experiences of those with autism consist mainly of visual images (Grandin, 1995a, 1995b; Hurlburt, Happé, & Frith, 1994). As Temple Grandin, a renowned individual with autism, wrote (1995a):

> “I think in pictures. Words are like a second language to me. I translate both spoken and written words into full-color movies…when somebody speaks to me, his words are instantly translated into pictures” (p. 19).

This description illuminates an internal world where thoughts are represented by a series of images. A thinking style such as this would not necessarily denote preferential encoding of pictorial information, but rather a processing style that benefits from information, pictorial or otherwise, that can be easily represented as an image. As Grandin (1995a) goes on to write:

> "Autistics have problems learning things that cannot be thought about in pictures. The easiest words for an autistic child to learn are nouns, because they directly relate to pictures" (p. 24).

The idea of an inner speech impairment, where children with autism have limited use of internal language, would be consistent with the idea of an internal world dominated by images. Further studies that assemble anecdotal reports from a range of individuals with autism would provide a clearer description about how those with autism represent the external world. Future research could also seek to elucidate the relationship between the internal representations of these individuals and limitations of inner speech.

Inner Speech Impairment in Children with Autism

This thesis has provided evidence that children with autism do not use inner speech to the same extent as ability-matched controls during the recall of pictorially presented information (Chapter 4) and during a task of mental switching (Chapter 5). As these studies are the first to provide direct empirical evidence that children with autism have limited use of inner speech, there is still a great deal to be learnt about these abilities. Ascertaining the exact nature of the impairment should be the first priority of future research. Cross-sectional studies that not only determine *how* children with autism use inner speech (e.g., is there a lack of inner speech, a delay in inner speech development, or poor awareness of how to use inner speech?) but also evaluate this population's use of inner speech with a range of comparison populations, will be important in extending this knowledge base. Longitudinal studies which track the development of inner speech in children with autism will also provide valuable information about how this deficit manifests in this population. Despite the need for corroborating research, the findings of this thesis have important implications for the linguistic, cognitive and neurological descriptions of autism, as well as for how autism is viewed in the context of other neurodevelopmental disorders. The final part of this Discussion will focus on these implications and the potential their impact upon current intervention practices.

The development of overt and covert speech are likely to be intimately related (Vygotsky, 1962). For example, the proficiency of inner speech is likely to be restricted by the lexical and syntactical development of overt linguistic ability (i.e., it is unlikely that children acquire and employ syntactical structures in an exclusively internal capacity). Accordingly, the inner speech deficits of those with autism may be merely a reflection of an overt linguistic impairment. Note, however, that in Chapters 4 and 5, there was no difference between the autism and control groups on verbal ability, as determined by the Peabody Picture Vocabulary Test – Version IIIA (Dunn & Dunn, 1997). Studies of children with autism, which examine the correlation between overt linguistic skills and the ability to utilise internal language, will provide important data concerning this issue. It is also important to consider, however, the possibility that inner speech limitations have a bearing upon the development of overt speech. This possibility is discussed below.

Lexical acquisition requires the ability to map phonetic strings to objects or actions (Alt, Plante, & Creusere, 2004). Studies have found that children can often acquire new words from only one exposure by forming quick and rough hypotheses about the meaning of a new word (Bloom, 2000; Dickinson, 1984). This process has been dubbed 'fast-mapping' (Bird, Chapman, & Schwartz, 2004). While an important component of fast mapping is the ability of the child to associate a novel phonetic sequence with a novel item, the child's ability to hold the phonetic string in memory plays an equally vital role (Bird et al., 2004). According to the fast-mapping framework, rather than being consolidated in memory by repeated environmental exposure, verbal information becomes entrenched in long-term memory through firstly, its temporary storage within the articulatory loop (Montgomery, 2002), and secondly, the refreshing of this information via subvocal rehearsal (Papagno, 1996). If children with autism have a reduced capacity to use this phonological code in rehearsal (as indicated in Chapter 4), poor vocabulary development may well result.

A common index of articulatory loop function, also known as phonological working memory (PWM), is performance on the nonword repetition test. In this task, children are aurally presented with, and required to repeat, nonwords ranging in length from 1 to 5 syllables. It is argued that this is a robust measure of PWM capacity because it requires a listener to encode and hold unfamiliar verbal information in memory via rehearsal within the articulatory loop. Numerous cross-sectional (Avons, Wragg, Cupples, & Lovegrove, 1998; Gathercole & Baddeley, 1990; Gathercole, Hitch, Service, & Martin, 1997) and longitudinal (Gathercole, Willis, Emslie, & Baddeley, 1992) studies of typically developing children have identified a strong positive correlation between PWM and vocabulary growth. Although there have been no such correlational studies conducted within the autistic population, recent evidence has suggested that a significant proportion of children with autism perform poorly on the non-word repetition test (Kjelgaard & Tager-Flusberg, 2001). As such, it is reasonable to speculate that the difficulty those with autism have with rehearsing a phonological code may lead to linguistic deficit.

Tasks of word learning (e.g., Ellis-Weismer & Evans, 2002; Gupta, 2003) provide a suitable experimental framework to assess the relationship between subvocal rehearsal and lexical development. In these tasks, a non-word (the 'to-be' learned word) is typically paired with a picture or object. Following an interval, participants are asked to either identify the picture/object from a range of other stimuli (a recognition task) or recall the label of the picture/object (a recall task). As inner speech limitations would reduce the utilisation of subvocal rehearsal during the interval phase, it would be expected that an autism group would demonstrate significantly poorer retention of a 'new' word than typically developing children. A condition in which the use of inner speech is obstructed during the word-learning interval, possibly via articulatory suppression, could also be included. Given the findings reported in Chapter 5 of this thesis, it would be expected that performance of the control group, but not the autism group, would be negatively affected by interference to inner speech.

While much less is known about the involvement of PWM in the development of morphology and syntax, two studies have provided evidence for a positive relationship. Adams and Gathercole (1995) found that PWM predicts the quality and quantity of spontaneous speech in 3-year-old children. Similarly, Blake, Austin, Cannon, Lisus and Vaughan (1994) found that PWM is a better predictor of mean length of utterance in 2- and 3-year olds than chronological or mental age. Learning a novel morpheme requires children to retain the novel phonological form, in addition to extracting its meaning relative to the rest of the sentence and build an appropriate representation that includes its phonological code along with its syntactic and semantic features (Montgomery, 2002; Pinker, 1984). Ellis-Weismer (Ellis-Weismer, 1996; Ellis-Weismer, Evans, & Hesketh, 1999) has provided data from children with Specific Language Impairment, indicating that limitations in verbal working memory lead to difficulties undertaking the storage and processing functions simultaneously. Future research could seek to clarify this relationship in children with autism.

Limitations in the internal planning/monitoring function of inner speech could also contribute to the broader language phenotype of those with autism. Prior to articulation, speakers are able to parse their internal speech in order to monitor erroneous or inadequate utterances (Levelt, 1989). It is conceivable that if one's use of inner speech is limited, as has been proposed for individuals with autism, then the effectiveness of internal language monitoring would be reduced. While reduced internal self monitoring would not necessarily compromise the development of syntactical and morphological structures, it would increase the frequency with which syntactical and morphological errors are generated in spontaneous speech. This could provide a possible explanation as to why individuals with autism have been shown to demonstrate relatively appropriate grammatical knowledge but significant impairment in communicative competence.

Cognitive characteristics in autism

As mentioned in Chapter 4, studies of typically developing children have identified that inner speech is strongly associated with two cognitive functions known to be deficient in those with autism: executive function and theory of mind. Future research should seek to clarify the nature of these relationships in those with autism.

Executive Function

The importance of inner speech for appropriate performance on tasks of executive function is well established in the literature. As discussed in Chapter 5, the performance of healthy children and adults on well-established measures of executive control is significantly impaired when the utilisation of inner speech is obstructed (Baddeley, Chincotta, & Adlam, 2001; Cinan & Tanor, 2002). Neuroimaging studies have also confirmed the involvement of inner speech in tasks of executive function. Gruber (2001), for example, examined the neural activation of typically developing adults during tasks of mental switching. *f*MRI scans recorded neural activity both with and without continuous articulation intended to interfere with inner speech. Under non-interference conditions, neural imaging demonstrated activation in areas known to be associated with verbal rehearsal (i.e., Broca's area, the left premotor cortex, the cortex along the left intraparietal sulcus and the right cerebellum). Importantly, the addition of articulatory suppression produced a significantly reduced level of activation in these neural areas, indicating decreased use of inner speech. Russell, Jarrold and Hood (1999) were the first to propose that inner-speech limitations may contribute to the executive dysfunction observed in the autistic population. The findings of Chapter 5 confirmed Russell et al.'s (1999) suggestion with regard to one component of executive function, mental switching. Future studies that investigate the involvement of inner speech in other elements of executive control such as planning, the ability to shift sets, and cognitive flexibility, will extend these results.

One possible extension of the work presented in this thesis takes account of points also raised by Russell et al. (1999). As highlighted in Chapter 5, Russell et al. separated tasks of executive function into two categories: rule-bound and non-rule bound tasks. According to Russell et al., rule-bound tasks contain arbitrary rules, and as such, adequate performance on these tasks is contingent upon the proficient use of inner speech to plan future cognitive actions. Russell et al. demonstrated that when a rule-bound task requires a verbal response - an experimental condition they claimed interfered with one's use of inner speech - there is no difference in the performance of children with autism and controls matched on verbal mental age. Russell et al. argued that the interference of inner speech negatively affected the performance of the typically developing children, but not the performance of the autism group. While this interpretation is consistent with evidence that typically developing children have superior performance to children with autism on rule-bound tasks that require a nonverbal response (e.g., in the Wisconsin Card Sorting Test, Rumsey & Hamburger, 1988), Russell et al. did not provide this direct comparison. The argument advanced by Russell et al. (1999) is very similar to that offered in Chapter 5 of this thesis. Whereas Russell et al. claimed that the use of inner speech is interrupted by the requirement of a verbal response, the study employed in Chapter 5 claimed that inner speech was interrupted by the addition of articulatory suppression. From this perspective, a further study comparing the performance of autism and control groups on a rule-bound task that does not require verbal response (such as the WCST), with and without articulatory suppression, would provide converging evidence on the role of inner speech in executive function performance.

Theory of Mind

Inner-speech limitations may also bear relevance to the theory of mind impairment experienced by individuals with autism. A number of studies of typically developing individuals have identified strong correlations between performance on theory of mind and executive function tasks (Carlson & Moses, 2001; Hughes, 1998; Perner, Lang, & Kloo, 2002). This relationship, combined with the established link between inner speech and executive function skills (Miyake, Emerson, Padilla, & Ahn, 2004) has led some to query whether inner speech and theory of mind may be similarly entwined (Carlson, Moses, & Claxton, 2004). Recent studies have started to illuminate this relationship. Zelazo, Jacques, Burack and Frye (2002) found a strong positive correlation between the ability of high functioning children with autism to adhere to arbitrary task rules - a cognitive capacity proposed to be a function of inner speech (Russell et al., 1999) - and the performance on tasks of theory of mind. Further research that focuses on this relationship may reveal more about the origins of the theory of mind impairment in the autistic population.

One area that would be of particular interest is the relationship between inner speech and performance on the false-belief task – a task often considered the litmus test for theory of mind understanding. This task assesses one's ability to understand that someone can hold a belief that is different to reality. A significant proportion of individuals with autism are known to perform poorly on tasks that assess this ability (Baron-Cohen, Leslie, & Frith, 1985; Yirmiya, Erel, Shaked, Solominca, & Levi, 1998). Performance on the false belief task has been shown to be intimately related to the mastery of the complement linguistic structure (deVilliers, 2000). An example of a sentence containing the complement structure is as follows.

Nat thought that Liz went to work

Knowledge of this structure is important for false belief success for two reasons. Firstly, it permits the report of an untruth (deVilliers, 2000), as portions of the sentence may be false with the greater sentence still being truthful (Tager-Flusberg, 2000). Secondly, it enables the communicator to take on more than one perspective of events. For example, the above sentence allows one to convey, firstly, Nat's thoughts (i.e., that Liz went to work), and secondly, the communicators thoughts (i.e., that Nat thought that Liz went to work). The work by Tager-Flusberg and colleagues (Hale & Tager-Flusberg, 2003; Tager-

Flusberg, 2000) has been important in dissecting the relationship between sentential complements and performance on the false-belief task. In one study (Tager-Flusberg, 2000), participants were told a brief story followed by a wh- question containing a complement (e.g., “When did the girl think that she broke the radio”). A correct answer was taken as evidence that an individual had knowledge of complement constructions. Participants were also given two trials of a false belief task. It was found that the individuals with autism who passed false belief tasks had detailed knowledge of the complement structure while those who failed did not have this same knowledge (Hale & Tager-Flusberg, 2003; Tager-Flusberg, 2000).

If, as these studies suggest, appropriate false-belief performance is facilitated by the ability to utilise the complement linguistic frame in order to describe an environmental situation, a deficit of inner speech could provide further limitations to false belief performance. That is, not only must individuals have knowledge of this structure, they must also employ it, not necessarily overtly, to the relevant situation. Inner speech limitations may prevent this occurring with optimal effectiveness. Establishing the extent to which inner speech deficits may retard the internal verbalization of the complement linguistic structure, and hence hinder performance on tasks of false belief, could be a goal for future research.

One possible means of determining the involvement of inner speech is by requiring participants to use articulatory suppression during tasks of false belief. In recent years, a number of nonverbal tests of false belief have been developed as a means of examining theory of mind in young children (Call & Tomasello, 1999; Onishi & Baillargeon, 2005), individuals with hearing impairment (Figueras-Costa & Harris, 2001) and great apes (Call & Tomasello, 1999). The importance of inner speech in successful false-belief performance could be investigated by employing parallel versions of one of these nonverbal tests of false belief in combination with a manipulation of articulatory suppression. Such a study could include both children with autism and typically developing children. Participants would be at an age where typically developing children would be expected to pass a typical false belief task, that is, at least four and a half years of age (Happe, 1995). It would be expected that under baseline conditions (i.e., performing while remaining silent), the typically developing children would pass the task, while a significant proportion of those with autism would fail. The addition of articulatory suppression (such as that employed in Chapter 5), however, would interfere with the use of inner speech and hence it would be expected that the performance of the typically developing participants (and those children with autism who passed) would be negatively affected. A further measure of complement knowledge, such as that utilised by Tager-Flusberg (2000), could also be included.

Autism Relative to Other Neurodevelopmental Disorders

The finding that children with autism have limitations in their use of inner speech may also have implications for how this disorder is viewed in relation to other neurodevelopmental disorders. There is increasing evidence that autism is closely related to other developmental disorders such as Attention Deficit Hyperactivity Disorder (ADHD) and Tourettes Syndrome (TS). Investigations of comorbidity, for example, have found that over half of children diagnosed with autism or Pervasive Developmental Disorder - Not Otherwise Specified (a disorder considered a mild form of autism), would meet the criteria for ADHD (Frazier et al., 2001; Goldstein & Schwenach, 2004; Sturm, Fernell, & Gillberg, 2004). An increased prevalence of TS has also been observed in the autistic population (Baron-Cohen, Scahill, Izaguirre, Hornsy, & Robertson, 1999; Zapella, 2002). It has been suggested, however, that autism can be differentiated from ADHD and TS based upon their executive function profile. For example, Ozonoff and Jensen (1999) found that individuals with autism show deficits in flexibility and planning, while those with ADHD and TS show inhibitory dysfunction (Ozonoff & Jensen, 1999). This dissociation has since been confirmed by Gioia, Isquith, Kenworthy and Barton (2002).

Intriguingly, however, there is evidence to suggest that, along with individuals with autism, those with ADHD (Barkley, 1997; Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004) and TS (Vercueil, 2003) show inner speech limitations. Individuals with ADHD, for example, have a greater proportion of private speech that is externalized (Berk & Potts, 1991) and demonstrate neural activation during tasks of working memory that is consistent with reduced subvocal rehearsal (Schweitzer et al., 2000). Similarly, the difficulties that individuals with TS have in reading silently, has been taken to indicate an inner speech deficit (Vercueil, 2003). The finding that children with autism show inner speech limitations is significant for a number of reasons. Firstly, it draws a common thread between the cognitive abilities of autism, ADHD and TS, which may help shed light on the other deficits shared by these populations (e.g., poor attention). Secondly, inner speech limitations affected the executive performance of those with autism, which raises the possibility that the executive deficits experienced by individuals with ADHD and TD (i.e., inhibition) might also be closely associated with poor inner speech. A direct investigation of the inner speech capabilities of individuals with autism, ADHD and TS, and the relationship that inner speech has with the different components of executive function may help shed more light on the cognitive similarities and differences among these three populations.

Neurological characteristics in autism

Evidence that some individuals with acquired neurological disorders have inner speech limitations may also influence the future direction of this area of research. Rogers, Sahakian, Hodges, Polkey, Kennard and Robbins (1998) investigated task switching in 24 individuals with damage to either the left frontal cortex ($N = 12$) or to the right frontal cortex ($N = 12$). As highlighted in Chapter 5, inner speech is one mechanism that can guide one's actions when switching between different tasks. Rogers et al. (1998) found that participants with left-sided, but not right-sided, frontal damage exhibited markedly increased time costs associated with these predictable switches. These findings indicate that the left frontal cortex is a cortical area that may be associated with the generation of inner speech. Further implicating the left frontal cortex in the production of inner speech, individuals with schizophrenia, a population known to have inner speech difficulties, have been found to have atypical neural activity in this cortical area (Ford & Mathalon, 2004; McGuire, Silbersweig, Wright, & Murray, 1996). A handful of studies have found preliminary evidence of atypical cortical structure and functioning in the left frontal cortex of individuals with autism. For example, studies have identified atypical cortical folding (Hardan, Jou, Keshaven, Varma, & Minshew, 2004), and abnormal electrophysiological (Gomot, Giard, Adrien, Barthelemy, & Bruneau, 2002; Oades, Walker, Geffen, & Stern, 1988) and metabolic (Jambaque, Mottron, Ponsot, & Chiron, 1998) activity, reduced blood flow (Baron-Cohen, Ring, Moriarty, Schmitz, Costa, & Ell, 1994) and decreased synthesis of serotonin (Chugani et al., 1997) in the left prefrontal cortex for individuals with autism. Electrophysiological and neuroimaging studies that monitor brain activity during tasks involving inner speech may be able to provide a link between neural and cognitive deficits.

Implications for Intervention: Determining the Exact Nature of Inner Speech Relationships

Research into the inner speech capabilities of those with autism, could potentially culminate in an examination of whether therapeutic benefit could be gained by teaching inner speech skills. This thesis has provided evidence that reduced inner speech facility may have links with some of the linguistic and cognitive deficits observed in those with autism. Thus, it is conceivable that teaching inner speech skills may in turn promote appropriate development. Establishing the exact nature of the relationship between inner speech and the cognitive deficits of autism is central to achieving this goal.

For example, as outlined previously in the Discussion, the theory of mind impairment of the autistic population may result from inner speech deficits. This could be because inner speech limitations restrict the extent to which the complement linguistic structure can be internally employed with optimal efficiency. From this perspective, teaching children with autism inner speech skills (i.e., making children aware of inner speech, teaching them the benefits of using inner speech, etc.) may see a reduction in theory of mind impairment. However without further insight into the direction of the inner speech-theory of mind relationship, it remains possible that the inner speech limitations of those with autism are simply a by-product of an impaired theory of mind module. For example, failing to understand that others' actions are governed by thoughts and beliefs may limit the extent to which individuals with autism understand the functions and uses of inner speech. In this circumstance, teaching inner speech may achieve little improvement in theory of mind skills. A similar conundrum exists with regard to the relationship between inner speech and language. As described previously in this Discussion, there is evidence to suggest that inner speech limitations would restrict lexical and syntactic development. Accordingly, linguistic development may be furthered by teaching inner speech skills. For example, linguistic comprehension could be promoted through teaching the importance of subvocal rehearsal during periods of comprehension, such as when receiving instructions from a teacher. However, as with the relationship between inner speech and theory of mind, there is a possibility that inner speech limitations may merely be a consequence of an underlying language disorder. Without knowledge of the direction of these relationships, intervention research is significantly compromised.

The developmental nature of autism disorder is an important factor to consider when investigating cognitive relationships for this population. Historically, the logic of deriving implications about the cognitive architecture from behavioural impairments was formulated through studies of adults with acquired disorders (Thomas & Karmiloff-Smith, 2002). Dubbed cognitive neuropsychology (Shallice, 1988), this framework compares behaviour post-neurological damage to that observed in adults without damage, as a means of providing insight into the various components of cognition. However, it is argued that this comparative framework has its limitations in investigating developmental disorders, with a number of researchers claiming the developmental process itself is an important mechanism in producing end-state impairment (Bishop, 1997; Karmiloff-Smith, 1997, 1998; Thomas & Karmiloff-Smith, 2002). Whereas lesions to an adult brain produce change to a fully developed cognitive system, children with developmental disorders incur a neurological insult *prior* to cognitive development (i.e., assuming a genetic impairment). As such, unlike the one-to-one association utilised within a cognitive neuropsychological framework, the behavioural impairments observed in developmental disorders (in this case, an inner speech deficit) are likely to be a manifestation of the dynamic interaction between an initial neural impairment and the developing neural/cognitive system. Evidence for this view comes from Thomas and Karmiloff-Smith (2002), who found that damage to a connectionist developmental model, produces markedly different end-state impairment depending on whether it occurs before or after training. From this perspective, longitudinal studies which trace the various cognitive deficits throughout development are essential in understanding the relationships between the cognitive deficits of autism.

Despite the cross-sectional design of the studies reported in this thesis, significant insight has been gained regarding the impact that an inner speech limitation may have upon executive function. Chapter 5 provided evidence that inner speech deficits may underpin the typically poor performance of children with autism on tasks of executive function. It is therefore possible that explicitly teaching individuals with autism the planning and monitoring benefits that can be gained through the use of inner speech may promote better performance on tasks of executive function. Future studies could investigate whether teaching inner speech skills produces a significant improvement in executive performance.

Summary

In summary, the finding that children with autism have limited use of inner speech leads to a number of important implications regarding the linguistic, cognitive and neurological descriptions of autism. Inner speech is associated with the development of a number of skills known to be impaired in those with autism (e.g., linguistic ability, executive function and theory of mind). This raises the possibility that an inner speech deficit may be a crucial component of the cognitive description of this disorder. Further research that seeks to establish the exact nature of these relationships will provide insights into how inner speech is involved in the complex cognitive matrix of those with autism, and whether the cognitive and linguistic abilities of these individuals would benefit from promoting inner speech skills.

FINAL COMMENTS

The thesis aimed, firstly, to contribute towards a better understanding of the way that children with autism gain meaning from verbal and pictorial information, and secondly, to gauge the extent to which inner speech may influence these, and other, processing abilities. A number of cognitive paradigms were employed, firstly, to reveal how children with autism process information in different modalities, and secondly, as a means of isolating and identifying underlying skills important in verbal and pictorial processing. Children with autism did not show atypical encoding of verbal information, but demonstrated an atypical processing of pictorial stimuli. Further investigations identified inner speech as a key cognitive component in the retention of pictorially presented information and in other areas such as the control of task-switching. The discussion outlined a number of areas where future research could build upon these findings.

The results of this study have provided mixed evidence for the proposal that individuals with autism atypically encode verbal and pictorial information. Firstly, the results provided evidence against the idea that individuals with autism have atypical encoding of verbal information. Children with autism encoded the semantic and phonological characteristics of verbal information to the same extent as typically developing controls. This result suggests that previous findings which have purported to demonstrate verbal encoding deficits in those with autism (Beversdorf et al., 2000; Toichi

& Kamio, 2002, 2003, 2005; Toichi et al., 2002) may instead represent atypical methods of information retrieval. Secondly, and in contrast to the finding of appropriate verbal encoding, this thesis found evidence that children with autism process pictorial information in an atypical manner. In particular, the children with autism demonstrated significantly less facility in processing pictures compared to typically developing control children. Intriguingly, this finding challenges evidence, albeit largely anecdotal, that children with autism have *enhanced* processing of pictorial information. Note, however, that there is only a very small empirical literature that has examined the pictorial processing abilities of those with autism (e.g., Chapter 4; Kamio & Toichi, 2000) and as such, it is very difficult to draw any conclusions regarding the pictorial processing abilities of this population. Studies that investigate a range of cognitive paradigms (e.g., weak visuospatial coherence) may help to shed further light on the proposal that those with autism have a pictorial processing bias.

Possibly the most significant finding of this thesis is that children with autism have limitations in their use of inner speech. It was proposed that limitations in inner speech were responsible for the atypical performance of the children with autism on the tasks of pictorial memory presented in Chapter 4. Chapter 5 provided further support for this interpretation in demonstrating that the inner speech deficits of those with autism extended to limitations in the ability to use internal planning. While other researchers have raised the notion that inner speech limitations may relate to the behavioural and cognitive impairments of those with autism (e.g., Bishop & Norbury, 2005; Russell et al., 1999), these findings provide solid, empirical evidence for these deficits.

Vygotsky (1962) wrote extensively on the importance of inner speech in social and cognitive development. Subsequent research has begun to provide empirical support for these associations; in particular, the relationship between inner speech and the development of linguistic (Ellis-Weismer & Evans, 2002; Levelt, 1989), executive function (Baddeley, Chincotta, & Adlam, 2001; Cinan & Tanor, 2002) and theory of mind (Carlson, Moses, & Claxton, 2004) abilities. As these skills are characteristically in deficit in those with autism, research interest in the inner speech limitations of this population is likely to increase. One of the greatest challenges of future research lies in determining the causal relations between inner speech and the other linguistic and cognitive characteristics of those with autism. Longitudinal research, which tracks the development of a range of cognitive skills, is likely to hold promise in teasing out the exact nature of these relationships.

To conclude, it is clear that understanding the basis of the underlying language deficit in the autistic population is one of the biggest challenges facing autism researchers. Language impairment has a crippling effect on the quality of life of those with autism. While this deficit is pervasive within the autistic population, it remains one of the least understood characteristics of this disorder. It is hoped that the ideas presented in this thesis have not only offered further insights into the language abilities of individuals with autism, but provided a solid base upon which future research can build.

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APPENDICES

APPENDIX A

Stimuli used in Chapter 2

Semantic subsets

Animals	Random
horse	glove
pig	wheel
sheep	nail
cow	bell
cat	cake
dog	drum
tiger	brush
lion	hat
monkey	envelope
rabbit	gun

Fruit	Random
banana	star
apple	flag
orange	ruler
grape	arrow
cherry	thimble
pear	kite
pineapple	ear
peach	doll
strawberry	lock
lemon	flute

Phonological subsets

st____ onset	Random
straw	chain
stone	eye
string	leaf
student	tent
stair	fence
star	axe
statue	dirt
station	watch
stool	moon
stove	thumb

ca____ onset	Random
cat	plug
camel	leaf
carrot	skirt
camera	desk
cannon	anchor
candle	barrel
can	toaster
canoe	well
caravan	needle
caterpillar	mountain

APPENDIX B

Stimuli used in Chapter 3 and Chapter 4, Experiment 1

Trial 1

A	**B**
ball	pen
telephone	book
rolling pin	apple
flag	lion
tie	nail
doll	clown
leaf	elephant
button	ruler
dress	corn
bowl	pot

Trial 2

A	**B**
hat	heart
window	owl
banana	dog
cow	bell
bed	nose
cigarette	camel
lock	boot
cup	bread
box	sun
shirt	ring

Trial 3

A	**B**
bottle	whistle
fish	lamp
toaster	kite
umbrella	key
balloon	gun
axe	hand
envelope	couch
table	violin
pig	basket
truck	potato

APPENDIX C

Stimuli used in Chapter 4, Experiment 2

Short-word pool	**Long-word pool**
ant	butterfly
box	caterpillar
bed	cigarette
car	crocodile
cat	elephant
cup	envelope
dog	motorcycle
eye	helicopter
fish	kangaroo
gun	pineapple
hat	rhinoceros
key	screwdriver
pen	strawberry
pot	telephone
sun	tomato
tie	watermelon

APPENDIX D

Example of stimuli used in Chapter 5

8	1	________
4	1	________
3	1	________
1	1	________
7	1	________
4	1	________
2	1	________
5	1	________
8	1	________
3	1	________
5	1	________
2	1	________
6	1	________
7	1	________
3	1	________
5	1	________
1	1	________
4	1	________
8	1	________
6	1	_______